Chapter 14

Asphalt Pavement Systems

Author
Bob M. Gallaway, P.E.
Professor Emeritus - Texas A & M

Updated April 2007

Expanded Shale, Clay & Slate Institute (ESCSI)
2225 E. Murray Holladay Rd, Suite 102
Salt Lake City, Utah 84117
(801) 272-7070 Fax: (801) 272-3377
info@escsi.org   www.escsi.org

The information set forth in this chapter, including but not limited to all technical and engineering data, figures, tables, designs, drawings, details, suggested procedures, and suggested specifications, is intended for general information. While every effort was made to insure accuracy, this information should not be used or relied upon for any specific application without independent competent professional examination and verification of its accuracy, suitability, and applicability. Because material, weather, road surface problems, and other site- specific conditions may vary, this general information should not be used or relied upon as accurate, adequate, or suitable to produce a desired result at a specific site. Anyone using this material does so at his or her own risk and assumes any and all liability resulting from such use. ESCSI disclaims any and all express or implied warranties of merchantability fitness for any general or particular purpose, or freedom from infringement of any patent, trademark, or copyright in regard to information or products contained or referred to herein.

For the purposes of this manual, the term ESCS means expanded shale, clay, and slate lightweight aggregates. ESCS is a unique, ceramic lightweight aggregate prepared by expanding select minerals in a rotary kiln at temperatures over 1000º C.

ESCSI Publication # 5510

PREFACE

This manual was prepared to provide technical assistance to the user, producer and sales engineer of Expanded Shale, Clay and Slate (ESCS) aggregates. It was also prepared to assist engineers, educational institutions and government organization involved in the design and construction of asphalt pavement systems.

Although there are basic similarities in asphalt paving technology, there are wide spread differences in the geographical practices. Therefore, the information supplied in this manual is usually stated in general terms. It is, therefore, necessary to exercise judgment in selecting, using, and applying ESCS aggregate. Proof of excellent service of ESCS aggregate in pavement application has provided assurance for more than three decades.

The recommendations in this manual are based on findings reported in industry literature, laboratory experiments, extensive field trials, thousands of miles of regular contract construction, and the considered judgment of the author.

Acknowledgements

I would like to thank the Expanded Shale, Clay, and Slate members for their help and support in preparing this manual. Special thanks goes to John P. Ries, President of the Expanded Shale, Clay and Slate Institute for doing extensive writing, editing and compiling of the information presented. Special thanks also goes to Scott Shuler for editing the manual and Texas Industries for participating in much of the original research.

Author

Bob M. Gallaway, Professor Emeritus of Civil Engineering, Texas A and M University, was the former Head of the Highway Materials and Construction Division of the Texas Transportation Institute, and Head of the Materials Division of the Civil Engineering Department of Texas A and M University for more than 25 years. He received the Borckett Professorship in Engineering in 1978, 1979, and 1980 at Texas A and M University. He is President of Consulting and Research Services.

Mr. Gallaway is a registered Professional Engineer, a former President of the Association of Asphalt Paving Technologists, Distinguished Faculty Achievement Award for Research, McGraw-Hill Award for Contributions to the Construction Industry in 1974, inducted to the Asphalt Hall of Fame in 1988, Expanded Shale, Clay, and Slate Institute's Frank G. Erskine Award recipient for outstanding contributions in the use of lightweight aggregate in 1993, listed in Who's Who in American Education and Engineering. He holds patents on highway materials applications and friction improvements of pavements, and is author or co-author of more than 300 technical papers with many in the general area of tire-pavement interactions, skid resistant pavements, seal coat, and surface treatment design and construction, maintenance methods for improvements of pavement surface properties, and Sulphur-asphalt binder system.

CHAPTER 14

Stability
Improved skid resistance
Jet airfields and bridge decks

14.10 Maintenance and Pothole Material (Plant-Mixed)
Workability and stability
Storage life
Stripping due to water susceptibility
Mixture design
Field applications
Pothole repair
Adequate and proper tack coat
Plant operations
Batch weights and segregation
Equipment wear
Water vapor release in the plant
Aggregate drying rate and dryer capacity

14.11 Asphalt-Stabilized Bases with ESCS
Use
Structural design considerations
Mix design considerations
Unit weight
Resistance to the action of water
Aggregate gradation and selection
Construction considerations

14.12 Micro-Surfacing and Slurry Seal
Use
Multi-course slurries
Field conditions
Aggregate gradation
Asphalt emulsions and tack coat
Rate of application

14.13 Stabilized Aggregate Bases made with ESCS and local soil binder, and ESCS Geotechnical Fills
Binder Material
Use
Stabilization of bases and sub-bases
Mechanical stabilization (compaction)
Chemical stabilization
Compaction of ESCS Geotechnical Fills
Laboratory maximum-dry density
Field or in-place density

14.14 Asphalt-Rubber Pavement

Asphalt-rubber chip seal

Guidelines and specifications for use of asphalt-rubber chip seal

Conclusions on the use and advantages of asphalt-rubber chip seal in the city of Phoenix, Arizona

Hot-mixed asphalt-rubber concrete pavements (open, dense, and gap-graded)

Aggregate for dense-graded asphalt-rubber concrete

Aggregate for open-graded asphalt-rubber concrete

California I-15 asphalt-rubber chip seal project

Appendix A State Specifications (Sections of)

• Colorado	Section 409	Seal Coat
	Section 702.04	Emulsified asphalt
	Section 703	Aggregates
• Kansas	Section 1109	Aggregates for cover material
• Louisiana	Section 507	Asphaltic surface treatment
	Section 1003	Aggregates
• Oklahoma		
• Texas		
	Item 303	Aggregate for surface treatment (lightweight)
	Item 316	Surface treatment
	Item 318	Hot asphalt-rubber surface treatments
	Item 334	Hot mix-cold laid asphaltic concrete pavement
	Item 340	Hot mix asphaltic concrete pavement
	Item 342	Plant mix seal
• Utah		
• Virginia		
	Section 206	Lightweight aggregate
	Section 311	Prime coat
	Section 312	Seal coat
	Section 313	Asphalt surface treatment
• Missouri/Kansas (Buildex Letter)		

Appendix B Sections from SHRP publication SHRP-H-322 (SHRP-M/FR-92-102) "*Standard Practice for Designs and Construction of Bituminous Surface Treatments*"

- Section 407 Chip seal
- Section 408 Slurry seal
- Section 702 Bituminous material
- Section 703 Aggregates

Appendix C Several states and SHRP's gradations for asphalt-aggregate surface treatment (chip seal) cover material using ESCS aggregates

Appendix D Design Methods: asphalt-aggregate surface treatment (chip seal, seal coat) design method and guidelines

Appendix E ASTM D 5360 "*Standard practice for Design and Construction of Bituminous Surface Treatments"*

Appendix F July 1971 Public Works Publication article titled "*A look at Open Mixes to Improve Skid Resistance"* by Verdi Adam, Materials and Research Engineer, Louisiana Department of Highways

Appendix G Design Methods for open-graded friction course, OGFC, (plant mix seal)

Appendix H International Surfacing Inc., Guide Specification for Open, Dense and Gap-Graded Asphalt Concrete Pavements with Asphalt-Rubber Binder

Appendix I International Surfacing Inc., Guide Specification for Asphalt-Rubber Stress Absorbing Treatments (SAM or SAMI) for Highways, Roads, Streets, and Airports

Appendix J Design of Hot-Mix Asphalt Laboratory Mixes from "*TXDOT Construction Bulletin C-14"*

Appendix K Asphalt Emulsions: looking at the basics "Roads & Bridges", March 1995 Issue

Appendix L *"An Introduction to Slurry Seal*" Akzo Nobel Newsletter, Spring 1997

Appendix M Suggested Reference Reading

Appendix N SI (Modern Metric) Conversion Factors

Chapter 14 Asphalt Pavement Systems

14.1 Introduction

For the purposes of this manual, the term ESCS means expanded shale, clay, and slate lightweight aggregates. ESCS is a unique ceramic lightweight aggregate prepared by expanding select minerals in a rotary kiln at temperatures over 1,000º C.

The expanded Shale, Clay and Slate Institute (ESCSI) produced this reference manual to provide an educational reference for ESCS aggregate producers and users in the asphalt pavement market. This manual serves to educate and guide designers, engineers, students, government agencies, and contractors on the advantages, applications, and performance of ESCS aggregate. It is especially useful to designers and contractors who are specifying and using ESCS aggregates for the first time and need guideline to assure a successful project.

This manual will be particularly valuable to government agencies responsible for the preparation of pavement designs and material specifications. The design engineers responsible for the introduction and proper use of such materials should also find this manual helpful.

What is more important however, are the public safety benefits of ESCS aggregates that produce long-lasting, high-friction surfaces that are economical, easy to construct, durable, and have a proven performance. Properly designed and constructed ESCS pavement surfaces retain frictional properties (high-friction resistance) for the life of the surface even under heavy traffic.

Although the information in this manual is current and factual, there are specific differences associated with given materials, environments, and services that require engineering judgment, and construction control to produce a quality job. (Indeed, this is true for any quality produce, whether it is a pavement, bridge, or sky scraper).

The physical properties for ESCS aggregate will vary because they are manufactured over a wide geographical area. For precise information on mix design, unit weights, and other physical properties of a particular ESCS material, consult the individual expanded shale, clay or slate producers. ESCS is available throughout the United States, Canada and much of the world.

ESCS's low-unit weight require bid forms, bid evaluations, and mix designs to be adjusted or converted to include an equivalent volume measurement rather than by only a weight measurement. This requirement keeps all materials on an equal competitive basis by correctly adjusting for the large difference in yield, caused by ESCS high volume to weight ratio.

14.2 ESCS Aggregate Industry Overview

History and Properties

How it started: Stephen J. Hayde, a contractor and brick-maker from Kansas City, Missouri, is universally recognized as the founder of the ESCS aggregate industry. Like many industrial pioneers, he got his start in 1908 by trying to solve one problem and ended up solving another problem of even greater magnitude. A problem of the industry for centuries had been the excessive bloating of some of the brick as the shale expands when subjected to high-heat during the burning process. It occurred to Mr. Hayde that the lighter bloated material, which was discarded, had the three essential characteristics for a structural lightweight aggregate; a) non-interconnected air voids, b) impermeable, glass-like matrix, and c) significantly less density than conventional aggregates.

His reasoning, which was later borne out by practical experimentation, was this aggregate could substantially reduce the dead-load of concrete structures, and thereby economically solve engineering problems. In 1918 Mr. Hayde was granted a patent under the name *Haydite* for producing expanded shale, clay, and slate lightweight aggregate by the rotary kiln method.

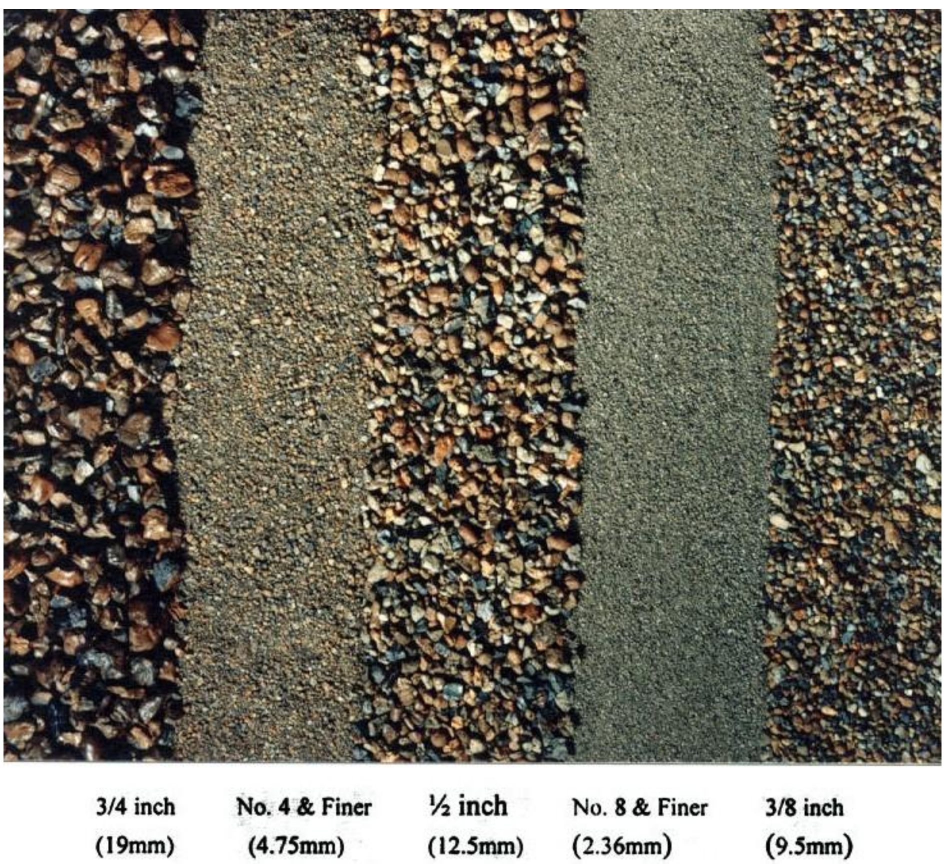


Figure 14.1. ***ESCS Lightweight Aggregate is produced in varying gradations and textures.***

How it is made: ESCS is manufactured in a controlled environment by applying heat to certain raw materials. The raw material (highly siliceous clay, shale, or slate) is introduced into a rotary kiln, similar to the type used in the portland cement industry. As it passes through the kiln, the material reaches temperatures greater than 1000º Celsius and begins to turn plastic. Internal gases cause the material to expand (bloat) and create a mass of small air cells retained after the material cools and solidifies. After leaving the kiln, the material is cooled, crushed and graded.

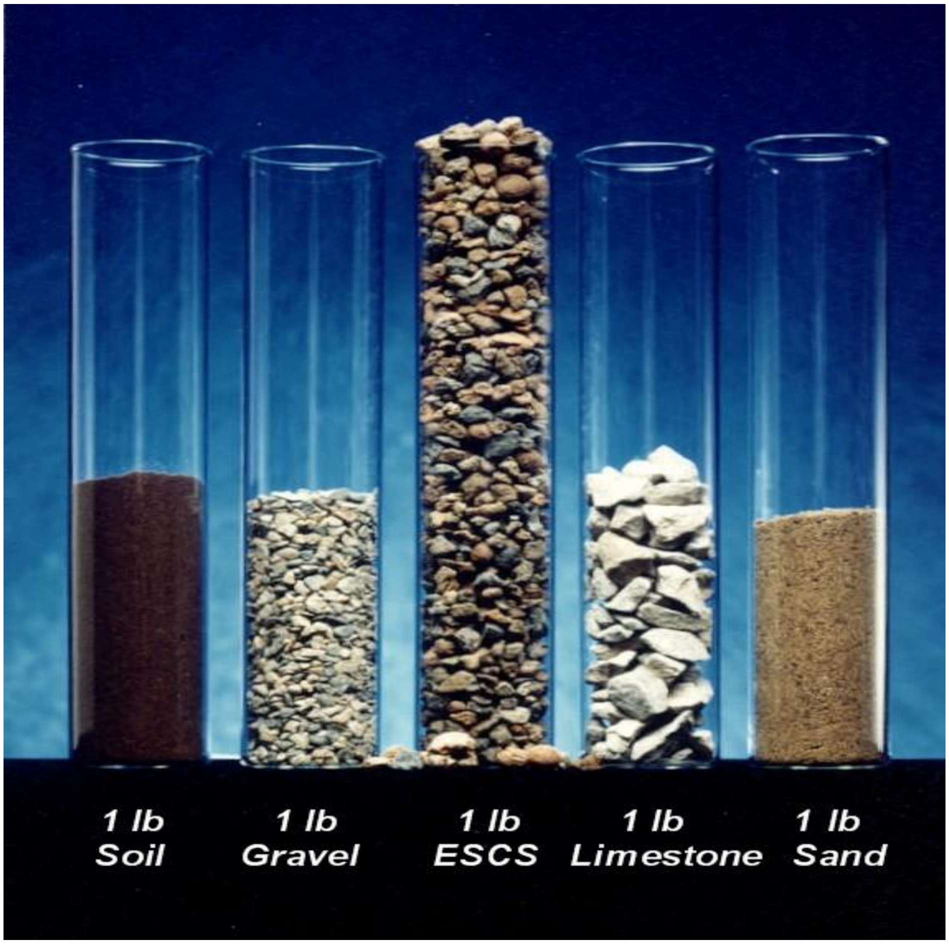


Figure 14.2. ***ESCS Aggregate offers more than twice the Volume for the same weight of conventional material.***

Aggregate properties: The aggregate particle is a uniform, high-quality product that is structurally strong, stable, durable, and inert, yet also light in weight and insulative. The surface of the ESCS particle is vesicular and more textured than natural stone which provides increased stability and friction for asphalt pavements. Many ESCS manufacturing plants crush oversized material to meet gradation requirements (Fig. 14.1). Crushing partially determines the surface texture and, to some extent, the particle shape.

The aggregate particle size and shape are important for chip seals, surface treatments, and plant mix applications. An excess of flat and elongated particles, or particles with sharp corners of projections are undesirable.

Depending on where it is manufactured, the unit weight of ESCS is generally half the weight of conventional material (Fig. 14.2) and ranges from 30 to 65 lbs/ft³ (700 and 1000 kg/m³). The maximum size of ESCS aggregate is normally 3/4 inch (19 mm) to less than 1/2 inch (12.55 mm) varying somewhat with the manufacturer.

The specific gravity of the dry ESCS aggregate is approximately one-half that of conventional aggregates. Asphalt pavement and structural lightweight concrete mixes made with ESCS aggregates are generally 25 to 40 percent lighter than conventional mixes.

ESCS is used in the generic sense regardless of which raw materials were actually used in manufacturing. In general, there is no distinction between the physical properties of asphalt or concrete mixes made with expanded shale, clay, or slate aggregates.

Where ESCS aggregate is used

It is interesting that an industry so closely identified with skyscrapers, long-span bridges, long-term durability, and life safety entered the market through concrete oceangoing ships in both World War I and II. The first large-scale commercial projects using ESCS began in 1918 with the construction of several large concrete ships made for the United States Fleet Corporation.

For nearly a century, ESCS has been used successfully around the world in more than fifty (50) different types of applications. Among the most notable are the concrete masonry, high-rise buildings, concrete bridge decks, precast and prestressed concrete elements, asphalt road surfaces, soil conditioner, and geotechnical fills. ESCS gives designers greater flexibility in creating solutions to meet the challenges of dead load, terrain, seismic conditions, construction schedules, and budgets.

A World of Uses

SmartWall® High Performance Concrete Masonry

- Concrete Masonry Units (CMU's) above and below grade
- Architectural units (split face, colored, etc.)
- Larger CMU's (8" x 8" x 24", etc.)
- Prison Construction
- Concrete brick (all shapes and colors)
- Segmental retaining walls
- Privacy fences and sound barrier walls
- Sound absorption walls
- Other (pre-cast lintels, loose fill, core insulation, pavers, patio units, etc.)

Asphalt Pavement (rural, city and freeway)

- Surface treatments (chip seal, seal coat, etc.)
- Plant mix seal overlay and open-graded friction coarse
- Hot mix surface coarse
- Micro-surfacing (slurry seal)
- Cold mix (pothole patch, minor repairs, etc.)

Structural Concrete (including high performance)

- Floors in steel frame buildings (fill on metal deck)
- Precast and prestressed elements (beams, double-tees, tilt-up walls, raised access floor panels, planks, hog slats, utility vaults, pipes, bridge decks, ornamentals, etc.)
- Concrete frame building and parking structures (all types, including post-tensioned floor systems)
- Floating docks, boats and offshore platforms
- Bridge decks, piers and AASHTO girders (prestressed, post-tensioned and normal reinforcement)
- Topping over precast concrete

Geotechnical

- Waterfront structures
- Landscape and elevated plaza fills
- Bulkheads and retaining walls
- Structural repairs and rehabilitation
- Fill over poor soils and marshlands
- Insulating backfill and insulating road base
- Shallow foundations
- Enveloping underground conduits and pipelines for insulations or when in unstable soil conditions
- Landfill leachate drainage systems

SOILMatrix™ Horticulture Applications

- Green roof (intensive, extensive)
- Bioswales
- Soil conditioner (planting, golf greens, potting soil, etc.)
- Soil conditioner for sports fields (baseball in-fields) and dirt tracks (running, bike, horse, stock car)
- Ground cover (decorative and insulating)
- Herbicide and fertilizer carrier
- Hydroponics

Specialty Concrete

- Topping on wood floor systems
- Roof fill for flat roofs (insulation and slope)
- Insulating fill around temperature sensitive elements
- Bagged concrete mix
- Cement wallboard
- Artificial stone

- Refractory (fireplace logs and boxes, chimney liners, etc.)
- Insulating refractory for industrial uses in kilns, boilers, stacks, petrochemical refining, etc.)
- Ferrocement and shotcrete
- Animal and environmental structures (sewage treatment, etc.)
- Lightweight concrete roof tiles

Miscellaneous

- Grog for clay brick
- Coverstone and ballast on built-up roofs
- De-slicking/traction grit for icy roads
- Medium in wastewater treatment and water filters
- Fire protection for impermeable plastic liners

14.3 ESCS Aggregate in the Asphalt Pavement Market

Usage: All types of asphalt roads (rural, city, and freeways) have utilized ESCS with proven performance. First introduced to the asphalt market in the mid-1950s, ESCS is currently used in more than 20 states and on more than 3,000 miles of road annually in the United States alone. The total installed costs of ESCS are competitive with those of normalweight aggregates, yet with additional advantages.

Although ESCS is primarily used in Chip seals and surface treatments, ESCS works extremely well in an open-grade friction course (plant-mix seal overlays), hot-mix surface course, micro-surfacing, slurry seal, and cold-mix (pothole patch).

Civil engineers may also be interested in other highway uses of ESCS aggregate; for example, lightweight-concrete bridge decks and structural elements, lightweight geotechnical fill, pipe bedding, drainage medium, and mechanically stabilized bases. Contact the Expanded Shale, Clay, and Slate Institute for additional information.

Background: ESCS was first used extensively as a Coverstone for seal coats and surface treatments in Texas. The Texas Department of Transportation (TXDOT) was searching for a Coverstone that would adhere to asphalt under normal construction procedures and at the same time would not damage automobile glass if thrown by traffic. Traditionally, pre-coated crushed stone (treated with 1 to 2 percent asphalt in a pug mill) was, and is still, used with some success to satisfy these demands. However, even under the best construction controls, some pre-coated stone, or any Coverstone for that matter, if left loose on the road surface, can cause vehicle damage. In contrast, ESCS aggregate was found to adhere to the asphalt better and does not damage windshields, headlamps, or paint. During the TXDOT's search for Coverstone, a revolutionary side benefit was discovered. Under medium to heavy traffic, ESCS aggregate does not polish like pre-coated crushed limestone.

ESCS aggregate is specified for coverstone on jobs in several districts in Texas with an option for conventional stone sometimes included. The following data from the TXDOT covering 1980 to 1996 specifies the use of ESCS lightweight aggregate in asphalt pavements. Currently, approximately 400,000 cubic yards of ESCS aggregate are used annually in Texas, primarily for seal coats (chip seal), with lesser amounts used for hot-mix, open-graded friction course, slurry seal, and pothole mix.

The 1979 to 1996 TXDOT data reveals the following:

a) In 1990, approximately 700 miles of the Brownwood (Texas) District's roads were seal coated with ESCS aggregate. The average daily traffic varied from approximately 700 to 14,700 vehicles. Interstate Highway 20 carried the most traffic, with 14,700 vehicles per day, 28% of which were trucks.
b) The TXDOT used the same cover material application rate for ESCS aggregate as normally used for Type B aggregate (crushed gravel, crushed slag, crushed stone, or natural limestone asphalt rock). The aggregate application rate varied from 125 to 130 square yards per cubic yard. (For ESCS that equals 9-14 lbs/yd^2, for Type B aggregate that equals 20 to 23 lbs/yd^2).
c) For the 1990 and 1991 seal coat (chip seal) season, the cost of uniformly graded (essentially 1/2 inch to No. 4) ESCS aggregate seal coat averaged $0.54 and $0.46 per square yard, respectively.
d) The Brownwood (Texas) District placed 1,700 miles (more than 3,400 lane miles) of ESCS seal coats.
e) The state of Texas placed 15,484 total lane miles of seal coat (chip seal) in 1996 at a average cost of $0.98 per/yd^2. Approximately 30% was placed with ESCS aggregate.

Industry direction: ESCS aggregate use in the asphalt market has been steadily increasing for several reasons:

a) Public safety: State and Federal highway agencies, insurance companies, consumer safety groups, and the general public are increasingly emphasizing the need for safer, longer-lasting road surfaces that maintain a high-friction surface course to minimize wet-weather accidents. The steady depletion of local quality aggregates that do not polish also compounds the problem of building safe, economical roads.
b) Automobile damage: Automobile damage remains a constant problem for DOT personnel and the public who are tired of damage to automobile windshields, headlamps, and paint.
c) Economies: Tight budgets are causing local, state, and Federal Transportation Departments to look for more cost-effective road surfaces that last longer and perform better.
d) Higher safety standards for all highways: Federal funds are available to states for safety improvements, including low-friction pavements. FHWA can also fund maintenance activities.

14.4 The benefits and physical characteristics of ESCS asphalt pavements

High Friction resistance - public safety

The skid resistance of a pavement surface is extremely important. State highway agencies across the nation are critically aware of the skidding potential of low-friction pavement surfaces and have prepared special specifications that put rigid limitations on the use of certain polishing type aggregate. In general, not more than 25% of the total aggregate in the surface layer of the pavements can be of the polishing type. Some states have ruled out polishing type aggregates altogether.
Skidding accidents will continue to increase as traffic volume increases unless prolonged high-skid resistance is built into road pavements. Many pavements made with normalweight aggregates (especially aggregates using limestone, dolomites, and some gravels) polish or become slick under traffic and lose a large percentage of their initial skid resistance.

The Federal Government's safety improvement program provides financial assistance to states for up-grading the friction coefficient of roadways where skidding-type accidents can be attributed to slippery pavement. ESCS aggregate and some normalweight aggregates assure improved skid resistance.

Certain normalweight aggregates have been used to produce friction resistant surfaces by two different mechanisms: (a) using materials such as sandstone and other non-polishing materials that abrade under traffic. The skid resistance, or surface renewal is maintained by the continual wearing down of the aggregate; (b) using fine-graded aggregates composed of approximately equal parts of very hard material and softer material. In this case, surface renewal occurs by different rates of wear, making it suitable for the lower speeds of residential and most urban traffic.

When ESCS lightweight aggregate is used in the surface course, the pavement maintains its high initial skid resistance (wet or dry) throughout its service life. The aggregate does not polish as it wears because the rough micro-surface texture of ESCS is constantly maintained as fresh interior cells with tough ceramic-like edges are continually exposed. Surface treatment composed of ESCS coverstone (½ inch to No. 4 size) produces values of wet coefficient from 0.5 to 0.6 at 50 mph. Neglecting the possibility of a flushed asphalt surface, the friction values are essentially maintained for the life of the surface.

Plant mixes of asphalt paving material with as little as 50 percent (by weight) of ESCS lightweight aggregate have measured an average wet coefficient of about 0.5 (at 40 mph) when first constructed. This wet coefficient value can be expected to increase with service and age. This improvement in skid resistance occurs when normal wear of the surface exposes the ESCS to the tire contact area. The surface, in effect, is etched by traffic wear and can eventually attain a coefficient of friction approaching 0.6.

The bleb (bubble space) structure of ESCS gives it a high friction value of lasting quality. The blebs are evident on the crushed face of a piece of ESCS and persist throughout the particle. The rubber of a braking vehicle tire engages the exposed cavities, creating friction or stopping ability. Although there are other ways to make pavement skid resistant, it is doubtful there is a more simple cost effective method. Properly designed and constructed flexible pavements that utilize ESCS aggregate offer ample skid resistance throughout their service life. Thousands of skid measurements made on hundreds of miles of lightweight aggregate seal coats constructed in Texas over the past 20 years attest to the prolonged friction resistance of ESCS. Several TXDOT districts have prepared special plant mix specifications that include ESCS in the coarse fraction of the aggregate skeleton, specifically for improved skid resistance.

The following quotes are taken from Research Report 490-2 "*Implication of Aggregates in the Construction and Performance of Seal Coat Pavement Overlays"*, Center for Transportation Research, The University of Texas at Austin, 1992.

"Adequate frictional performance of seal coats is achieved mainly by the selection of satisfactory aggregates, by the use of properly designed application rates of asphalt and aggregate, and by assuring a careful quality control of construction operations."

"It has been accepted worldwide that, for a natural aggregate to have high, prolonged frictional resistance, it should be comprised of sand-size hard grains weakly bonded in a softer matrix so that differential wear occurs exposing the hard grains. Generally, it has been proved that sandstone aggregates with high polish value (PVs) have high, long-lasting frictional resistance, whereas carbonate aggregates with low PVs such as limestone and dolomites and some siliceous gravel lose their initial frictional resistance rapidly under traffic exposure. On the other hand, synthetic aggregates, particularly lightweight aggregates [ESCS], have proven to be highly superior to most natural aggregates in terms of maintaining comparatively highly favorable frictional resistance."

"The polish value of over 60 different aggregate samples was tested by the accelerated polish test (Test Method Tex-438-A) to provide an estimate of the extent to which coarse aggregate in the wearing surface of the roadway are likely to polish when subjected to traffic."

"The PV ranged from a lowest value of 25 for a crushed siliceous gravel (SIGR) aggregate to a highest value of 51 for a ESCS lightweight (LTWT) aggregate. The LTWT aggregates all had PVs greater than 41, while all the natural aggregates had PVs less than 42. The PV range was 36 to 41 for the crushed sandstone (SDST) and rhyolite (RHYO) aggregates and 34 to 40 for the limestone rock asphalt (LMRA) ones. For the crushed limestone (LMST) and SIGR groups, the PV ranged between 27 and 37 for the former and between 25 and 34 for the latter. The traprock (TPRK) source had a PV of 34."

"Shape and size of aggregate particles are other features important to satisfactory frictional performance of an aggregate. Angular aggregate particles have proven to provide higher frictional resistance than sub-rounded or rounded particles, particularly in the case of siliceous gravels. Rounded siliceous gravels have provided satisfactory performance on low traffic volume roads. Although lightweight aggregate particles are often not angular, they tend to have the rough surface features desired for good chip seal surfaces. The presence of flat and elongated particles should be minimized and, if possible, avoided."

"An aggregate with a "one size" gradation which will produce superior particle interlocking and will result in an optimum contact area between the tire and seal coat surface is preferred for chip seals. In Texas, it is a common practice to select large maximum size aggregate that improves pavement surface drainage and thus reduces the potential for hydroplaning."

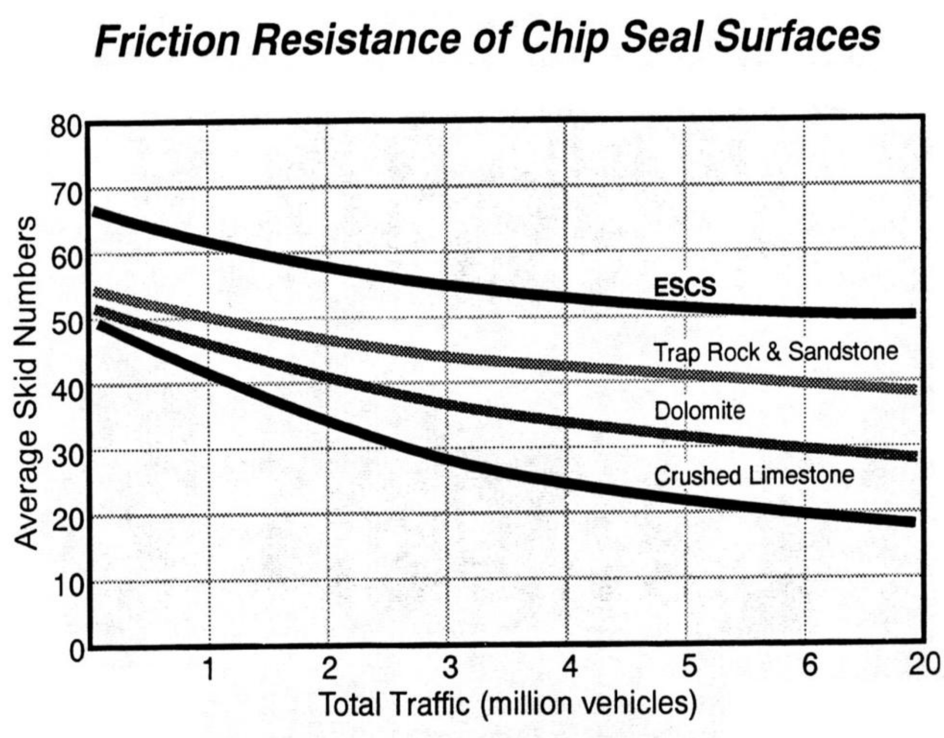


Figure 14.3 ***Friction resistance of chip seal surfaces***

Figure 14.3 shows decay curves for the friction coefficients of ESCS and three commonly used natural aggregates in chip seal surface treatments. These figures show the superior performance of ESCS aggregate. Figure 4 shows similar results for hot-mixes in which ESCS aggregate predominates in the plus No. 8 (2.36 mm) sieve size material.

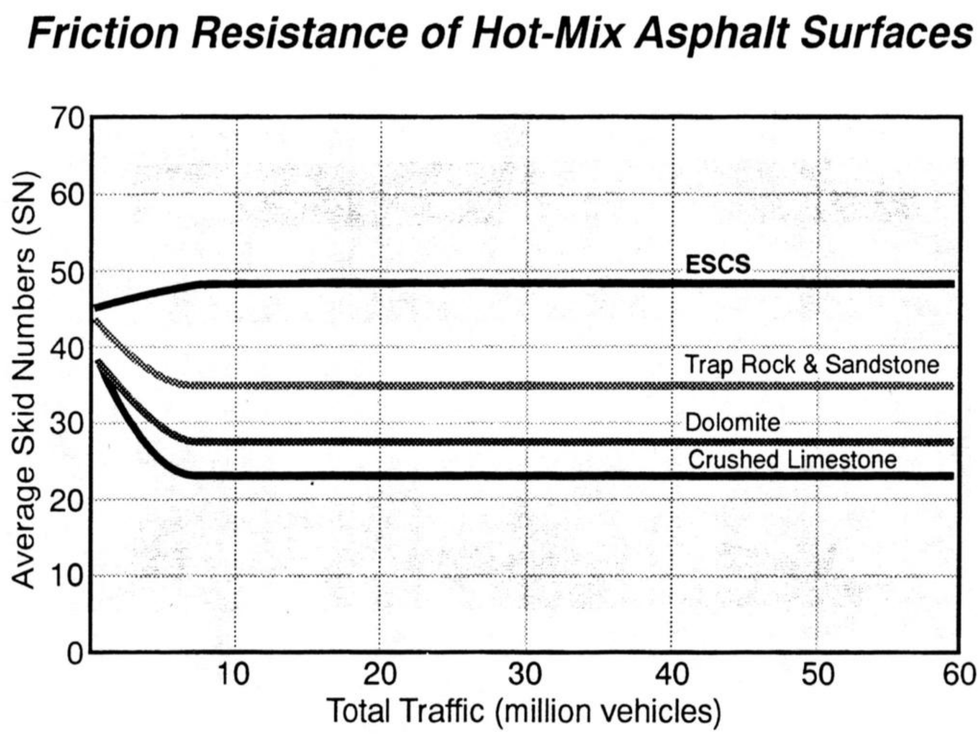


Figure 14.4 ***Friction resistance of hot-mix asphalt surfaces***

Note: The Texas Transportation Institute and The Texas Department of Transportation, Fort Worth, District provided the information in Figures 14.3 and 14.4. Each plot represents 75 to 200 skid tests with each test representing up to six data points averaged.

The consistent high-friction performance of ESCS is further proven by the fact that all original equipment automobile tires are certified and graded by the United States Department of Transportation for frictional performance at the Federal Highway Safety Administration's Goodfellow Air Force Base test facility in San Angelo, Texas. The asphalt test surface must maintain a high uniform friction and remain extremely durable for a long service life. ESCS aggregate in the hot-mix delivering an SN of 50 plus at 40 miles per hour (according to ASTM E 274 “Skid Resistance of Paved Surfaces Using a Full-Scale Tire”, as shown in Fig. 14.5) has met these requirement for more than 15 years. No other material was found suitable for this long lasting, high-friction test track. The track does not polish with time after millions of vehicle passes and maintains its constant performance year after year.

Figure 14.5 ***Friction resistance test (ASTM E 274)***
"Skid Resistance of Paved Surfaces Using a Full-Scale Tire".

Automobile damage - windshields, headlamps, paint chips

Motorists' complaints of cracked windshields, broken headlamps, and paint chips continue to plague highway departments across the nation where normalweight chip seal coverstone (trap rock, sandstone, dolomite, crushed limestone, crushed gravel, blast furnace slag, etc.) is used

Any chip seal surface treatment application contains some loose stones that can be thrown by vehicle tires into oncoming traffic. Using ESCS aggregate significantly reduces damage to windshields, headlights, and paint caused by flying stones. The lower density of the aggregate and the higher-wind resistance caused by the rough surface texture lowers the impact. The resulting striking force is much less than normalweight aggregates, thus reducing damage potential. Rough surface texture also provides a better surface for asphalt bonding, reducing the number of loose particles.

Extensive tests at Texas A & M's Transportation Institute have conclusively shown that automotive glass damage caused by flying stones on new asphalt-aggregate surface treatment (chip seal) construction is dramatically reduced on projects using ESCS aggregate as coverstone. The bar chart of Figure 14.6 shows comparative effects of normalweight and ESCS aggregate. Figures 14.7 and 14.8 show actual photographs of results of firing normalweight and ESCS aggregate particles into automobile windshields.

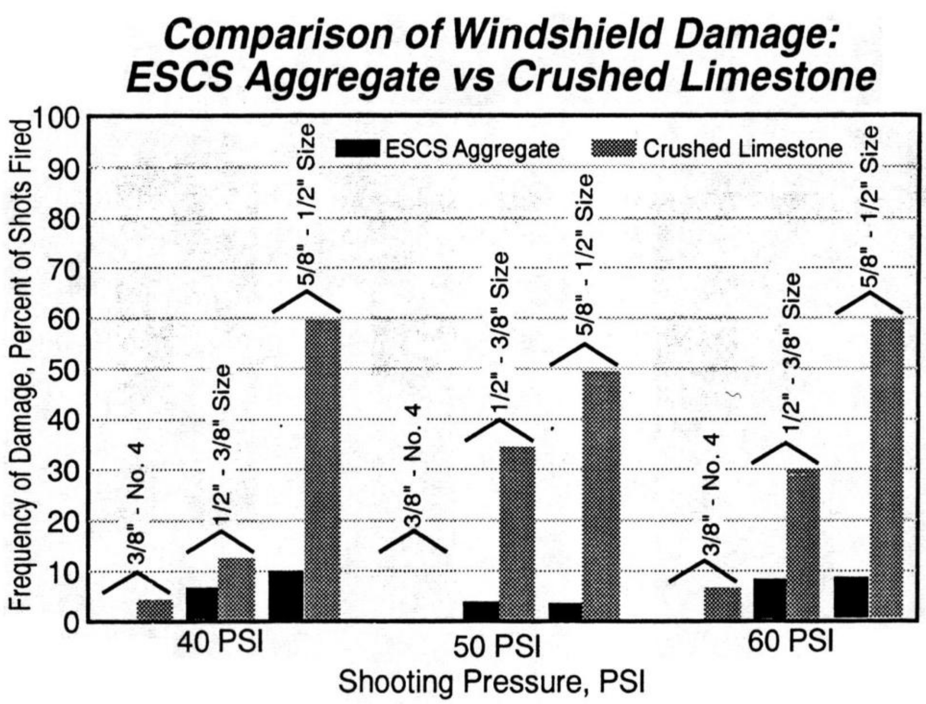


Figure 14.6 ***Comparison of windshield damage. ESCS aggregate versus crushed limestone***

Using ESCS as a cover aggregate on chip seal greatly reduces comprehensive automobile insurance costs. (The second costliest item for insurance companies is glass damage.)

Figure 14.7 ***Windshield damage with normalweight cover aggregate (trap rock, crushed limestone, gravel, blast furnace slag, etc.)***

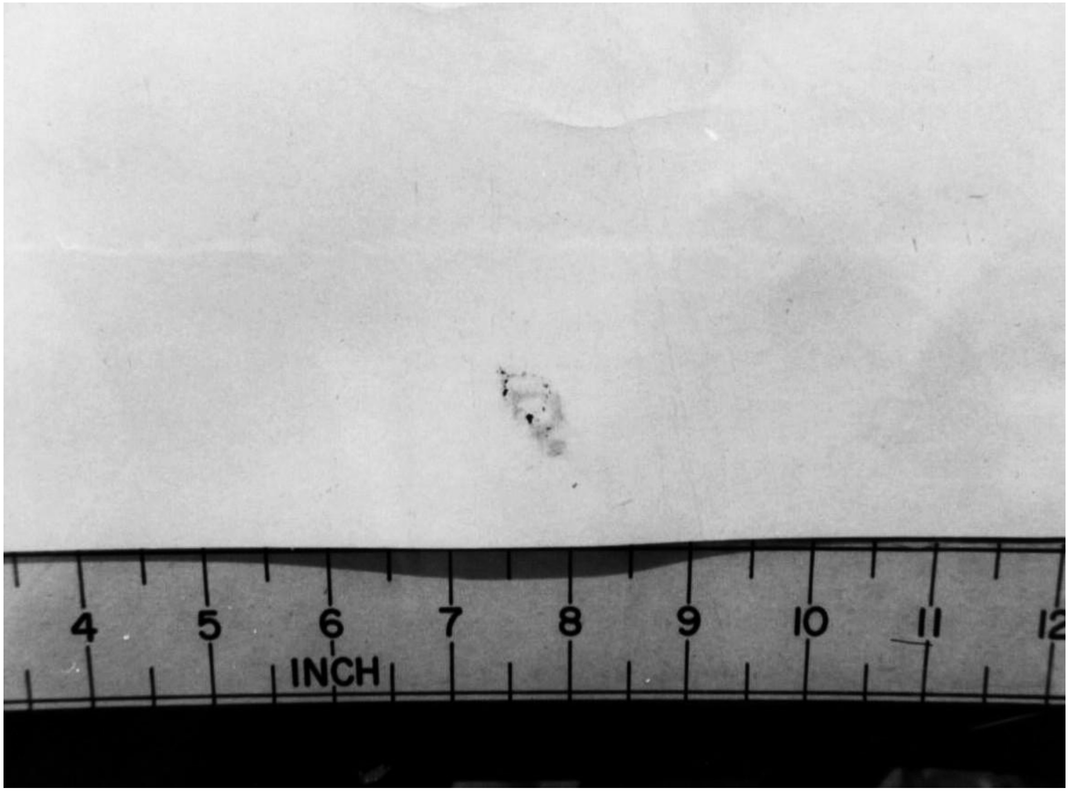


Figure 14.8 ***Windshield damage with ESCS is essentially eliminated. (Note: White paper and tape measure held behind windshield glass for this photograph)***

Adhesion of asphalt to aggregate

The rough micro-surface texture of ESCS aggregate provides unique and superior bonding capabilities with asphalt thus extending roadway service life. When bonded to asphalt, ESCS presents a tough, durable pavement that holds up well under traffic and often outlasts pavements made with normalweight aggregate.

Pavement surface texture and aggregate top size

The asphalt pavement surface texture is determined by the aggregate gradation, top size, and surface texture of the aggregate particles. For a given top size, ESCS produces a more textured pavement surface than most natural aggregates of similar grading because the lower-density large particles tend to "float" up in the mat during placement. For this reason, top size should be kept near ½ inch for surface course mixes. A segregation problem may occur at ¾ inch top size or larger.

Glare

ESCS aggregate surfaces produce little or no reflected sunlight glare, allowing pavement markings to stand out, thereby offering added safety.

Paint Stripes

Traffic marking paints adhere better to ESCS due to the good bond tenacity and, to some extent, the slightly higher absorption. Thus, paint stripes last longer.

Tire Noise

Because ESCS has a rough micro surface texture that absorbs sound, the noise level of otherwise comparable asphalt pavement surfaces is lower. Noise is also pitched lower, which is a real advantage in urban areas. Aggregate size should be ½ inch or less.

Snowplow Damage

ESCS resists being rolled and pulled out more than normalweight aggregate. If snowplow damage occurs with chip seal surface treatments, the top of the ESCS aggregate is usually sheared, leaving most of the particle still embedded in asphalt. In contrast, normalweight aggregate is often rolled or pulled out of the asphalt, leaving an unsafe bare asphalt surface.

Strength-Abrasion Resistance

The laboratory abrasion resistance of ESCS aggregate meets the ASTM requirements for normalweight aggregate. The field service of ESCS surprises most materials engineers. Resistance to abrasion is often predicted by estimating crushing resistance, and is often predicted in a superficial way, like the well known *heel test.* The “heel test” is described as grinding an aggregate particle under the heal of your shoe. Standard ASTM Los Angeles abrasion test values are typically in the range of 18 to 30 percent losses, which is much lower than might be predicted for such materials. Field service records bear out laboratory results. In plant-mixed asphalt paving mixtures and, to a considerable extent, in chip seal and surface treatment work, the aggregate particle is partially cradled in the pavement surface matrix which reduces stress concentrations and minimizes crushing under rubber tires.

Aggregate Durability: Resistance to freezing, thawing, and sulfate action

Aggregate freezing-thawing resistance is important in cold climates. In the United States, high traffic volume creates a demand for ice-free streets and highways, which is often accomplished by using deicing salts. Deicing salts and freezing-thawing cycles affect concrete bridges, streets, and highways similarly.

For more than 70 years, structural lightweight concrete made with ESCS aggregate has solved the weight and durability problems associated with exposed structures. This proven performance history in bridges and marine structures results from using durable ESCS aggregates encased in a durable cement mortar.

Similarly, ESCS aggregates have proven to be durable in asphalt pavement for more than 40 years regardless of whether the aggregates are exposed in surface treatment or encased in hot-mix asphalt pavement.

14.5 General Design and Construction Information

Specifications

As with all materials, ESCS asphalt pavement must be properly specified to assure performance. The specification for ESCS aggregate pavement is only slightly different from the specification for normalweight aggregate pavement. Some of the specific differences are discussed in the following section, *Bidding, Estimating, and Payment.*
Appendix A includes specifications from several states. These specifications can be used to assist engineers in writing specific job specifications. The asphalt Institute's, "*The Asphalt Handbook",* Manual Series N. 4 (MS-4), also provides extensive and detailed information for the user and designer of asphalt pavements. Also, Appendix B, C, D and E provide detailed information on the use and design of asphalt-aggregate surface treatments (Chip seal, seal coat, etc.).

Bidding, Estimating and Payment

Bid forms and bid evaluations are best converted to include equivalent volume measurements. This keeps all materials on an equal and competitive basis by correctly adjusting for the large difference in the aggregate weight to volume ratio. ESCS lightweight aggregate weighs approximately half as much as normalweight aggregates (crushed limestone, gravel, trap rock, etc.). The weight difference is easy to adjust and must not be overlooked during the design, bidding, or construction phase of the project.

If the aggregate is bid by the ton, adjustment for weight is essential because one ton of ESCS will be about twice the volume of one (1) ton of normalweight aggregate.

When comparing quantities of ESCS lightweight aggregate with normalweight aggregate always base the comparison on equal volume of materials, for example, dollars per cubic yard. With chip seal projects, the spread rate of each aggregate should also be included to determine cost accurately. Spread rates given in square yards per cubic yard or square meters per cubic meter provide the easiest method of comparison.

Because ESCS aggregate is light, it offers many cost advantages that need to be considered when estimating projects. Additional information is provided in *Construction Consideration's and Advantages.*

Mixture Designs

Mixture designs must also be adjusted volumetrically using appropriate weights for ESCS aggregate. It is easy to mix coarse and fine aggregates of different densities provided the batching weights have been adjusted to provide the correct volume of each aggregate in the mixture. Many specifications refer to aggregate percentage by weight, so percentage by weight must be converted to percentage by volume.

Asphalt cement must also be used on a volume basis and is essentially the same amount for ESCS mixtures as for normalweight mixtures. Contrary to some industry myths, ESCS aggregate does not absorb asphalt, or the asphalt absorption is negligible even though some ESCS aggregates may have in excess of twenty-percent (20%) water absorption after 24 hours. There are two primary reasons for this:

> First, the kinematic viscosity of asphalt at 135ºC (275ºF) ranges from about 150 to 400 centistokes depending on the asphalt grade. The kinematic viscosity of emulsified asphalt ranges from 20 to 400 centistokes depending on the grade. In contrast, water has a kinematic viscosity of one centistokes at 20ºC (68ºF). Because of a much higher viscosity even when hot, asphalt does not penetrate the bleb structure of the aggregate easily.
>
> Second, Exposure time is also a factor, for example, water absorption is usually measured after 24 hours with many aggregates reaching there full absorption only after several days of continuous wetting. In contrast, the asphalt is only hot and in a potential absorptive position for one to three hours depending on the asphalt pavement applications.

Reports of high absorption are almost always a misinterpretation of the calculations. For example, a 100 lb normalweight aggregate asphalt mixture with 5.5% asphalt would have

5.5 lbs. of asphalt in it. The same volume of ESCS aggregate asphalt mixture weighing 65 lbs. would have 8.4% asphalt, but still the same 5.5 lbs. of asphalt. The reason is the volume of aggregate material is about the same and the aggregate surface areas to be coated with asphalt are also about the same.

Construction Considerations and Advantages

ESCS aggregate offers the following cost advantages in transporting and handling:

A. Material haul costs are reduced. ESCS aggregate weighs approximately one-half that of normalweight aggregate, thus allowing a larger volume of material per truck load. To increase hauling capacity, side boards are often added to truck beds or bulk trailers. Trucks with larger bulk hauling capacity are also used. In addition, less overall tonnage is hauled, fewer trucks are needed, and fewer trips are required.

B. Contractors consistently report less equipment wear and tear with fewer breakdowns. For example, spreader belts often last all season.

C. ESCS aggregate is much easier to spread manually than normalweight aggregate. Often large grain scoops are used allowing the labor to carry twice the amount of aggregate per trip.

D. Surface treatment projects are safer for workers because passing vehicles dislodge fewer flying particles. The ESCS particle is also less dangerous because it is lighter. Windshields, headlights, and chipped paint damage insurance claims are almost entirely eliminated.

E. When needed, brooming or vacuuming excess ESCS chips from surface treatment projects is much easier because the aggregate weighs less.

F. ESCS is easily prewetted and holds moisture for days in a stockpile which provides almost dust-free placement, a plus when emulsions are used with chip seals. ESCS creates minimal dust, unlike normalweight aggregate which is often coated with dust that prevents uniform bonding and creates public complaints during application.

G. ESCS aggregate is available throughout the U.S., Canada, and much of the world. The material is often shipped long distances because of its lighter weight.

H. The contractor can use the same machinery and equipment for normalweight or ESCS aggregate pavements. **Caution: Use only pneumatic rubber-tire rollers with any asphalt-aggregate surface treatment (chip seal) projects. Steel-wheel rollers should not be used.** (*Construction Procedures and Equipment; Rolling Operations).*

14.6 Chip Seal: Asphalt – Aggregate Surface Treatment

General Considerations

ASTM defines surface treatment as an application of bituminous material followed by a layer of mineral aggregate. Multiple applications of bituminous material and mineral aggregate may be used. However, there are many names that refer to Asphalt-Aggregate surface treatment depending on the region. The most common name is chip seal, however, other names like *seal coast, surface treatment, inverted penetration, oil and chip, chip and seal, sprinkle treatment, and armor coat* are also used. For simplicity, the term "chip seal" will be used in this manual.

Chip seal is normally used on low to medium volume rural roads or city streets. However, because of its high-friction resistance, superior bonding capability, and lack of windshields, headlight and paint damage to vehicles, ESCS chip seals have been used on high-speed and high-volume city streets and highways such as the Autobahn in Germany and interstate highways in the United States.

Even though ESCS performs well in almost all road applications, maintaining close cooperation with the ESCS aggregate producer, contractor, and owner is essential to insure a successful project. The attention to detail and adequate project control, particularly during the construction periods, and when traffic is first allowed on the new road surface, cannot be over-emphasized. To help maintenance personnel make a reliable, objective determination of the real-world rating for a chip seal, the Strategic Highway Research Program (SHRP) developed a simple procedure to rate the construction quality of a chip seal project. This procedure is described in publication No. SHRP-H-322 (SHRP-M/FR-92-102) "Development of a Procedure to Rate the Application of Pavement Maintenance Treatments". The publication covers the Rating Tree Procedure and specifications for chip seals, slurry seals, and cracks sealing, and is available from the Transportation Research Board.

Appendix B includes four section from this SHRP publication:

Section 407 Chip Seal
Section 408 Slurry Seal
Section 702 Bituminous Materials

Section 703 Aggregates

This SHRP publication was written using normalweight aggregate, but also applies when ESCS aggregate is used provided the necessary adjustments are made to compensate for the differences in unit weight.

Appendix E: ASTM D5360 "*Standard Practice for Design and Construction of Bituminous Surface Treatments"* also provides detailed information.

Like all materials, ESCS chip seal must be properly designed to utilize the merits of the material. Assuming a high-quality aggregate is selected, the designer must take into account the following factors:

- Aggregate unit weight
- Proper application
- Aggregate grading and top size
- Moisture content of the aggregate
- Asphalt type
- Asphalt and aggregate application rate
- Embedment depths
- Weather considerations
- Construction procedure and equipment
- Road patches and other precautions

In general, ESCS chip seal offers the engineer an economical, long-lasting road surface that is safer to drive on and free of motorist complaints. Appendix D provides a complete detailed design method for chip seal surface treatment. This method has been used extensively by the TXDOT.

The standard industry design and construction practices as published by the Asphalt Institute, Publication ES-11 "Asphalt Surface Treatment – Specifications" and Publication ES-12 "Asphalt Surface Treatments – Construction Techniques" also apply to ESCS chip seal.

Appendix I International Surfacing Inc., "Guide Specifications for Asphalt-Rubber Chip Seal", will prove very helpful if asphalt-rubber is being considered.

Appendix K "Asphalt Emulsion Looking at the Basics" is a good one-page overview of how to do quality chip seals, published in March 1995 issue of Better Roads.

Proper Application: City Streets versus Rural Highways

There is a basic difference in magnitude and frequency of the horizontal and transverse shear imparted to a road surface in urban and rural areas. City streets are subjected to more starting, turning, and stopping for a given volume of traffic than rural highway surfaces. Quite often a new material is introduced by placing it on a rural section where there is little or no turning and stopping. Rural areas are good places to use ESCS as coverstone for an initial chip seal surface treatment. The same design, using exactly the same materials, may not be satisfactory on a city street with identical traffic volume because ESCS is highly textured and develops a high coefficient of friction with rubber tires. This characteristic, coupled with the stops, starts, and turns of city traffic may tumble and dislodge the stones. In comparison, the rolling friction normally developed by the same traffic on a rural highway would cause no trouble.

To minimize tumbling and dislodging of the stones under city traffic, three actions are necessary:

- Use a maximum aggregate of 3/8 inch (9.5 mm).
- Use a more viscous asphaltic binder than is used on rural roads in the same geographic area, and specify polymer modified asphalt for the binder to increase adhesive quality.
- Establish the appropriate pneumatic rolling pattern. Note: The equipment and pattern may be slightly different for city streets then for rural roads.

Aggregate grading and top size

ESCS grading is similar to crushed stone, however, with ESCS a cleaner product results thus reducing the potential for dislodgement due to dust coating on the particles. One of the major causes of failure of chip seals is too much clay, or silt in the aggregate. Dirty chips are unable to form a sufficiently strong bond with the asphalt and are quickly dislodged by traffic. In contrast, ESCS aggregate does not contain any clay or silt. The fines or dust in ESCS aggregate is just very fine ESCS material.

Uniform grading (essentially one-size aggregate no larger than 5/8 inch (15.75 mm) is highly recommended for chip seal construction. All other design factors being equal, uniform grading permits a wide variation in asphalt application rate. This is very important since most road surfaces demand varying quantities of asphalt for chip seal construction. Stated another way, uniformly-graded cover materials permit a larger margin of error in binder quantity than either well-graded or poorly-graded materials. Appendix C includes a list of ESCS gradations used by several different states. Note: The producer should, if at all economically practical, restrict the furnished materials to the minimum of both ends of the gradations listed in Appendix C. Although these gradings include several different top size materials, experience indicates that intermediate sizes perform better than coarser sizes. Thousands of miles of existing ESCS chip seal projects have proven that ½ inch to No. 4 (12.5 mm to 4.75 mm) material is the optimum size for single-course chip seal projects. However, cover material in the 3/8 inch to No. 8 (9.5 mm to 2.36 mm) size has also performed well and is often preferred on low traffic residential streets.

Designers and specifiers please note: It is essential that the ESCS producer be contacted during the design and specification writing stage of the project because some gradations are more economical to manufacture than others for a given ESCS plant. As can be seen in Appendix B, gradations vary from state to state and still perform well. Matching the gradation specified with an economically produced plant gradation helps ensure competitive bids without compromising road-surface performance.

Asphalt type

Many agencies across the United States use liquid asphalt binders such as emulsion for surface treatments. Liquid asphalt binders such as RS-2, CRS-2, HFRS-2 can be used successfully with ESCS, but the user is cautioned to consider the lower bond associated with these materials, particularly in the very early life of the surface. Rapid-setting emulsions with high-viscosity residual can also be used. Hot-sprayed AC-10 is highly suitable for ESCS chip seal and commonly used in hotter climates such as Texas and Arizona. Properly designed liquid asphalt materials can be used in the cool climate areas of Canada and northern United States.

It is essential to provide the time needed to develop a good bond between asphalt and aggregate. If it is necessary to open the road to traffic immediately following construction, the Asphalt Institute recommends limiting driving speed to twenty miles per hour for the first 24 hours. Appendix B, Section 702 – "Bituminous Materials" published in 1992, covers the latest information from SHRP.

Asphalt and aggregate application rate

This manual is not written to give detailed design procedures for chip seal surface treatments because that information is widely available for conventional stone, and there are only minor differences when ESCS aggregate is used. Figure 9 illustrates the effects when varying the application rate of both the binder and the coverstone. The results shown are from laboratory-controlled tests on a given size of aggregate and indicate the folly of using anything other than the proper amounts of binder and coverstone of a selected size.

With maintenance work, it is often necessary to decide whether it is more economical to do the following: 1) reseal the old surface, 2) rework the top inch or two of the surface, or 3) overlay with hot-mix asphaltic concrete. The life expectancy of a chip seal surface treatment can be disappointingly short if the road has wide variations in asphalt demand.

ESCS aggregate sized in the 5/8 inch or ½ inch and finer (Appendix C) are most effective for chip seal projects because this grading permits higher binder application rates without danger of flushing. Of course, spot corrections are in order if the surface condition is too variable with both dry and flushed areas, to expect a successful surface treatment job, or if funds are not available to rework or overlay the road. With spot corrections, excessively dry areas can be primed, and flushed areas can be planed off or oxidized by burning. In some cases additional ESCS aggregate is added and rolled to correct bleeding.

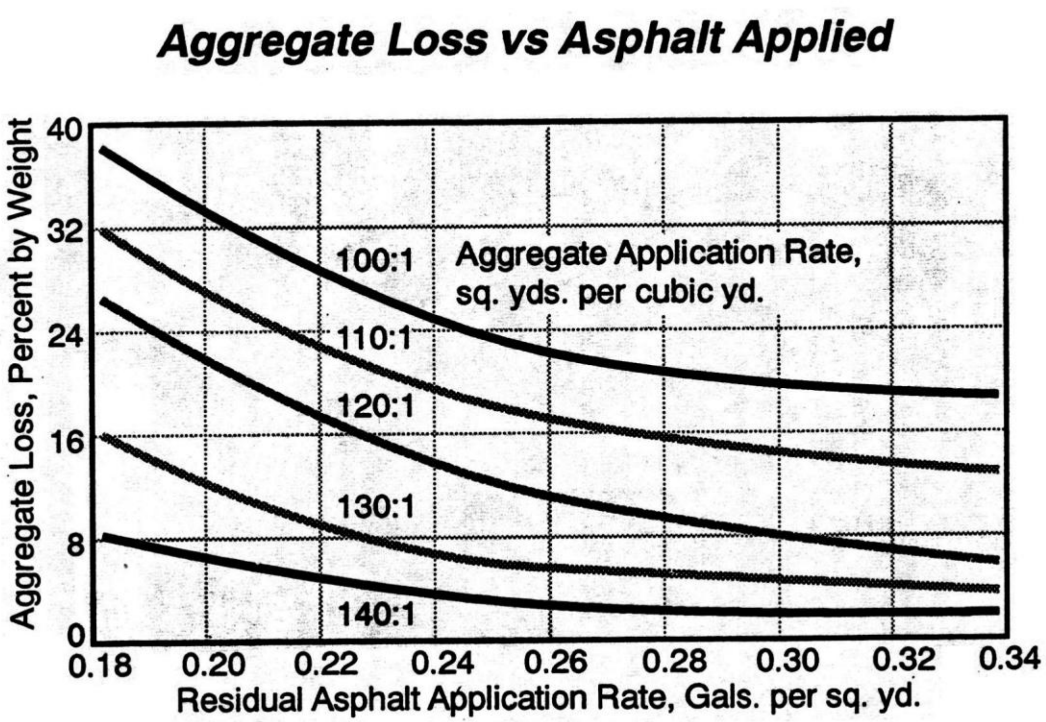


Figure 14.9 *Aggregate loss vs. Asphalt applied for variable aggregate Cover rates in square yards per cubic yards. ESCS lightweight aggregate grade ½ inch to No. 4 (12.5 mm to 4.75 mm)*

Chip seal surface treatment projects involving sprayed binders must be carefully designed to accommodate surface conditions, traffic, weather, and climate. Limited data are available on suggested adjustments in binder application rates for different traffic volume. Figure 14.9 shows adjustments offered as guides but should be used with considered judgment. These suggested corrections apply only to chip seal on old, consolidated surfaces. The effect of traffic volume on the asphalt application rate is less critical on older surfaces than it is on new or reworked surfaces because the old surface is usually well consolidated. Inadequate density, at or near the surface of a new or reworked job, permits the coverstone to intrude, resulting in a flushed surface. For this reason, the corrections suggested in Figure 14.10 should not be used on new surfaces. In any case, it is important to evaluate the surface carefully to arrive at the most desirable quantity of asphalt to be applied.

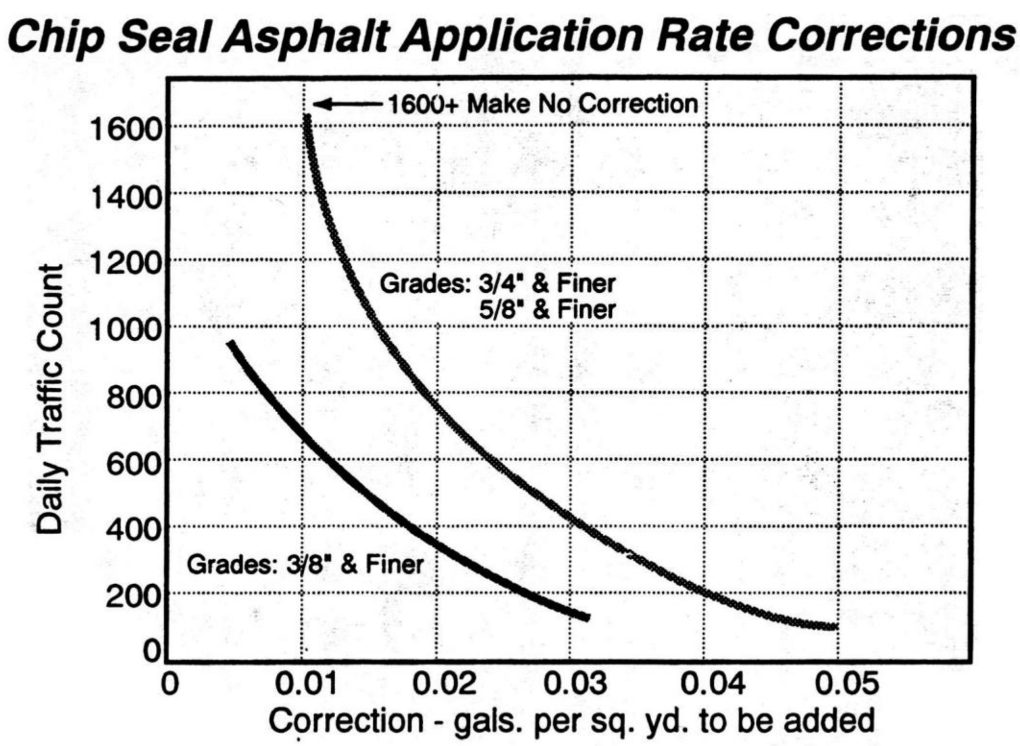


Figure 14.10 ***Chip seal asphalt application rate. Correction due to traffic for older consolidated surfaces.***

The excess aggregate menace: For example, with a ESCS aggregate weighing about 1100 to 1300 pounds per cubic yard and uniformly graded to meet the size requirements of 5/8 inch and finer (Appendix C), a cover rate of nine to eleven pounds per square yard is ample. This is equivalent to a range of 110 to 130 sq yds/cu yd. Ideally, the material should be sampled after it is stockpiled on the job site, and laboratory tests (See

Appendix D) used to establish the appropriate cover rate. The amount of aggregate required to cover a unit area one-particle deep determines the cover rate. In the past, the laboratory cover rate was automatically adjusted upward ten percent to take care of spreading inaccuracies in the field and to minimize asphalt pickup on equipment. Actually, this increase is not always necessary, provided good equipment and careful construction controls are employed. Also, slight deficit is preferable to an excess of ESCS aggregate. Figure 14.11 shows a close-up of a road surface before rolling, where it appears that not enough aggregate was used to cover the surface adequately. Figure 14.12 shows the same surface after rolling and one month of light traffic; the surface is completely covered. Inspection at the edge of this road revealed a very small (less than one-half of one percent) loss of aggregate.

Jobs have been observed, particularly with county agencies and in cities, where an excess of more than 50 percent of stone was applied. In chip seal work, the general rule is that any aggregate applied in amounts exceeding that required to cover the surface one-particle deep can jeopardize the success of the job and cause short service life or immediate failure.

Loose normalweight stones (gravel, crushed limestone, trap rock, etc.) present a hazard to vehicle glass, headlights, and paint finish. Also, loose stones act as an abrasive scouring agent under traffic, breaking down both loose particles and in-place particles. The resulting dust is a possible hazard and, at least, a nuisance. Loose aggregate promotes tumbling of bonded particles and reduces the overall coefficient of friction of the road surface. In comparison, loose ESCS aggregate does not present the above mentioned vehicle hazards, yet still acts as an abrasive scouring agent under traffic, breaking down both loose and in place particles. In all cases, loose aggregate is a menace and a waste.

Figure 14.11 ***Road Surface before rolling showing what appears to be an inadequate aggregate cover***

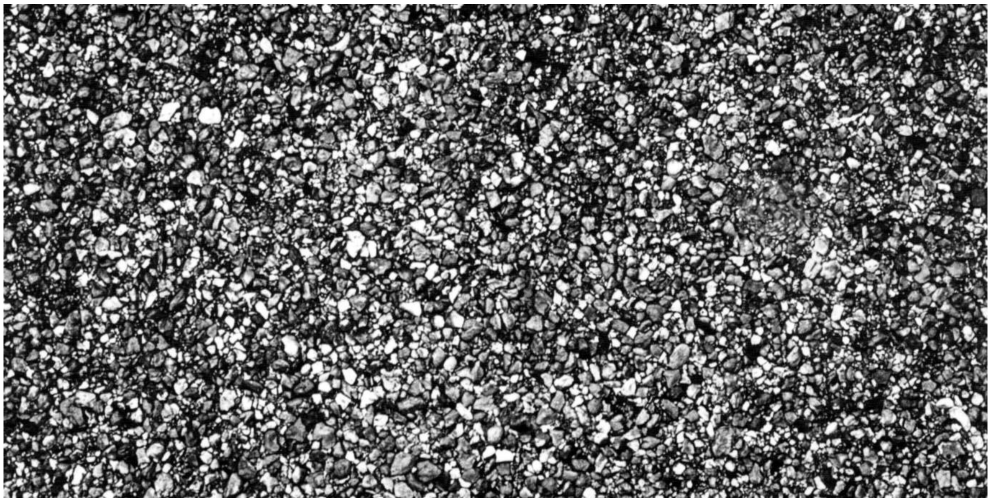


Figure 14.12 ***Same surface as Figure 14.11 after rolling and one month of light traffic***

Embedment Depths

Embedment depths should be in the range of 40 to 60 percent of the particle diameter immediately after adequate construction compaction (seating) with pneumatic rollers. The lighter the traffic, the higher the initial embedment depth, if all other factors are equal (see Table 14.1). On the average ESCS, aggregate should be embedded somewhat deeper than conventional stone. Added embedment is necessary primarily because of the high coefficient of friction of ESCS aggregate. Less embedment depth and higher-viscosity asphalts are needed if anticipating a high percentage of trucks in the traffic stream because truck-tire pressures and axle loads are higher.

Table 14.1 Initial Aggregate Embedment Depth for ESCS Chip Seal Surface Treatments

TRAFFIC VOLUME	SUGGESTED INITIAL AGGREGATE EMBEDMENT DEPTH
Low <500 vpd/lane	High approximately 60%
Medium 500 to 2000	Medium approximately 50%
High>2000	Low approximately 40% Note: A higher initial depth may be required with polymer modified asphalt
If High Percentage of Trucks	Low approximately 40% with a higher-viscosity asphalt

Weather Conditions

Chip seals constructed with ESCS aggregate are somewhat more sensitive to inclement weather during and immediately following construction than are normalweight aggregate chip seals. There are two primary reasons for this:

First: ESCS lightweight materials generally have higher water absorption capacities than natural stone. Note: it's important to reiterate that even though the water absorption is higher ESCS does not absorb asphalt or at least the absorption amount is negligible. (See section 14.5, Mixture Designs)

Second: ESCS aggregate has a more textured surface.

Because ESCS aggregate may contain more moisture when it is placed, a strong bond may take longer to establish between the asphalt and the aggregate surface. Textured surfaces may require more waiting time than do smooth surfaces; however, once the bond is established, it is stronger.

It is easy to minimize the effect of a high-water content in the more absorptive aggregate by keeping traffic off the surface for at least one hour or using a pilot car to take traffic over the surface at low speeds. A rapid-setting cationic emulsion can also be used as a source of asphalt binder for damp or even wet aggregate. Across the U.S., more and more agencies are using cationic rapid set, anionic and high-float emulsions with a polymer additive. For clarification;

- Anionic means the asphalt globules are electro-negatively charged.
- Cationic means the asphalt globules are electro-positively.
- High-float (HF) – High-float emulsions have a quality, imported by the addition of certain chemicals that permits a thicker asphalt film on the aggregate particles with minimum probability of drainage. The HF is measured by ASTM D 139 or AASHTO T50.

Hot weather is ideal for chip seal work. Mild wind movement and low humidity are desirable but not necessary for success.

Rain: Rain during or immediately after placement, combined with a textured and absorptive aggregate, can ruin an otherwise perfect chip seal job. One might wonder at first how water absorption affects placement. In fact, the effect of the rough surface texture may also be puzzling. Water absorption and rough-surface texture may work together in the first few hours of a chip seal to cause almost complete loss of coverstone when a surface is placed, rained on, and immediately turned over to traffic. The absorptive aggregate holds more water and, therefore, remains wet longer after the rain stops. Under these conditions, some absorbed water is released and prevents early bond establishment between the aggregate and binder especially with asphalt cements. If the initial wet condition is prolonged, the incomplete bond allows the particle to be tumbled and pulled out under traffic action. The result may be a road stripped of cover material. Fortunately, this does not happen often and can be avoided entirely by placing the material during good weather or using emulsified asphalt with a hard residual, such as CRS-2h with a polymer. Note: CRS-2h is available in some local markets (Texas, etc.) but is not a standard material according to ASTM D 2367.

Construction Procedures and Equipment

ESCS chip seals use the same construction procedure and equipment as conventional stone chip seals. (See Asphalt Institute publication ES-12 "Asphalt Surface Treatment – Construction Techniques" and MS-19 "A Basic Asphalt Emulsion Manual").

The performance of chip seals depends to a large degree on the quality of construction. Key factors which may contribute to successfully constructing high quality chip seal include:

1. proper preparation of the existing surface upon which the seal coat is to be placed—for example, if the surface is exhibiting a bleeding distress, special corrective measures should be taken to reduce the potential for bleeding in the new chip seal;
2. satisfactory environmental conditions—experience has shown that the ideal environment for the construction of chip seal is hot, dry weather with no rain for the next several days;
3. selection of equipment in good operating condition and proper handling of equipment during construction;
4. carefully planned sequence and timing of construction operations;
5. implementation of an adequate field inspection and quality control plan; and
6. adequate traffic control during construction particularly in the first hours after completion of construction.

Rolling operations: ESCS cover aggregate on chip seals need to be seated with a light, approximately 5 to 7 ton pneumatic roller. Field tests show the comparative effects of roller type and service. Figure 14.13 compares the degradation of a ESCS ½ inch (112.5 mm) and finer aggregate subjected to flat-wheel steel rollers and light (5 to 7 ton) pneumatic rollers This comparison shows that seating the cover aggregate with steel-wheel rollers, surface No. 1, is unwise because steel wheels cause aggregate degradation by creating very high-point stresses on the individual aggregate particles. Even with 50 times the amount of traffic, surface No. 2 with pneumatic rolling only suffered little degradation.

Quote from the Asphalt Handbook – Asphalt Institute MS-4 1989 Edition:

> "**Roller:** Seating of aggregate particles is an important part of the surface Treatment operation. There are several types of compactors, but pneumatic-tired are usually used. A self-propelled pneumatic-tired roller with tire pressures in the range of 415-620 kPa (60-90 psi) is recommended for use on asphalt-aggregate surface treatments. The tires force the aggregate firmly into the asphalt binder and to the flat side without crushing the particles. Steel-wheeled rollers bridge the smaller size particles and small depressions in the surface. Steel-wheeled rollers also may crush the softer particles so that degradation takes place even before traffic uses the new surface.
>
> **"Rolling:** Rolling seats the aggregate in the asphalt membrane and thus promotes the bond necessary to resist traffic stresses.
>
> "Pneumatic-tired rollers should be used on all surface treatment jobs. Pneumatic-tire rollers give uniform pressure over the entire area. Better results will be obtained if two self-propelled rollers are used with each aggregate spreader".

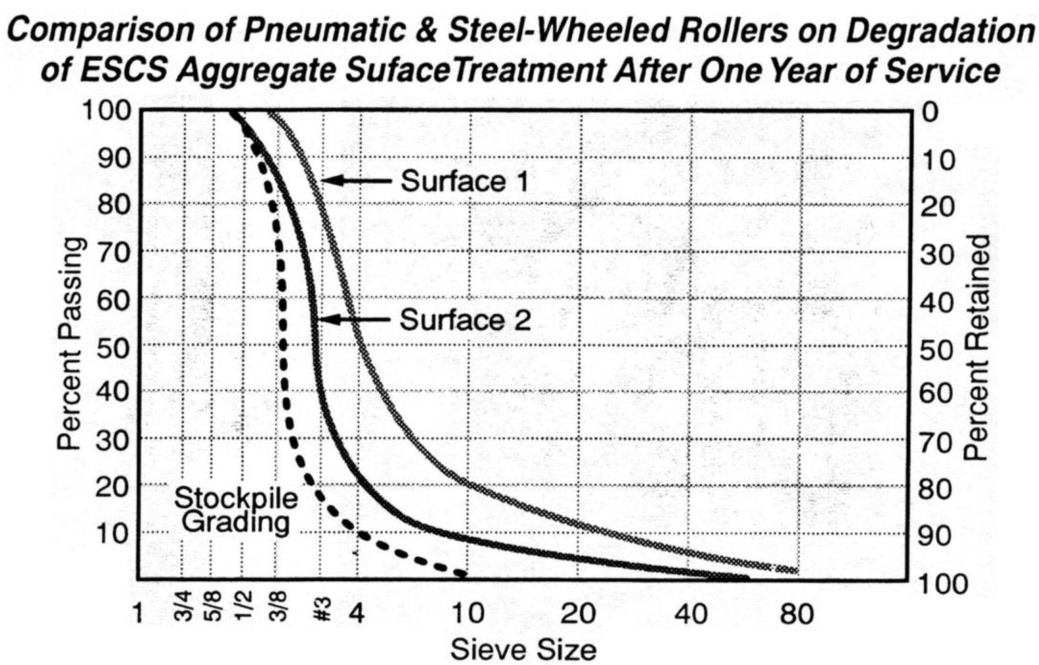


Figure 14.13 ***Comparison of pneumatic and steel-wheeled rollers on degradation of ESCS aggregate surface treatment after one (1) year of service.***

Surface #1: 5 hrs. of rolling with a 6.0 ton steel-wheel/mile
5 hrs. of rolling with 1.0 ton steel-wheel/mile
5 hrs. of rolling with a light (5 ton) pneumatic/mile
Age: 1 year
Traffic: 150 vpd

Surface #2: 5 hrs. of rolling with a light (5 ton) pneumatic/mile
Age: 1 year
Traffic: 7700 vpd

Figure 14.14 is a photograph of a cloud of dust rising from surface 1 (Fig. 14.13) rolled with steel rollers. Stockpile samples of the aggregate before construction showed less than 1.0 percent passing the No. 200 sieve; therefore, it is evident that construction compaction created the fines (dust) that are apparent in the photograph.

Figure 14.14 ***Dust caused by steel-wheeled roller use.***

Figure 14.15 shows a ESCS aggregate trial section (Surface 2, Figure 14.13) subjected to pneumatic rolling plus roughly 50 time more traffic as the road shown in figure 14.14. This trial section was in excellent condition after six years of service. The wet coefficient of friction (at 40 mph) is still well above the 0.5. The Texas Highway Department

District in which this section is located has since used ESCS as cover aggregate on thousands of miles of primary highways to reduce damage to windshields and raise the coefficient of friction.

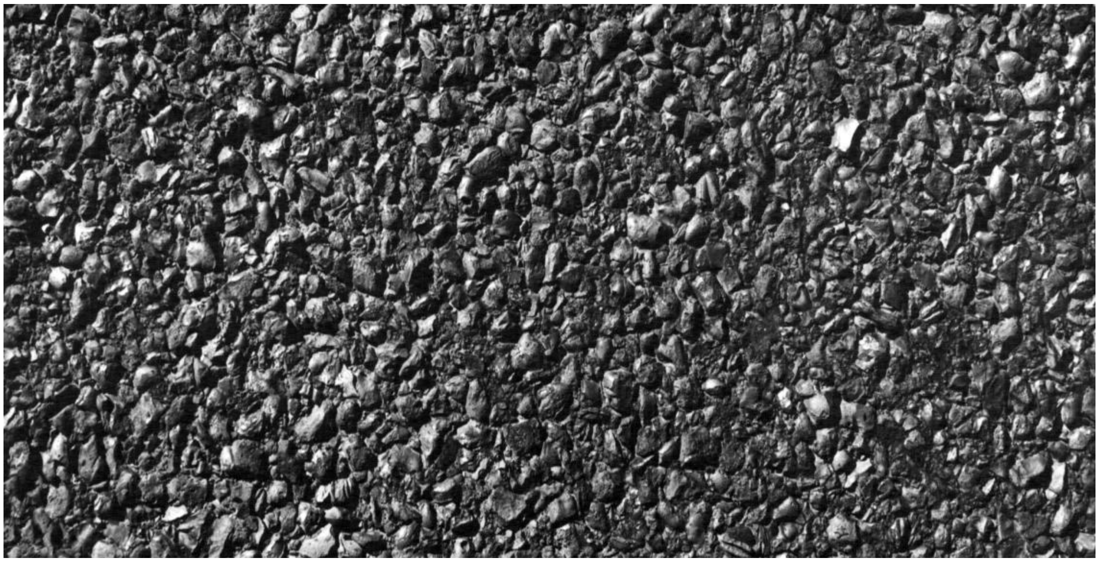


Figure 14.15 ***Showing excellent surface texture of ESCS aggregate coverstone after five million vehicle applications. Photo taken in the wheel path.***

Caution: It is extremely important that the ESCS aggregate seating and compaction be performed only with pneumatic rollers. Steel-wheel rollers change the grading of almost any stone (lightweight or normalweight) regardless of its hardness or toughness, thereby altering the design. Steel-wheel rollers create very concentrated stresses on individual aggregate particles causing excessive degradation as shown in Figure 14.13. Also, low areas in the road surface are bridged over while excessive crushing occurs on the high points, resulting in bleeding in the areas of excessive crushing and raveling in the low areas. Steel-wheeled rollers are not recommended with any type of chip seal.

Spreading aggregate: The aggregate spreader is second in importance only to the asphalt distributor. The aggregate spreader needs to apply a uniform aggregate cover at a specified rate over a freshly-sprayed asphalt membrane. The most effective aggregate spreaders are modern self-propelled spreaders that are equipped with an automatic application rate and speed-control computers. The computer varies the gate opening to maintain a preset application rate regardless of the chip-spreader speed. Application accuracy is maintained when starting and stopping and when the chip-spreader speed is adjusted to meet job requirements. Increased accuracy reduces aggregate expense and results in an improved road surface. The computer-controlled spreaders can store several different aggregate/application rate combinations in memory. Application rates can be

varied infinitely or memory presets can be selected on the go. The computer can also be set to control the spreader's forward speed for consistent speed when following the distributor.
Aggregate spreaders that separate the aggregate so the larger particles hit the asphalt membrane before the smaller particles also work very well, especially if the aggregate being spread is not close to a single-size material. Aggregate separating attachments are available from most equipment suppliers even though they are not commonly used.

Aggregate that is clean, close to one size, and spread at an even and consistent application rate will provide the best results (See Appendix C).

Multi-Course Surface Treatments

In general, it is not economical to use more than a double asphalt-aggregate surface treatment, therefore, this discussion is limited to doubles.

Equipment: Multi-course surface treatment work requires the same equipment as singles; however, the aggregate spreaders and rollers discussed below work best for doubles application.

Use modern self-propelled aggregate spreading equipment preferably computer controlled to insure a uniform and consistent aggregate application rate. Gradation and size sorting of the cover material is even more important for doubles than for singles. The use of an aggregate-separating attachment on older non-computer controlled equipment helps the highly-textured lightweight aggregate to nest more effectively, thereby reducing degradation during construction and early service. Improved nesting assures a nearly uniform distribution of the second layer of asphalt and aggregate resulting in a waterproof surface.

Using light (approximate 5 to 7 ton) pneumatic rollers is very important because textured materials have a strong tendency to stack when applied. Stacking creates localized high points on the pavement surface and can lead to over-stressing.

Caution: As stated previously, steel-wheel rollers should not be used in any phase of the chip seal surfacing operation.

Asphalt quantities and order of placing: The design of a two-course chip seal requires about the same quantity of material as two single chip seals made with the same type and grading of cover aggregate. One important difference, however, is the distribution method of the total amount of asphaltic material calculated for the two sizes of aggregate used alone. For example: separate designs of two singles, one using Texas Grade 3 (Appendix C – ¾ inch and finer) and the other Texas Grade 4 aggregate (Appendix C –

5/8 inch and finer) require for the average surface a total of 0.650 gallons of residual asphalt per square yard of surface. The larger aggregate (Grade 3) should be placed first with the asphalt requirement of the smaller stone (Grade 4). That is, if the Grade 3 requires 0.35 gallons per square yard and the Grade 4 requires 0.30 gallons per square yard, then one should spray 0.30 gallons per square yard residual and then apply the Grade 3 stone. This is easy to understand when one carefully examines the highly-textured nature of the surface receiving the second applications of asphalt. The surface is referred to as “hungry” and, therefore, the surface needs more binder as well as the smaller-sized second course of coverstone. Notice in the previous example that Grades 3 and 4 were selected as companion aggregates for the double treatment. Texas Grades 4 and 5 would also be satisfactory, but under equal design conditions would require less asphalt. Generally speaking, it is unwise to select two sizes of cover aggregate that differ more than one-grading size as shown in Appendix C.

Caution: The first course could be vulnerable to aggregate loss if left alone and open to traffic, especially if placed with too low a binder quantity and if marginal weather follows.

It is not a good practice to reverse the aggregate size when placing doubles made with ESCS aggregate; that is, do not place the smaller aggregate in the first course and cover it with larger aggregate. To do so requires more asphaltic binder to hold the same size aggregate adequately and may cause flushing. On the other hand, using the usual amount of asphaltic binder causes coarse-stone raveling and, in turn, a flushed surface.

Precautions

General: When using ESCS aggregate in asphalt pavement the first few times, it is wise to use with considered judgment, and not accept test locations that are excessively difficult to do under emergency conditions. Any construction material used as an alternate requires a learning curve and must not only perform as well as existing materials filling that need, but must also have other desirable attributes. ESCS aggregate compares favorably with the best natural aggregates in the areas of bond tenacity and general service durability.

ESCS excels in reducing windshield and other vehicle damage, and is a high-friction resistant surface. ESCS aggregate can, however, be abused during construction or by using improper designs, or improper binder choice. For example, low-viscosity asphalt cement with excellent service records may give successful results if used with smooth-textured natural aggregates, but low-viscosity asphalt may not be sufficiently viscous to hold highly-textured ESCS aggregate, especially in the early life of the pavement. This is particularly true if the pavement handles heavy, urban traffic with its many stopping and turning motions. When choosing asphalt viscosity with ESCS aggregate the more viscous binder is better. However, choosing the proper viscosity is less important in rural areas. Under cool conditions the aggregate should be heated and applied at temperatures above 250º F (120º C) for the best results.

Road patches: Cover aggregate may be submerged or intruded into the existing surface due to an improperly compacted surface like a patch or a new or reworked surface. Submerged cover aggregate may also result in spite of careful designs that take into account aggregate size, traffic, and climate. Therefore, freshly repaired roads should not be chip sealed for 60 to 90 days. Delaying the chip seal resurfacing allows the patch to densify and cure, and greatly reduces the possibility of localized failures.

Comments on the Handling, Construction, and Service of ESCS Aggregate Compared to Precoated Natural-Rock Aggregate for Chip Seal

The following comments represent a cross-section of those received in interviews with several states' DOT personnel and contractors who used expanded shale, clay, and slate lightweight aggregate for chip seals.

State and district personnel:

A. "Seal coat work should be done during hot, dry weather conditions".

B. "Use pneumatic rollers exclusively".

C. "Light brooming the morning following placement, works well".

D. "Use calibrated nozzles and make adjustments as needed for traffic volume, emulsion volume adjustment due to shot temperature 150º F, existing surface conditions, and wheelpath adjustment. Smaller nozzles are used for each wheelpath application to avoid bleeding – usually a reduction in shot rate for the wheelpath is about twenty percent (20%). (Sets of calibrated nozzles maybe purchased from the Etnyre Co.). Shoot only one traffic lane at a time (12 ft. ±)". [This practice is standard in some areas like Brownwood, Texas, however, other engineers' feel it unnecessary provided quality equipment and materials are used and good construction practices are followed].

E. "Heavy traffic, particularly with a large percent of trucks, demands less asphalt, all other factors being equal".

F. "Design shot rates and actual shot rates shown on data sheet represents emulsion not residual asphalt. Some CRS-2 and CRS-2h are supplied with sixty-five percent

(65%) residual. However, consult the asphalt supplier before finalizing design".

G. "Aggregate embedment for design purposes should be about forty percent (40%) for most roads, however, higher embedment may be needed with traffic at 8,000 vpd or higher".

H. "At the end of one year of traffic, embedment depth in the wheelpath should be about eighty percent (80%)."

I. "It is neither wise nor economical to place an excess of coverstone. Placing of more than 115 sq. yds/cu.yd does more damage than good for the grading of lightweight".

J. "Precoating of seal coat [chip seal] coverstone is advantageous and is usually cost effective when AC 5 or AC 10 binders are used. When emulsions are used, precoating is usually not needed".

K. "Within its area of competitive haul, the expanded shale aggregate is an important alternate to other materials because of reduction in windshield breakage alone. The material is dark in color which reduces glare and it appears to have a natural affinity for asphalt. The material has not degraded appreciably under normal surface rolling".

L. "The hard freezes during the winter of 1963 did not damage the lightweight. It performs as well as precoated and has less flying particles immediately after construction. Lightweight dusts a little but the grading is good, and it is a valuable material for seal coat [chip seal] surface treatment work".

M. "After two years of service, we are still pleased with the performance of ESCS lightweight aggregate. The color contrast produced by lightweight has remained throughout the life of the surface, whereas precoated natural rock fades out in a few months."

N. "Of all the stone available for seal coat and surface treatment, I prefer the overall characteristics of lightweight. The contractor's men prefer the handling ease afforded by lightweight aggregate and it bonds well to the asphalt."

O. We had one job, a double surface treatment (lightweight), that bled severely but this was in the early trial stages and was caused by a fault in design. We have had some trouble with variation in the amount of oil used on our precoated natural rock material. Nevertheless, both lightweight and precoated rock does a good job when properly designed and constructed".

P. "High-speed traffic on new surfaces of lightweight does not create a flying stone hazard. Loose stone is thrown but is carried only a short way from the vehicle wheel.

It is not necessary to sweep loose stone back on a new surface made with lightweight. Initial adhesion is good with lightweight".

Q. "Where lightweight is used, the reduced gross loads of equipment during construction minimize damage to shoulders on low-traffic roads".

R. "Retention of lightweight aggregate is as good as that of precoated, natural rock aggregate when placed under identical conditions. Lightweight aggregate is naturally dust free and has an inherent affinity for asphalt. This material has produced excellent results on high-traffic roads when placed under favorable weather conditions".

Resident Engineer and Contractor Personnel:

A. "Some dusting was experienced on one surface one to four days after construction. (The lightweight aggregate seal was rolled with steel and pneumatic rollers. We stopped using the steel rollers and the dusting problem stopped.) At speeds up to 60 mph some stone was thrown by traffic. Stones were airborne for a distance of 20 to 40 feet. No windshield damage was observed or reported on this lightweight aggregate section".

B. "Lightweight aggregate adheres well to the asphalt. The grading is uniform and the material is clean when delivered. Due to its lightweight and good bond, it can be swept effectively with a blade broom."

C. "The material (lightweight) is easy to handle. Job progress is more rapid and laborers handling the hand, touch-up work find their job easier. Laborers can also use larger shovel, thus making less trips".

D. "Without special modification of handling equipment, overloading is eliminated and this extends equipment life.

E. "The lightweight aggregate is easier on equipment and has less overall breakdowns. For example, belts on spreader boxes often last all season."

Summarizing these observations on ESCS:

A. Retention is comparable for like designs and service conditions.

B. Bleeding, where observed, was about the same and could not, for either lightweight or precoated rock, be definitely attributed to any characteristics of the materials involved.

C. Serious raveling was encountered on one precoated job but this was attributed to improper design. Minor raveling was observed on several other sections but there was no great difference in the degree of raveling for ESCS lightweight or precoated rock materials. As a general rule, where minor raveling occurred it took place between the wheel paths, possible, indicating the need for a slight increase of asphalt application rate.

D. Degradation during construction rolling was comparable except where the ESCS lightweight material was rolled with steel, flat-wheel rollers. We no longer use or recommend steel rollers on any chip seal surface treatment.

E. General appearance of the ESCS and precoated rock is good. Precoated rock material used for contrast purposes often fades or loses color within a few months.

F. Contractors prefer the lightweight material due to ease of handling and increased production rate of finished road surface. Wear and tear on equipment is reduced significantly because there is less weight overload.

G. No broken windshields attributable to ESCS were reported from any of the engineers or contractors interviewed.

H. Some engineers and maintenance personnel indicated a preference for the ESCS lightweight material. No one interviewed objected to the use of ESCS, and all were satisfied with its performance.

14.7 Open-Graded Wearing Surface (OGFC)

Use and Performance

General

Open-graded wearing surfaces are also referred to as plant mix seal (PMS) coats or open-graded asphalt friction course (OGFC). An open-graded friction course is a special purpose mixture, increasingly used in pavement surfaces around the world for improved safety in all types of weather conditions and to reduce vehicle-tire noise. This gap-graded bituminous mixture consists largely of single-sized aggregate and contains a relatively high percent (15% to 25%) of air voids. The many benefits of OGFC have been widely published and, therefore, only briefly discussed here. (For additional information, consult the National Asphalt Pavement Association [NAPA] Publication No. IS-115, "Open-Graded Asphalt Friction Courses:, No. CL-10, and Appendix F, A look at Open Mixes to Improve Skid Resistance by Verdi Adam. Appendix A also includes Texas specification, Section 342, "Plant Mix Seal". Appendix H includes International

Surfacing, Inc. Guide Specification for Open, Dense and Gap-Graded Asphalt Cement Pavements with Asphalt-Rubber Binder).

Since 1972, ESCS's open-graded friction course has been used on thousands of miles of state and federal highways carrying traffic ranging from 2500 vehicles per day on rural roads to more than 150,000 vehicles per day on interstate highways with truck volume in the 10 to 20 percent range. The effective life of ESCS OGFC overlays in Texas and other southern states range from 5 to 12 years. Texas roads are subjected to severe performance demands caused by extensive sunshine, high temperatures during the long summers, and high moisture.

Improve skid resistance

OGFC made with ESCS is primarily used to improve skid resistance, reduce hydroplaning, and provide better vehicle control during inclement weather. An optimized OGFC furnishes ample micro and macro texture as well as drainage at the tire-pavement interface through permeable voids (interconnected voids) in approximately the top inch of pavement surface.

Splash and spray

In the mid 1970's the Texas Transportation Institute conducted full-scale water spray and splash field tests on OGFC and regular hot-mix asphalt (HMA) surfaces (Fig. 14.16 and 14.17). a rain simulator was used to test the rate of drainage of a 24-foot wide pavement overlaid with one inch of OGFC on a substrata of one percent cross slope. The rainfall rate was 0.25 inches per hour. In Figure 14.16, note the excessive amounts of splash and spray. Slight surfacing of water in the wheel paths of the outer lane and water sheeting across the regular HMA shoulder was observed during the field test.

Figure 16.17 shows the reduction of splash and spray with OGFC. These photographs were taken about five minutes apart on a divided highway where the southbound lands (Figure 14.16) were HMA, and the northbound lanes (Figure 14.17) were OGFC.

Figure 14.16 ***Regular hot-mix asphalt surface with hazardous truck spray and splash***

Figure 14.17 ***Open-graded friction course without spray and splash***

Noise reduction: Because of the permeable voids, OGFC's do not create percussion cups between tire and road surfaces. The result is a much quieter road surface—a real advantage for adjacent home owners and vehicle operators as well as a cost savings by eliminating or reducing the need for sound barrier walls.

Hydroplaning: A primary reason for specifying OGFC is to reduce hydroplaning on wet pavement. Hydroplaning potential is inversely proportional to the percent of voids in an open-graded mix. The near one-sized coarse, aggregate gradation ensures a high-void (15% to 25%) content mixture.

Wheel path: The mixture in the wheel path retains its drainage properties even if the mixture on either side partially clogs with debris.

Water-susceptible pavements: Do not use OGFC pavement of any type, (ESCS or Normalweight) on water-susceptible pavement. The OGFC will hold water on the underlying pavement for enough time for water susceptibility damage to develop if the overlayed pavement is susceptible. OGFC alone does not seal the underlying pavement surface sufficiently to prevent water damage.

Existing road conditions: In general, OGFC should be placed only on pavement with fair-to-good cross drainage, never on water-susceptible, cracked, or deteriorating pavements.

Aggregate Type and Friction Resistance

ESCS lightweight aggregate performs extremely well in OGFC because it provides the microtextures and macrotextures necessary for a quality pavement. Some natural aggregate, such as trap rocks, sandstones, rhyolite, and impure limestone, also meet OGFC specifications. The initial friction values of OGFC may be somewhat low until the asphalt coating is worn from the exposed surface aggregate. Sharp sand in the fines fraction minimizes the low initial skid values. Figure 14.18 shows the coefficient of friction of several aggregates used in HMA as compared with ESCS-OGFC. Also, Appendix F compares the friction resistance of several different aggregate types.

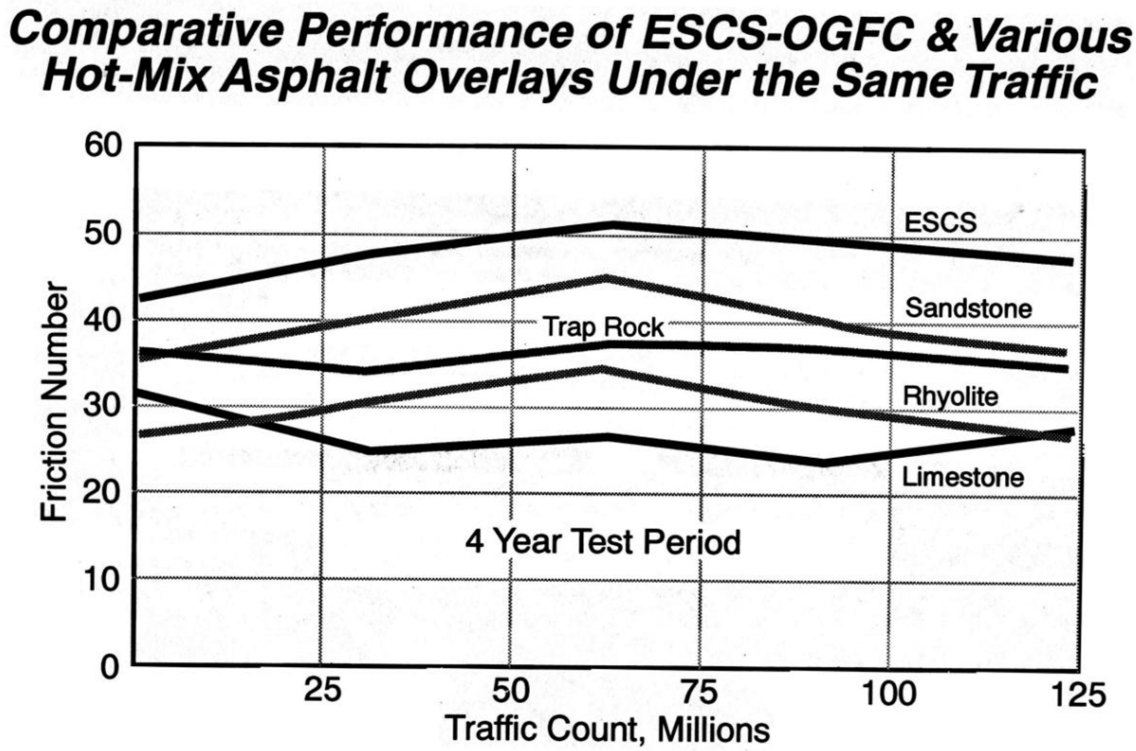


Figure 14.18 ***Comparative Performance of ESCS-OGFC and Various Dense Graded Hot-Mix Asphalt Overlays Under the Same Traffic. Study performed on Interstate 35 E, Dallas County, TX.***

Mixture Design Guidelines

The following guidelines are based on information obtained from laboratory trial mixes and field experiences. These guideline should be helpful in developing mixture designs and design procedures.

Aggregate: Use a non-polishing coarse aggregate that complies with current quality tests for chip seal surface treatments. Crushed aggregate helps to stabilize the compacted mix.

Gradation: Aggregates used in OGFC paving mixtures are considered gap-graded because they consist only of coarse and fine fractions. The coarse fraction provides the important macrotexture and microtexture properties that combine to develop the frictional drag at the tire-pavement interface. The fine fraction passing the No. 8 (2.36 mm) sieve, serve three main purposes: (a) stabilizing the coarse aggregate, (b) controlling the void content of the pavement and (c) controlling the rate of asphalt drain down during construction. The mixture is generally 10 to 15 percent fine material.

The fine fraction must also include enough mineral filler to provide the total aggregate blend with about three percent mineral filler. The mineral filler (minus 200 mesh (75 µm) material) helps to stabilize the asphalt film around the coarse aggregate. Increasing filler content permits a broader thermal range during delivery and construction. One or two percent mineral filler also helps to prevent drain down during mixing and placing. Adding fines minus No. 8 (2.36 mm) sieve in amounts of 15 percent or less toughens an otherwise tender mix.

In general, the larger aggregate produces a more open surface, depending on the relative amount of coarse and fine aggregate used. The maximum aggregate size should not be more than one-half the depth of the compacted mixture. The large aggregate size should be the predominant aggregate.

Aggregate that is all the same size produces the greatest number of voids. Aggregate size does not appreciably affect the homogenous voids in the pavement, but it does affect permeability caused by surface tension and pore friction.

Example: In general, Texas uses aggregates that conform to the material requirements of aggregates for chip seal surface treatments (Appendix A and C) with two exceptions: the stone must have polish value of 35 or higher and no uncrushed gravel is permitted. Table 14.2 lists the master gradation limits for plant-mix seals in Texas and the recommended gradation from Federal Highway Administration, Publication (FHWA) T5040.31. Also, included in Table 2 is a gradation from Appendix H which covers the use of asphalt-rubber in open mixtures.

Table 14.2 Gradation Limits for OGFC (plant-mix seal)

	Percent Passing				
Sieve Size	**Texas**		**FHWA**	**Appendix 'H' Asphalt Rubber**	
	Grade 1	**Grade 2**	**T5040.31**	**2/8 inch**	**½ inch**
5/8 inch (15.75 mm)	**100**	**100**	**100**	**100**	**100**
½ inch (12.5 mm)	**95-100**	**95-100**	**100**	**100**	**95-100**
3/8 inch (9.5 mm)	**50-80**	**50-80**	**95-100**	**85-100**	**75-95**
No. 4 (4.75 mm)	**0-8**	**5-20**	**30-50**	**25-55**	**20-56**
No. 8 (2.36 mm)			**5-15**	**5-15**	**5-15**
No. 10 (2.06 mm)	**0-4**	**5-15**		**0-10**	**0-10**
No. 30				**0-10**	**0-10**
No. 200 (75 µm)	**0-2**	**0-5**	**2-5**	**0-5**	**0-5**

Void Content: Final permeable voids, as measured in the finished pavement for the Grade 2 grading (Table 2), are typically about fifteen percent (15%). The total volume of voids is about twenty percent (20%). Grading Grade 1 yields about twenty-five percent (25%) voids, of which about 18 percent are permeable voids. The mixture should be designed for a minimum of twenty percent (20%) voids. FHWA recommends, or at least assumes, a design air-void content of at least fifteen percent (15%).

Tack Coat: It is important to bond OGFC to the substrate; therefore, using an adequate amount of tack is necessary.

Asphalt: Use the most viscous asphalt that still remains ductile at the expected road surface temperature. The Asphalt Handbook (MS-4, 1989) reports asphalt cement AC-10 to AC-40, AR-4000 to AR-16000, or 85-100 to 40-50 penetration is used for OGFC. However, the use of these asphalt cements is becoming less common because the Strategic Highway Research Program (SHRP) developed a new system for specifying asphalt materials. The new system, called "Superpave", represents an improved system for specifying asphalt binders and mineral aggregates that will develop asphalt mix design and pavement performance predictions. Superpave includes a new binder specification (AASHTO MP1) that is unique, in that it is performance based and the binders are selected to fit the climate and traffic in which they are intended to serve. The AASHTO MP1 specification and recommendations are covered in the Asphalt Institute Publications, No. SP-1 "Performance Graded Asphalt Binder Specification and Testing" and "Superpave Mix Design" Superpave Series No. 2 (SP-2). Consult these references before specifying the asphalt binder.

The asphalt content for the gradings listed in Table 2 should be approximately 13 to 16 percent by volume. The optimum asphalt content is the amount of asphalt that produces the greatest film thickness around the aggregate without separating during mixing and placing.

Performing a drainage test is a good way to determine the optimum asphalt content. Visual inspection during trial mixing can establish minimum and maximum asphalt content. (Optimum asphalt should be near the midpoint.)

Stability: The stability of the compacted mix is a function of the aggregate particle shape, surface texture, aggregate gradation, type of asphalt, and amount of asphalt.

Design Methods: Appendix G contains two design methods for OGFC used by the TxDOT.

Test Methods

The following test methods are recommended:

a. **Permeable voids:** The lateral and vertical permeable voids in the finished pavement should be measured by test method ASTM D 3637, *The Standard Test Method for Permeability of Bituminous Mixtures (*Method A). Measurements are taken at intervals of about six months to monitor the traffic reduction rate of permeable voids.

b. **Asphalt content:** ASTM D 2172 standard test method for *Quantitative Extraction of Bitumen from Bituminous Paving Mixtures.*

c. **Surface texture:** The silicone putty method or the sand patch procedure.

Construction

Construction activities vary, depending on location, contractor, and equipment. For this reason, the following suggestions and precautions are general, rather than specific.

Equipment and procedures: All phases of OGFC (mixing, transporting, placing, and compacting) require the same equipment and procedures that apply to the ht-mixed asphalt production and placement.

Mix temperature: A 260ºF (127ºC) mixing temperature is an efficient batching temperature. Placement temperatures at approximately 245ºF (118ºC) are advised, with compaction beginning when the mat temperature reaches about 240ºF (115ºC). Latex can solve drain down problems. Latex mixtures can be heated to 250ºF to 260ºF (121ºC – 127ºC) and hauled 40 miles or more without drain down problems. Care must be exercised to assure that the OGFC bonds to the underlying pavement.

When dumped into the truck at the proper temperature, the OGFC mixtures "peaks" or "stands up" without excess slumping. To prevent surface cooling during hauling, the mixture should be covered with tarpaulins. Regardless of the operations, plant-mix temperatures should be controlled within plus or minus 15ºF (9ºC) of the specified temperatures to assure quality and uniformity.

Rolling: The mixture should be rolled with a light static steel-wheel roller (approximately 10 to 12 tons) as soon as practical after lay-down.

Traffic: Traffic can resume as soon as the finished mat is cool enough, approximately 150ºF (65ºC) to prevent picking up particles. On bridges and other areas that must be opened to traffic immediately, spraying the surface with water can quickly cool it.

Control test: To insure quality, asphalt extraction tests should be performed as needed-usually a minimum of three per day to monitor asphalt and aggregate gradation. Asphalt stripping tests should also be performed periodically. For example, some transportation inspectors use the water-boiling test at maximum 10-day intervals. The mix is redesigned if stripping exceeds fifteen percent (15%).

Precautions: When large-sized 5/8 inch-1/2 inch (15.75 mm – 12.5 mm) ESCS aggregate is used, delayed release of moisture can become a problem when steam-filled asphalt bubbles rise to the top of the load in the truck and lay-down machine hopper. Removing sufficient moisture when drying and heating the aggregate minimizes delayed release of moisture. Dual dryers are effective under inclement weather conditions.

14.8 Hot-Mix Asphalt (HMA) Surface Course

Projects, Performance, and Superpave

ESCS aggregate HMA has performed well for nearly 40 years on all types of roadways. Laboratory and fieldwork shows that ESCS aggregate HMA performs well even if the aggregate skeleton is composed of all or part ESCS aggregate.

When comparing the same grading, ESCS aggregate HMA at twelve percent (12%) asphalt binder by weight contains about the same amount of asphalt per unit volume of pavement as Normalweight aggregate HMA at six percent (6%) asphalt binder by weight. The reason for this is ESCS is about one-half (1/2) the weight of Normalweight aggregate. The asphalt film thickness for both mixes would be about the same.

Several years ago, the State of Louisiana placed an experimental section of ESCS aggregate HMA with a conventional finishing machine in a two-inch lift. The paving mixture was designed by the Marshal Method and used ESCS aggregate as all the plus No. 40 sieve-size material. The minus No. 40 mesh material was field sand. The design also used 12 percent by weigh of 85 to 100 penetration asphalt cement. More than five years after it was placed, the surface was inspected and found to be in good condition—even after carrying more than 7,000 vehicles per day.

The State of Virginia began placing experimental sections of HMA made from ESCS aggregate in 1955 using the Hubbard-Field design method which used 100 percent ESCS aggregate. The mixture contained 11.2 percent by weight asphalt cement. The surface handled more than 12,000 vehicles per day. According to reports, the surface was in excellent condition after two years of service. For 13 years, the Dallas-Ft. Worth turnpike, with a 2-inch overlay of ESCS aggregate as the coarse fraction, handled 50,000 vehicles per day. Tennessee, Texas, Wyoming, Mississippi, and Alabama have also used ESCS aggregate HMA pavements.

TxDOT placed sections of surface material made from blends of ESCS aggregate and local sand on Interstate 20 east of Dallas. At the time of placement traffic exceeded 33,000 vehicles per day. The new sections were checked for skid resistance at 6 months and 2 ½ years after construction. The wet coefficient, as measured by ASTM E 274 Standard Test Method for "Skid" Resistance of Paved Surfaces Using a Full-Scale Tire" was 0.48 at 50 mph. Two comparable sections built at the same time from locally available natural aggregate measured 0.37 and later polished to 0.25. With only fifty percent (50%) ESCS aggregate in the mix, the friction coefficient improved more than 30 percent! These sections used 7.0 percent by weight of 90 penetration asphalt. Although the aggregate stockpiles were wet from rain a day before construction started, the operation proceeded smoothly. Some slumping of the mix occurred in the haul trucks because of delayed moisture release, but the slumping caused no problem in the laying operation.

Approximately 20-lane miles of ESCS aggregate HMA was placed on Interstate Highway 35 in Austin, Texas, with a performing SN (skid number) of 0.45, a 50 percent improvement over the limestone covered by the overlay. The SN in this case is expected to increase to 0.5 and remain at 0.5 for the life of the pavement. Generally, friction values gradually increase for the first 10 to 12 million vehicle passages, and then become stable at about 0.5.

Three typical hot-mix asphalt projects are:

- **Texas Department of Transportation project in Tarrant County, near Fort Worth –** Interstate 20 was overlaid with 1 inch of lightweight aggregate hot-mix in 1975. This roadway has successfully endured continuous traffic since that time.

- **Interstate 30 in Tarrant County, Texas between Oakland Blvd. and Davis Dr. –** This expanse of roadway was overlaid in 1975 and has remained in tact with an average daily traffic count of 93,000 vehicles per day.

- **A portion of US 377 in Texas from US 80 to the Fort Worth traffic circle –** The surface on this roadway has consisted of lightweight aggregate since 1978 and carries an average of 12,300 vehicles per day.

Superpave: (*Superior Performing Asphalt Pavements*) Superpave is a product of the Strategic Highway Research Program (SHRP) asphalt research. SHRP was established by Congress in 1987 as a five (5) year, $150 million research program to improve the performance and durability of United States roads and to make those roads safer for both motorists and highway workers. The Asphalt Institute's *Superpave Mix Design* Superpave Series No. 2 (SP-2) Publication, should be reviewed before specifications are written because ESCS aggregate meets and exceeds the Superpave aggregate criteria. The following excerpt from SP-2 gives a glimpse into the future of pavement design.

> **"Mineral Aggregates.** Mineral aggregate properties are obviously important to asphalt mixture performance. However, the Marshall and Hveem mix design methods do not incorporate aggregate criteria into their procedures. Conversely, aggregate criteria are directly incorporated into Superpave mix design procedures. While no new aggregate test procedures were developed, existing procedures were refined to fit within the Superpave system: consensus properties and source properties.
>
> "Consensus properties are those that SHRP researchers believed were critical in achieving high performance HMA. These properties must be met at various levels depending on traffic volume and position within the pavement. High traffic levels and surface mixtures (i.e. shallow pavement position) require more strict values for consensus properties. Many agencies already use these properties as quality requirements for aggregates used in HMA. The Superpave consensus properties are coarse aggregate angularity; fine aggregate angularity; flat and elongated particles; and clay content.
>
> "By specifying coarse and fine aggregate angularity, Superpave seeks to achieve HMA with a high degree of internal friction and thus, high shear strength for rutting resistance. [ESCS HMA has a high degree of internal friction and high shear strength]. Limiting elongated pieces ensures that the HMA will not be as susceptible to aggregate breakage during handling and construction and under traffic. Limiting the amount of clay enhances the adhesive bond between asphalt binder and the aggregate."

Design Considerations

Appendix J provides a test method for laboratory design of HMA mixtures.

Weight difference: The volume of ESCS hot-mix is almost twice the volume of natural aggregate hot-mix for the same given weight. The weight/volume difference must be adjusted in the design and construction of ESCS hot-mix.

Design methods and general considerations: The hot-mix design when using ESCS lightweight aggregate is no different from design using other aggregates. For surface course designs, one should use top-size aggregate of about ½ inch (12.5 mm). Because

ESCS aggregate is highly textured, more fines are required to produce mixes of equal workability in the field.

Experience shows there are advantages to restricting the ESCS fraction of the aggregate to the plus No. 8 or No. 10 (2.36 mm or 2.06 mm) sieve. Material finer than No. 8 or No. 10 is supplied from locally available natural aggregate or crusher fines. It is also critically important to select fines that are not susceptible to moisture damage.

Any commonly used design methods can be employed. The most widely practiced methods are the Marshall, the Hveem and the new Superpave method introduced in 1996. Measured by weight, the asphalt content by percent appears rather high, but this is not an issue because volume, rather than weight, is important in a pavement structure. For example, a normal mix with 5.5 weight percent of asphalt (assuming a compacted unit weight of 145 lbs/ft^3) contains 7.95 pounds of asphalt cement (AC) per cubic foot, whereas a given ESCS lightweight mix weighing about 110 lbs/ft^3 requires 7.2 weight percent of binder or the same 7.95 pounds of asphalt cement per cubic foot. In practice, the asphalt-cement content weight percent varies depending on the unit weight of the mixture without adversely affecting stability. For example, if the unit weight of the ESCS lightweight mixture is 90 lbs/ft^3, the weight of asphalt cement is 8.7 percent for the same volume of mixture, and contains 7.95 pounds of asphalt cement per cubic foot.

Stabilities for ESCS HMA also measure higher than expected. The Hveem stability is rather insensitive to asphalt content because this stability measuring method derives its value from the internal friction of the aggregate system. ESCS lightweight aggregate is highly textured and, therefore, exhibits high-internal friction which results in high Hveem stability for the mix.

One of the primary considerations in designing an asphalt paving mixture is the aggregate gradation. The aggregate blend can vary from a uniform size distribution of materials to a gap-or skip-graded mixture. Using gap-graded blends containing ESCS aggregate are generally satisfactory due to the stability of theses blends. They will nearly always meet specified requirements and are more workable in the field.

Aggregate Blending: A major factor in blending or combining ESCS with normalweight aggregates is the difference in unit weight. Normally, ESCS has a dry, loose unit weight of 35 to 65 lbs/ft^3 (560 to 1236 kg/m^3) depending on the aggregate source, whereas sand or normalweight aggregate weigh from 90 to110 lbs/ft^3 (1440 to 1760 kg/m^3). These weight differences can cause design problems if not considered during blending. Figure 19 illustrates the difference in the positions of two blended gradation curves. The weight curve is the blend of a ESCS material with a normalweight aggregate material by weight percent; the volume curve is a blend of the same two materials using the same percent only by volume-notice the large difference! The volume composition curve closely represents the desired grading curve of the aggregate system. Because batching is most often done by weight in the field, job weights and formulas must be adjusted by volume first. Uniform blending is of the utmost importance and needs to be checked regularly.

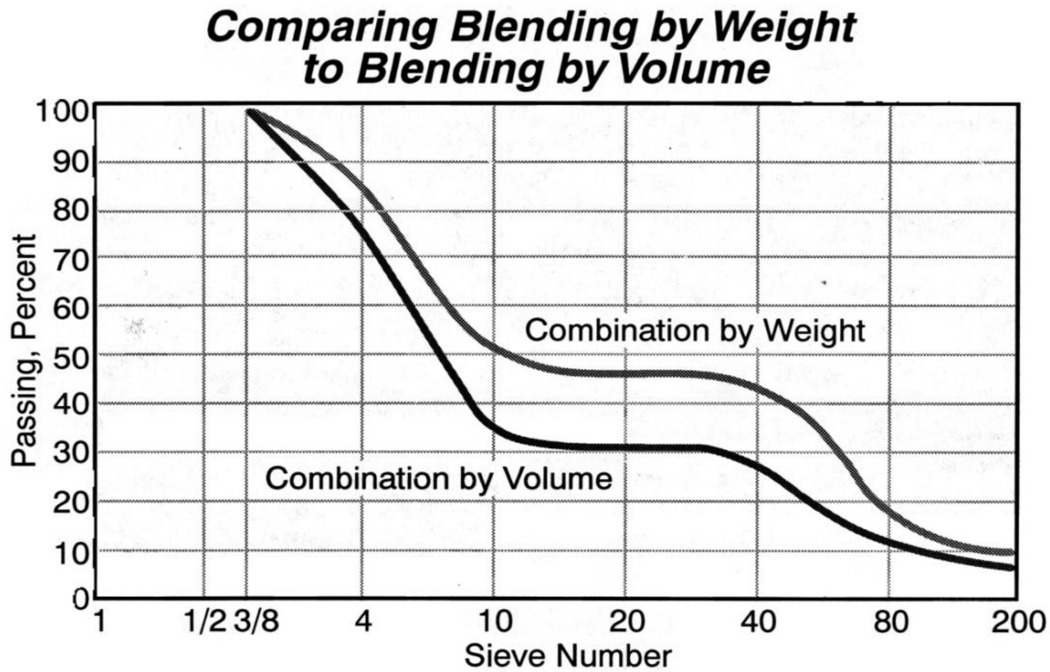


Figure 14.19 ***Comparing blending by weight to blending by volume.***

Workability: Any method used to improve the workability of hot-mix made from normalweight or ESCS aggregate should be done with caution. For example: (a) reducing aggregate top size, (b) increasing asphalt content, (c) introducing a gap in the grading between the No. 8 sieve and the No. 40 sieve, (d) decreasing the amount of material finer than the No. 200 sieve, and (e) substituting natural rounded fines (minus No. 8) for crushed fines may improve workability, but could also be highly detrimental to long term pavement performance. Some of these methods may reduce the shear strength of the aggregate mass, thus lowering the internal friction of the pavement mixture, making it more susceptible to rutting.

Aggregate top size: ½ inch (12.5 mm) top size aggregate is recommended. Aggregate availability and overall cost of the mixture must also be considered when establishing the aggregate top size and gradation.

Rollers: Using pneumatic rollers is encouraged for compacting and surface sealing HMA made with ESCS aggregate. A steel-wheeled roller can be used successfully for breakdown and finish rolling, but most of the compaction (particle nesting) should be done with rubber-tire rollers. Again, the high-internal friction of ESCS HMA demands this approach. Higher tire-inflation pressure is more effective than an increase in roller weight. Caution: Over use of rubber tired rollers can jeopardize smoothness.

Slumping: ESCS aggregates with higher than normal water absorption values require care in drying and mixing operations. High-absorption aggregate can cause the mixture in the truck to slump when moisture continues to be released from the aggregate.

Bidding and payment: Customarily, asphalt paving mixtures are sold by the ton. Selling by the ton is acceptable provided adjustments are made to correct for the weight to volume ratio difference between lightweight and normalweight. HMA made with normalweight aggregates require 108 to 112 pounds of material to cover one square yard, one inch deep. ESCS HMA made with 100 percent ESCS aggregate requires abut 65 to 70 pounds of material to cover one square yard, one inch deep. HMA made with a blend of ESCS and normalweight aggregate requires about 85 pounds to cover the same area. With blended mixtures, the weight will vary depending on the percent of ESCS to normalweight aggregate.

Accordingly, if no provisions are made for this weight-coverage differential in bidding, the job should be bid on a depth-coverage formula. (Fig. 14.20 shows the conversion formula). This formula assumes the ultimate field density is about equal to the laboratory density of the HMA in question. If the construction compaction requirement is 95 percent of laboratory density, then the "as constructed" depth of the pavement should be somewhat more than one inch. This is not particularly important to the user but should be considered. What is important is the standard of reference which is the unit weight of the compacted laboratory specimen. For example, if the unit weigh of a given laboratory design is 100 lbs/ft^3, 75 pounds of this mixture (compacted to ultimate density) is required to cover one square yard, one inch deep. Stated another way, 111 pounds of normalweight HMA (or 48% more) is required to produce the same mat thickness. Using this approach, the asphalt paving contractor, in truth, bids and is paid by the compacted cubic yard rather than a tonnage formula.

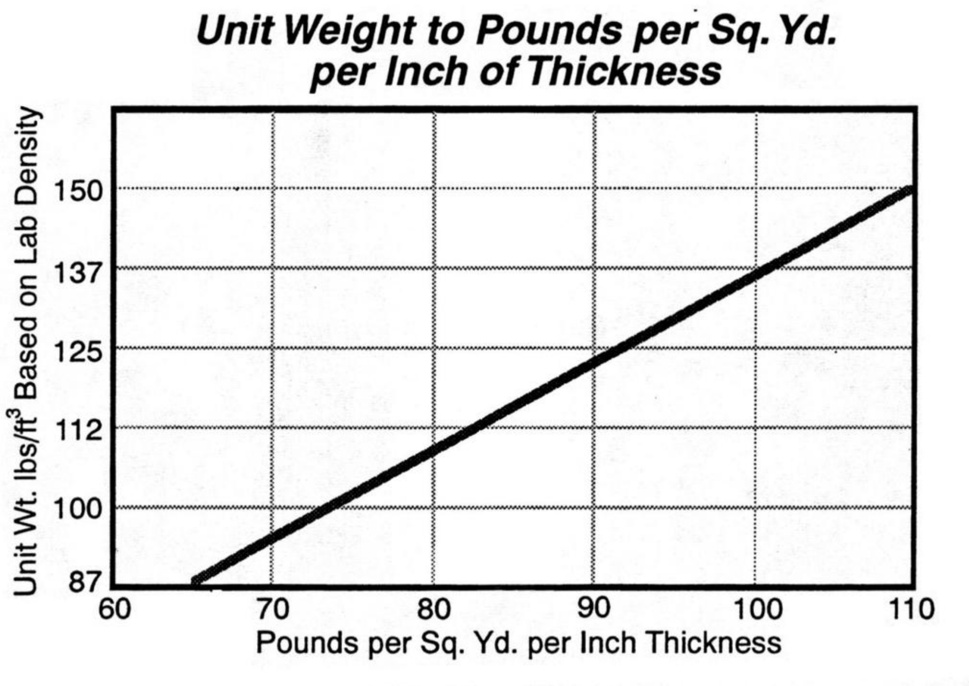


Figure 14.20 ***Conversion chart, asphalt mixture unit weight to pounds per square yard, per inch of thickness.***

Table 14.3 Comparing an equal amount of installed ESCS and normalweight HMA.

Type of HMA	Mixture Unit Weight	Total Volume of Mixture	Total Weight	HMA Price per Ton	Price per Sq. Yd. Installed	Total Bid Price for 10 sq. yds installed
Normalweight	**148 lb/ft^3**	**11.25 ft.^{3}**	**1665 lbs or .8325 tons**	**$9.80**	**$0.816**	**$8.16**
ESCS and Normalweight Blend	**112 lbs/ft^3**	**11.25 ft.^{3}**	**1260 lbs. Or .63 tons**	**$12.95**	**$0.816**	**$8.16**
ESCS-100%	**85 lbs/ft^3**	**11.25 ft.^{3}**	**956.25 lbs. Or .4781 tons**	**$17.07**	**$0.816**	**$8.16**

Assume: Normalweight HMA is bid at a hypothetical $9.80/tone installed and the area covered equals 10 yds^2, at 1-1/2 inch thick which equals 11.25 ft^3 of HMA. Notice that the total bid and price per square yard installed is the same for all three types of HMA, even though the unit price per ton ranges from \$9.80 to \$17.07. Current per ton prices are considerably more than in Table 14.3, however, the comparison is the same.

14.9 Thin Hot-Mixed Asphalt (HMA) Overlays

Minimum Weight: Minimizing the weight and thickness of a pavement overlay is often desirable. Where dead load is a factor, ESCS lightweight aggregate is the ideal choice and, by limiting the aggregate top size, very thin overlays are possible. Thin ESCS HMA is useful for bridge deck overlays and pavements when needed to reduce excessive crown build-up. Successful thin hot-mix designs have been in service in Texas for years. These specific designs are also used to arrest surface scaling on bridge decks and improve resistance to skidding. Asphalt contents range from 8 to 12 percent by weight. The aggregate gradations meet Asphalt Institute gradation standards for coarse-graded sheet asphalt, and are adjusted to account for the lighter weight to equal volume effect of ESCS aggregate. The unit weight of these mixtures is 85 to 95 pcf, depending on aggregate size and the weight of the aggregates used.

Water tightness: With very thin HMA overlays, it is often difficult to obtain sufficient compaction before the mixture becomes cold and unworkable. ESCS aggregate mixtures are similar to other materials in this respect. To help offset this problem, it may be better to design the mixture to meet conventional HMA specifications and use a heavy tack coat.

Stability: High-stability mixtures are possible with ESCS aggregate. The usual grading should not be altered by increasing the mineral filler excessively or raising the asphalt content above what regular laboratory design methods recommend. Aggregate grading should be designed by volume rather than weight; however, batching can be done on a weight basis provided the batch weights are adjusted to account for the aggregate's lower unit weight.

Shear stresses are high near the surface of a pavement, and in time, most thin overlays will reach the expected density level. There are exceptions to this, however, and if the user is familiar with the service performance of a given material, then design alterations will improve the mixture performance.

Improved friction resistance: One major advantage of ESCS thin HMA overlays is its inherent high-friction resistance. Field performances show that thin HMA overlays made with at least 50 percent (by weight) of ESCS aggregate have a higher-frictional coefficient than natural rock pavements. The high-friction resistance of ESCS is discussed in details in Section 14.4 and illustrated schematically in Figure 14.21.

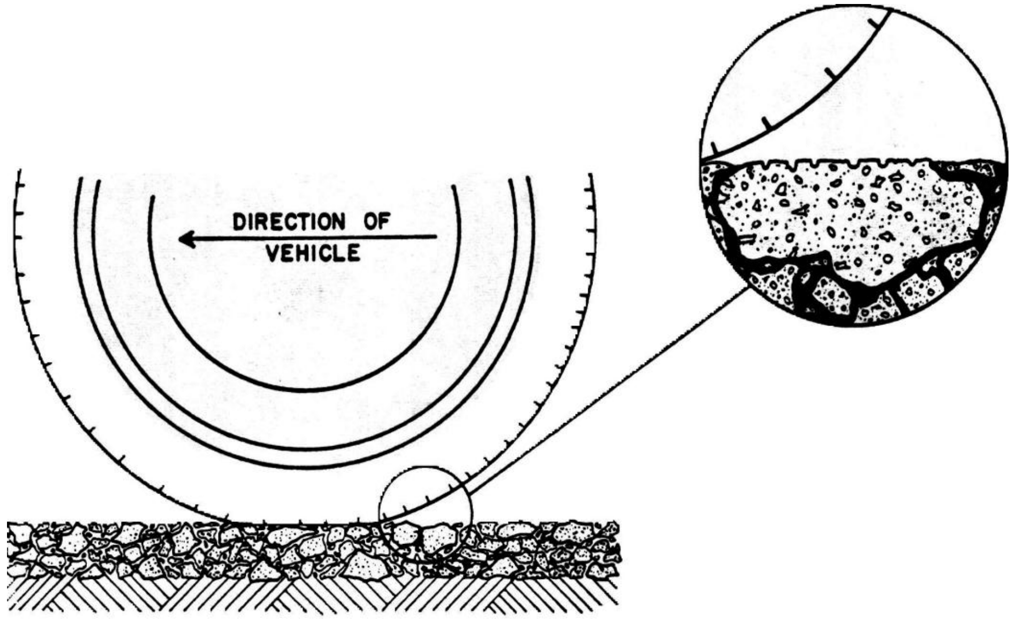


Figure 14.21 ***ESCS aggregate bleb or bubble structure throughout***

In comparison, when natural rock aggregate is used in thin HMA overlays, it is much more difficult to achieve and maintain a comparable friction-resistant surface. There are other methods used to achieve friction resistance with natural rock aggregates: 1) the differential rates of wear and 2) surface renewal through attrition method. The differential rates of wear, method uses two aggregates with distinctly different rates of wear. The surface renewal method is restricted to structurally sound roads and requires very strict design controls for asphalt and traffic volume because this mix is designed to ravel as it is used and, therefore, not commonly specified.

Jet airfields and bridge decks: ESCS thin hot-mix overlays are used on airfields to improve friction resistance and minimize heat damage caused by hot exhaust at takeoff. (Note: ESCS aggregate is combined with high-temperature cement and is used as a refractory [fireplace logs and boxes, chimney liners, etc.] and as a insulating refractory for industrial uses in kilns, boilers, stacks, and petro-chemical refining).

ESCS thin, hot-mix overlays are not only used on bridge decks to overlay distressed surfaces often caused by de-icing chemicals, but also to minimize dead loads and improve skid resistance.

With both jet airfield and bridge deck applications, the mixes must be highly stable. The designs must contain ESCS aggregate as the major portion of the aggregate systems. The designs should use small top-size aggregate only, and have higher final voids than regular mixtures. The thin, stable HMA overlay is designed to contain 8 percent voids for its in-service state of compaction. Laboratory-design void contents of 6 to 10 percent are common. Thin overlays may contain 8 to 14 percent voids when turned over to traffic. ESCS aggregate rough microsurface texture, allows the designer to use high-asphalt contents without danger of flushing and the associated loss of stability. The pavement receiving this mixture should be tacked with approximately double the normal amount of asphalt.

14.10 Maintenance and Pothole Material (Plant-Mixed)

More conventional wisdom holds that if a pothole repair is to stand a chance of holding up under traffic and adverse weather condition, it should be squared up, cleaned, and dried before it is filled. However, the results of a 1994 Strategic Highway Research Program (SHRP) study, Innovative Materials Development and Testing, Volume 2: Pothole Repair, indicate that the technique referred to as the "semi-permanent procedure" is not always cost effective.

The study found, that if quality materials are used, the throw-and-roll procedure (which involves dumping the patch material in the pothole with no preparation of the hole and then driving the truck over the patch several times to level it) is just as effective as the semi-permanent procedure. What seems to matter most is the quality of the materials used and the workmanship, rather than the procedure used to fill the hole. Mechanical patching machines developed in the last 5 to 10 years, also produce excellent pot-hole patches in most cases.

The study drew the following conclusions and recommendations:

- "Use the best materials possible. Although you might save some money by purchasing lower quality materials, this savings will be quickly eaten up by the cost of patching the same potholes over and over. The initial purchase cost of materials is minor compared with the costs of labor, equipment, and motorist's delays associated with patching operations.

- "In adverse weather, use quality materials and the throw-and-roll or spray-injection procedure. These procedures produce high-quality repairs, and they minimize the time maintenance crews must spend out in the elements. If you use spray-injection equipment, make sure it is operated by a trained technician.

- "Don't expect patches placed under severe weather conditions to perform as well as those placed under more temperate conditions. The first few weeks after it's placed is the most critical time in the patch's service life. Wet weather and low temperatures mean the patch will take longer to set, which will provide more opportunities for failure.

- "When considering the cost of a more expensive cold mix, include in your calculation the time savings; motorists will encounter fewer maintenance-caused delays, and maintenance crews will spend less time on the street."

Paving-mixtures designed for pavement maintenance and pothole repair can be placed hot or cold; however, most maintenance material is placed cold after having been stockpiled. In using plant-mixed maintenance material, the primary considerations are workability, compacted stability, storage capability, and resistance to stripping.

Workability and stability: For mixtures made with natural, normalweight aggregates, workability improvements usually reduce stability. In contrast, mixtures made with ESCS aggregates are very stable because the aggregate has a highly-textured particle surface, and can therefore be altered substantially and still remain stable. However, because of ESCS textured surface, workability can be a problem in the field unless certain precautions are taken. As in HMA paving mixtures, the amount of fines in the design should be increased. In some instances, it is also useful to introduce a gap in the aggregate grading between the No. 8 to the No. 50 sieve. Contact the ESCS producer for specific recommendations.

In maintenance work, it is very important to make durable repairs. One common fault is inadequate compaction of new base material used to repair a weakened area of a road. The best maintenance material for surfacing often lacks workability, making it difficult to seal out moisture initially. Providing a stable base or support under the surface is critical.

Storage life: With ESCS aggregate, softer asphalt cements, more primer, and additional water can be used to assure good storage properties. A reasonable storage life is essential for maintenance material; however, improvements in storage life should not be at the expense of other desirable properties of the mixture design. Using excess primer or water to improve storage capacity can adversely affect curing time and the associated development of stability. Therefore, altering the aggregate grading may be necessary to maintain stability and improve storage life.

Special qualities such as quick-setting, or improved or extended-storage characteristics are sometimes required. Sound judgment must be exercised in formulating special designs. Some experimentation is advisable, especially if a large amount of material is involved.

Users of small amounts of cold-lay patch material can cover their stockpiles with plastic to extend storage life and reduce waste often caused by surface crusting of the stockpile.

Protecting the stockpile from air exposure extends storage life and practically eliminates waste due to crusting. Without protection, emulsion mixtures can lose their water rapidly in windy weather.

Stripping due to water susceptibility: Because maintenance work is often carried out in poor weather, good patching material must resist the stripping action of water. Adding a satisfactory anti-stripping agent to the primer during batching operations is the best way to assure water-stripping resistance. ESCS aggregate is less susceptible to stripping than most good-quality normalweight aggregates. ESCS is almost 100 percent non-stripping in a “boil test” the direct result of the calcining (firing) process used in manufacturing the aggregate. Properly calcined clays, shales, and slates are essentially non-reactive in flexible paving mixtures.

Service records and field experience show superior adhesion when the asphalt film is attached to the aggregate. Using anti-strip agents in the asphalt or, in the case of cold-lay designs, in the primer conveniently minimizes water susceptibility.

A water susceptibility problem can generally be traced to natural aggregate fines used to fill out the grading requirement of a given specification. To assure that a selected natural aggregate is not susceptible, the minus No. 4 material should have a sand equivalent value of 55 or higher or, as mentioned above, an effective anti-strip agent should be used. Selecting the anti-strip agent should be done carefully, because some of them are ineffective if overheated. Lime is also an effective anti-stripping agent, but care must be used so the lime is not removed at the hot-mix plant during the drying and mixing operations.

Mixture design: Because the aggregate absorption may vary between ESCS manufacturers, mixture designs should be altered to suit the characteristics of the material being used. Generally, the hot-mix, hot-lay designs can be converted to a cold-lay mixture by adding primer and water, and reducing the mixing temperature from the usual 275ºF (135ºC) to about 210ºF (99ºC). Liquid ingredients should be added in the following order: asphalt, primer, water. An asphalt in the range of 120 to 150 penetration is satisfactory for cold-lay designs. If harder asphalts are used, the design requires more primer; even then, the mixture may setup in the stockpile if stored for an extended period. (Primer is defined here as a low viscosity liquid asphalt or emulsions applied to an absorbent surface). Colder climates require softer asphalts.

The following is a typical mixture design formula for the liquid fractions:

5 to 8 percent asphalt

1.5 percent primer
3 percent water

Note: There are many good primers available on the market. Diesel fuel or other solvents that lower the asphalt viscosity are also satisfactory primers, and are normally less expensive.

The following is an example of the mixing cycle for a coarse-graded aggregate:

5 to 10 seconds dry
30 to 40 seconds with asphalt
5 to 10 seconds with primer

In general, coarser-grade mixtures require shorter mixing cycles than do the fine graded mixtures. After it is mixed, the batch should be stockpiled with little stirring or agitation, because stirring promotes the loss of primer and water which are both vital for adequate storage life. To extend storage life, cover the stockpile.

Field applications

Pothole repair: Hot-mixed, cold-lay asphaltic materials made with ESCS aggregate, local crusher fines, or concrete sand work well for pothole repair and spot leveling. Cold-lay patching materials are manufactured with fluxibles or cutter stock to assure good storage properties and work ability during placing. These materials produce mixtures with high-internal friction, a property highly desirable in patch material.

Figures 14.22 and 14.23 show experimental cold-lay mixes being placed from one-year old exposed stockpiles. These experimental sections have performed well with little or no patch distortion.

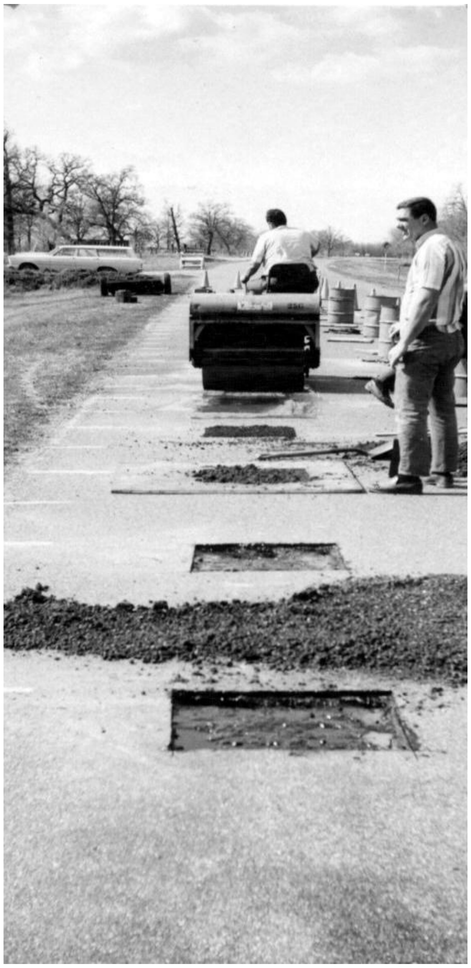


Figure 14.22 ***Hot-mix cold-lay patching material made with ESCS aggregate***

Figure 14.23 ***Completed patches where patching material had been in open storage for one year.***

Pothole repair and general surface maintenance are most often necessary immediately after wet weather. Consequently, moisture is most likely a problem during repairs. Using an anti-stripping agent in the cold-lay formulation is strongly recommended.

Adequate and proper tack coat: To use tack coats properly for maintenance work, the jobs should be divided into two operations: skin patches or thin overlays, and thick patches, such as potholes.

Skin patches allow more tack to be used than potholes. Because cutbacks are sometimes used for tack purposes, it is quite important to avoid excessive amounts of cutbacks in potholes where the volatile fraction may be trapped and thus keep the patch soft. Slow set emulsions diluted 50:50, SS-lh, or CSS-lh is preferable to cutback for tack.

Plant Operations

Batch weights and segregation: Remember the volume for a given weight of ESCS is significantly more than the equal weight of natural rock. For batch plants, total batch weight must be cut by about 30 percent to avoid overfilling the pugmill. In addition, it is important to see that the mixer paddles are not worn excessively because there is a tendency for segregation to occur in the pugmill. Segregation is usually not a problem for drum plants, but still needs to be monitored.

Equipment wear: The plant operators find that overall wear on a plant processing ESCS aggregate is considerably less than wear caused in processing most natural aggregates. This is particularly true for conveyors and bearings. Power consumption is also reduced, and loaders and hauling equipment need less maintenance because of lighter loads. This, of course, assumes that loaders and hauling equipment have not been modified to carry more volume. If equipment is modified to carry increased volume, haling costs are less, because less trips are required to move the same volume of material.

Water vapor release in the plant: The delayed release of water vapor in the mixing operations lubricates the mixture and protects the asphalt from the oxidative effects of air in the pugmill or drum plant. On the other hand, water-vapor release aids in emulsifying the asphalt and can weaken or delay the bond between asphalt and aggregate. These two factors, oxidation and water vapor, reduce the total hardening that usually take s place in the plant, thereby producing a more workable mixture.

Aggregate drying rate and dryer capacity: Because hot-mix, cold-laid materials are generally designed to contain residual moisture for adequate storage, there is no reason to dry the aggregate completely as long as adequate coating is achieved. Hot-mix, cold-lay material should reach the stockpile with 2 to 3 percent water in the mixture. ESCS aggregate may contain 4 percent or more depending on its absorption value. For these reasons, the dryer must be able to handle volume quantities of ESCS aggregate equal to those of natural aggregates.

14.11 Asphalt-Stabilized Bases with ESCS

Use: ESCS asphalt bases can be used in almost all applications in which base courses are specified. ESCS asphalt bases are, however, preferable to conventional bases in the following instances:

- In deep lifts because ESCS aggregate has a lower heat capacity than dense natural rock, thus allowing the pavement mat to cool more uniformly and compact evenly. Placing asphalt in deep lifts is definitely advantageous when design and specification requirements permit.

- Over thermal-sensitive areas because lightweight pavement has much better insulating qualities than dense natural-rock penetration – a real advantage if water lines and other frost-sensitive structures are beneath the pavement. Loose ESCS aggregate sub-bases have also been successfully used for this applications in Calgary, Canada.

- On weight-sensitive areas, because the lower overall weight of the ESCS asphalt bases can be a design advantage in bridge restoration and grade adjustments, over unstable soil, and in other weight-sensitive areas. ESCS is also used to reduce the weight of compacted geotechnical fills by up to one-half, and to convert unstable soil into usable land. (Ref. ESCS Publications, "Rotary Kiln Produced Lightweight Aggregate for Geotechnical Applications" #6600.

Structural design considerations: Laboratory and field work from several sources show that ESCS is entirely suitable as aggregate for asphalt-stabilized bases. Because of the natural, high stability of mix designs produced with ESCS as the major percentage of aggregate, the asphalt content can be altered easily to change void content and assure adequate durability.

Little, if any, change in design procedures is necessary when ESCS forms the major portion of the aggregate in flexible bases. Internal friction is generally high, because of the rough microsurface texture of the ESCS aggregate. The rough surface also allowing somewhat greater than average asphalt-film thicknesses on the aggregate particles. This in turn permits movement in the pavement to relieve slowly applied stresses with a minimum of distress.

Mixture Design Considerations

- **Unit weight:** As mentioned in Section 14.8, the ESCS mixture design must be proportioned by volume to adjust for the increased volume of ESCS aggregate for an equal weight of natural rock aggregate. This weight/volume adjustment insures the proper mixture of asphalt and aggregate. Because base material is usually bid by the cubic yard, it may not be necessary to adjust the bid document when ESCS is used. However, the contractor saves a substantial amount in freight costs because a much larger volume of ECSC mixture can be hauled per truckload.

- **Resistance to the action of water:** Probably more than anything else, adequate construction compaction is the best way to insure a waterproof and high-performance asphalt base. Unfortunately, not all bases are adequately compacted during construction. Low-compaction density permits the intrusion of moisture that can be extremely damaging under certain environmental and service conditions. To help prevent water intrusion, the contractor should use an aggregate that is not water susceptible and which is covered with an adequate film thickness of asphaltic binder. Consult the Asphalt Institute Publication SP-2 "Superpave Mix-Design for Asphalt Binder Recommendations".

- **Aggregate gradation and selection:** Restricting the top size of many ESCS aggregates is structurally advantageous because the point stress is reduced in a given mass of material subjected to a fixed load if the number of stress points is increased. Materials of finer particle size and of fixed quality are less likely to degrade. It should also be pointed out that, if the finished product is crushed before use, the weaker particles are most likely to be crushed which results in a more finely graded, more resistant material. Smaller top sizes also permit use of local sands.

  Laboratory experiments and field trials verify the advantages of gap-graded mixtures with ESCS aggregate. Gap grading improves the workability of the mixture when the gap is introduced between the No. 8 (2.36 mm) and the No. 30 (600 µm) sieves. Laboratory test and field trials should be made on all mixtures before they are used. However, experience shows that mixtures made with fifty-nine percent (59%) field sand and seven percent (7%) viscosity graded asphalt showed good workability in the field. In these mixtures the ESCS was well graded from the ½ inch (12.5 mm) to the No. 8 (2.36 mm) sieve. The field sand was one-hundred percent (100%) passing the No. 30 (600 µm) sieve with about fifteen percent (15%) passing the No. 200 (75 µm). (Note: In this manual, asphalt content is figured as percent by weight of the total mixture. In the preceding example, aggregate constitutes ninety-three percent (93%) by weight of the total mixture).

  The same ESCS aggregate mixture as above may produce a satisfactory and durable mix, by replacing some of the field sand with natural river sand that meets the approximate grading requirements of fine aggregate for Portland cement concrete. However, caution must be taken when introducing natural river sand and superpave requirements on fine aggregate angularity should be followed. Natural river sand may reduce the pavements internal friction and ultimate stability.

  Using local, natural fines is encouraged, provided the selected materials are not water susceptible. A well-graded fine material sized from the No. 8 (2.36 mm) to dust is satisfactory. Plastic fines should be eliminated. The sand equivalent test is also useful to measure quality of the minus No. 4 (4.75 mm) fraction of the aggregate system. General limits are not established for ESCS aggregate-natural fines mixtures; therefore, limits should be established by laboratory testing on the specific materials being used. The obvious advantage of using local fines is cost reduction. If using local fines does not lower costs, then ESCS fines are the better choice. ESCS fines, if crushed, alter the workability of the mix, thereby requiring an increase in the amount of fines, and, most likely, an increase in the asphalt content. During construction, such a design requires close compaction procedure control since it is more difficult to compact, just as are mixtures made with crushed, natural aggregates. The cost of base mixtures could be reduced by using ¾ inch (19 mm) top-size material and reducing the asphalt content.

Construction considerations: The design considerations previously discussed in Section 14.8, generally apply to asphalt bases using ESCS aggregate.

Delayed release of moisture from the aggregate may cause slumping of the hot mix as it leaves the plant. If so then it is wise to increase the dryer temperature or decrease the feed rate. On the other hand, if mixture slumping creates no problem in placing or compacting, there is no need to eliminate slumping. In fact, delayed release of moisture can provide certain advantages, such as reduced asphalt oxidation and improved mixture workability.

Using a pneumatic rubber-tire roller as the intermediate compaction device is advisable. This is especially important for deep lifts up to 6 inches. Final compaction with a steel-wheel tandem roller removes any tire marks, provided rolling is properly timed.

14.12 Micro-Surfacing and Slurry Seal

This section is a brief introduction to micro-surfacing and slurry seal. For detailed information and guidance the reader is advised to contact The International Slurry Surfacing Association (ISSA), 1101 Connecticut Avenue, N.W., Suite 700, Washington D.C 20036-4303, Phone (202) 857-1160. Their publication A 143 “Recommended Performance Guidelines for Emulsified Asphalt Slurry Seal” should prove particularly useful. These guidelines also apply when ESCS aggregates are used. Appendix L “An Introduction to Slurry Seal” by Akzo Nobel, Spring 1997 Newsletter provides a good overview.

The ISSA describe Micro-Surfacing and Slurry Seal as follows:

> “**Micro-Surfacing** is one of the most versatile tools in the road maintenance

arsenal. Micro-surfacing is a polymer modified old-mix paving system that can remedy a broad range of problems on today's streets, highways, and airfields.

"Like its parent product, slurry seal, Micro-Surfacing begins as a mixture of dense-graded aggregate, asphalt emulsion, water, and mineral fillers. Micro-Surfacing is made and applied to existing pavements by a specialized machine, which carries all components, mixes them on-site, and spreads the mixture onto the road surface.

"Materials are continuously and accurately measured, and then thoroughly combined in the Micro-Surfacing machine's mixer. As the machine moves forward, the mixture is continuously fed into a full-width 'surfacing' box which spreads the Micro-surfacing across the width of a traffic lane in a single pass. Or specially engineered 'rut' boxes, designed to deliver the largest aggregate particles into the deepest part of the rut to give maximum stability in the wheel path, may be used. Edges of the Micro-Surfacing are automatically feathered.

"The new surface is initially a dark brown color and changes to the finished black surface as the water is chemically ejected and the surface cures, permitting traffic within one hour, in most cases".

Slurry Seal consists of a mixture of emulsified asphalt, mineral aggregate, water and specified additives, proportioned, mixed and uniformly spread over a properly prepared surface. The completed slurry seal leaves a homogeneous mat that adheres firmly to the prepared surface, and provides a friction resistant surface texture throughout its service life.

Use: It is essential to observe proper design and construction procedures in using micro-surfacing and slurry seal, as with any other paving material. These operations appear simple, so material evaluation and engineered mixture designs are often overlooked and misused. ESCS micro-surfaces and slurry seals are best used for the following applications:

A. Improving the friction resistance of the roadway.
B. Stopping an asphalt surface from raveling.
C. Carrying light traffic pending the application of a permanent overlaid surface course.
D. Acting as a holding device on prime bases during construction.
E. Changing the surface color of structurally sound pavements.
F. Leveling the wheel path of rutted pavements.

Generally, slurries are placed as "wipe coats" or as distinct layers 1/8 to ¼ inch thick, with the ¼ inch thickness most commonly used. Wipe coats cure or break rapidly and work well with multi-course applications. Wipe coats are primarily used to stop surface raveling.

Multi-course slurries: Using more than one course of slurry is advisable under certain circumstances, however, allow time to cure each layer adequately. Adequate curing time is extremely critical in humid areas.

Field conditions: Micro-surfacing should never be placed on surfaces that are dry, dusty or contain free-standing water. Micro-surfacing should also be restricted to sound pavement, free of weak areas.

Aggregate Gradation

Well-graded material from1/4 inch to dust performs very well. Because a rubber squeegee in the spreader box controls the thickness of the micro-surface layer, no oversized aggregate can be tolerated. Oversized material hangs under the squeegee, causing striations in the soft, fresh slurry and leaves a poor surface appearance.

ISSA recommends that the following aggregate gradation (including the mineral filler) be within one of the following bands, or one currently recognized by the local paving authority. Aggregate should be tested in accordance to AASHTO T27 (ASTM C 136) and AASHTO T11 (ASTM C 117).

Sieve Size No.	**Type I** Percent Passing	**Type II** Percent Passing	**Type III** Percent Passing	Stockpile Tolerance
3/8 (9.5 mm)	100	100	100	
4 (4.75 mm)	100	90-100	70-90	±5%
8 (2.26 mm)	90-100	65-90	45-70	±5%
16 (1.18 mm)	65-90	45-70	28-50	±5%
30 (600 µm)	40-65	30-50	19-34	±5%
50 (330 µm)	25-42	18-30	12-25	±4%
100 (150 µm)	15-30	10-21	7-18	±3%
200 (75 µm)	10-20	5-15	5-15	±2%

Some agencies have successfully placed rather heavy lifts of slurry containing aggregate with a top size of ½ inch (12.5 mm) to ¾ inch (19 mm). Such mixes are not considered true slurries and are not discussed in this manual.

Asphalt Emulsions and Tack Coat

Residual asphalt contents of twelve to eighteen percent (12% to 18%) are used in micro-surfaces, depending on the slurry's thickness and aggregate particle shape, texture, and absorption. It is always advisable to design a micro-surface mixture in the laboratory and subject the design to abrasion in the presence of water to determine susceptibility to stripping. Water-susceptible mixes should be avoided, or an anti-stripping agent should be used.

Most ESCS aggregates absorb more water than natural aggregates. For this reason, adequate curing is delayed slightly. Using cationic emulsion of the SS type is advised because break occurs by aggregate surface attraction rather than loss of water through evaporation and absorption. Cationic asphalt emulsions of the SS type are available with break times of 15 to 20 minutes when properly designed and placed under good weather conditions.

If anionic emulsions are used, slurries should not be placed during humid or cool weather because it may require 24 hours or longer for them to cure.

Ideally, the surface receiving slurry should be lightly tacked with a diluted asphalt emulsion that has been allowed to break before the slurry is placed. Rolling the tacked surface with a pneumatic-tire roller can reduce break time of this tack coat. All traffic should be kept off the tacked surface.

Rate of Application

The following information was taken from ISSA Publications A 105 and A 143.

The slurry seal mixture shall be of proper consistency at all times so as to provide the application rate required by the surface condition. The average application rate, shall be in accordance with the following table.

Suggested Application Rate

		Slurry Seal	Micro-Surfacing
Type I	Parking Areas, Urban and Residential Streets Airport Runways	8-12 lbs/yd^2 (3.63-5.44 kgs/m^2)	
Type II	Urban and Residential Streets Airport Runways	12-20 lbs/yd^2 (5.44-9.07 kgs/m^2)	10-20 lbs/yd^2 (5.4-18.6 kgs/m^2)
Type III	Primary and Interstate Routes	18-30 lbs/yd^2 (8.16-13.6 kgs/m^2)	15-30 lbs/yd^2 (8.1-16.2 kgs/m^2)
	Wheel ruts		Consult Publication A 143

Application rates are affected by the unit weight of the aggregate, the gradation of the aggregate and the demand of the surface to which the slurry seal is being applied. ISSA technical bulletin 112 gives a method to determine expected application rates.

Micro-Surfacing is often put down in two full width passes in place of rut-filling when the rutting or deformation is not severe. When two passes are used, the first pass (scratch course) is made using a metal strike off and applying only what the surface demands for leveling. The second course is applied at 15-30 lbs/yd^2 (8.1-16.2 kgs/m^2).

14.13 Stabilized Aggregate Bases (made with ESCS and local soil binder) and ESCS Geotechnical Fills

Use: The following paragraphs discuss the mechanical stabilization of bases and sub-bases in which ESCS forms the major portion of the aggregate system. In general, there is not fundamental difference in design and construction of bases made with ESCS lightweight and natural aggregates. Both ESCS and crushed stone develop high-internal friction and form a strong aggregate interlock.

ESCS stabilized bases, sub-bases, and geotechnical fills are, however, preferable to natural material in the following instances:

- On weight-sensitive areas ESCS bases are about half the weigh of natural aggregate base. This over-all weight reduction is a real design and economical advantage when roads and embankments are built over unstable soil or marsh lands. Time consuming delays for consolidation are avoided.

  The reduction in weight, coupled with the increase in stability provided by

ESCS's high angle of internal friction, greatly reduces long-term differential and overall settlement. Service life and motorist satisfaction are increased because with less differential settlement a smoother ride is provided. Maintenance problems and costs are also much less when ESCS base is used over unstable soil.

- ESCS Geotechnical fills are used for elevated parks and plazas, behind retaining walls, over underground structures, or wherever reduction of dead load or lateral pressure is required.

- Over thermal sensitive areas, ESCS base has much better insulating qualities than dense natural-aggregate bases. In cold climates water pipes can be installed at shallower depths when placed under ESCS insulating bases or when ESCS is used as cover and bedding around water pipes.

  ESCS bases can greatly reduce frost heave by insulating road sub-bases and preventing formation of ice lenses. ESCS also reduces moisture movement by acting as a capillarity brake.

  ESCS is used in parking lots, industrial areas, and electrical sub-stations to insulate shallow foundations and eliminate structural movement caused by frost heave.

A successful project must employ a competent materials engineer to make sure ESCS lightweight aggregate is used effectively. The engineer should be knowledgeable about pavement design and the stresses produced within each layer of pavement during construction. In thermal sensitive uses, the engineer must understand the thermal properties of the ESCS material being used. For additional information, see ESCSI Publication #6600, "Rotary Kiln Produced Lightweight Aggregate for Geotechnical Applications".

Binder material

ESCS aggregate contains no clay, silt, or plastic fines. Fines with a low plasticity, such as a sand and clay, must be added to produce a water bound, flexible base material in which the major constituent is ESCS aggregate. The sandy clay should have a plasticity index of 15-25. Plant blending the ESCS and sandy clay is preferred to insure a uniform, well-graded mixture with the right moisture content. Decreased construction time to achieve the specified proctor density, should easily offset the plant-blending costs. Plant-blended material should meet the specification, thus minimizing costly material rejection during construction inspections.

Low-plasticity index clays can be used to produce controlled plasticity, if the ESCS aggregate is well-graded down to the No. 50 (330 μm) sieve size. Many ESCS aggregate plants produce smokestack fines suitable for this purpose, but adequate quality control must be exercised to insure a serviceable end-product.

It is important to remember that the purpose of introducing the fines' fraction is to improve compatibility when needed to meet a specific weight and strength specification. Excess fines, whether plastic or not, can cause base failure during construction or later when the road is in service.

Stabilization of Bases and Sub-bases

Mechanical stabilization: Mechanical stabilization (compaction) is defined as the structural improvement of a given pavement layer as it is compacted. Compaction is necessary to improve the structural strength of all layers of any flexible pavement. The crushing strength of ESCS aggregate is less than natural rock or crushed stone, therefore, it is advisable to densify ESCS blends using pneumatic rollers only. The tire pressure should be low at first, increasing as the density of a lift builds-up. Pneumatic rollers exert a contact pressure approximately equal to the tire-inflation pressure which is very important in achieving the desired in-place density.
Steel rollers should not be used because they exert a surface stress intensity of about 500 psi, regardless of the rollers' gross weight. This stress level exceeds the crushing strength of most ESCS particles. Sheepsfoot and grid rollers should also be avoided as well as, slush rolling should not be practiced because it leaves a plane of weakness between successive layers and increases the likelihood of degradation. Slush rolling is defined here as placing a layer of large clean aggregate over a much fine sub-base and then using large quantities of water and heavy rolling to blend the two layers together.

It is essential to control the moisture content carefully at all times. For best results, begin compaction on the wet side of optimum, and compact back through optimum.

Chemical stabilization: Cementing-type chemicals can be used with bases made with ESCS aggregates as well as many natural aggregates. The two most widely used chemical stabilizers-hydrated lime and Portland cement-both work well with ESCS. The characteristics of the fines fraction of the base material normally determine the selection of one of these agents over the other. Generally, hydrated lime is more effective on materials containing plastic fines', whereas Portland cement is most effective for non-plastic materials. In any case, it is advisable to perform laboratory tests to arrive at the most satisfactory and economical design.

Adequate moist curing is essential for cement-stabilized materials. The base exchange and cementing action of hydrated lime require warm soil conditions, preferably 60ºF (15ºC) and above. Reaction rates at temperatures much below 60ºF (15ºC) are quite low. For temperatures continuously below 50ºF (10ºC) lime stabilization is not recommended. Other stabilizers, such as fly ash, are available but are not discussed in this manual.

Compaction of ESCS Geotechnical Fills

Compaction requirements of conventional geotechnical fills, i.e., soil, are commonly established by choosing a desire degree of relative compaction (typically 90 percent) based on a maximum dry density obtained in the laboratory using methods such as ASTM D 698, D 1557 or similar. Field density is generally determined using test methods such as ASTM D 1556, D 2922, or similar.

For ESCS fills, this practice cannot be applied directly due to the following reasons:

- **Laboratory maximum dry density:** Test methods such as ASTM D 698, D 1557 or similar, increase the amount of fine particles in the test sample as a result of particle crushing during impact of the compaction rod. This results in a "measured" density that is higher than what would be obtained with the same compaction energy if no crushing occurred, which is the case when field compaction is performed using rubber-tire equipment. The determined maximum dry density using these methods should be considered an "approximate" value and should not be used to establish a pas/fail criterion.

- **Field or in-place density:** Evaluation of field density in ESCS fills using the Sand Cone method (ASTM D 1556) is generally difficult due to the instability of the test hole. Use of a nuclear gage (ASTM D 2922) should be done only if the gage has been calibrated using ESCS fill. Gages used in daily geotechnical practice are typically calibrated using standardized blocks ranging from about 100 to 150 lbs/ft^3 in density. Trying to calibrate a nuclear gage for ESCS use from the standard blocks is not recommended. Calibrating a nuclear gage for ESCS must be done on a block of ESCS aggregate. The density of the ESCS test lock is determined by other methods.

For these reasons, it is recommended that compaction requirements for ESCS fills be established using a Method-Based specification. The specification should contain a desired gradation, maximum dry density, maximum loose thickness of lift, equipment type (or contact pressures), and minimum number of equipment passes.

Compaction of ESCS fills is best accomplished using rubber-tired equipment. Steel-tracked compaction equipment should be avoided as it may cause excessive particle crushing.

Contact the ESCS producer for details on selection of gradation, maximum dry density, compaction equipment, number of passes, and calibration of the nuclear gage.

14.14 Asphalt-Rubber Pavement

The properties and use of asphalt-rubber materials for various paving and maintenance activities have been well documented and, therefore, will only be covered briefly here. Substituting ESCS aggregate for normalweight aggregate (by volume) is essentially all that is required to achieve the many benefits previously mentioned in this manual.

Asphalt-rubber is a mixture of seventy-five to eighty percent (75-80%) hot-asphalt cement and twenty to twenty-five percent (210-25%) ground, recycled-tire rubber, mixed at a temperature of about 400ºF (200ºC) to cause a reaction. A small amount of diluents is added to the mixture to improve its flow characteristics for spray application.

Asphalt-rubber pavements are used in Arizona, California, Texas and Florida, and when ESCS aggregate has been incorporated the resulting pavement has performed very well.

Asphalt-rubber chip seal

In the mid 1960's, the city of Phoenix, Arizona pioneered the use of asphalt-rubber chip seal. In 1988 they installed the first asphalt-rubber chip seal using ESCS aggregate to eliminate automotive-windshield damage on high-traffic volume streets (30,000 ADT plus). With a typical service life of approximately fifteen years and an installation cost of about one-half that of a 1-1/2 inch hot-mixed asphalt overlay, asphalt-rubber chip seal offers many advantages.
The Asphalt-Rubber Producers Group (ARPG), 312 Massachusetts Ave., N.E., Washington, D.C. 20002, has publication, *A Twenty Year Study of Asphalt-Rubber Pavements in the City of Phoenix, Arizona*, by E. Charania, J.O. Cano, and R.H. Schnormeir, that covers the use of Stress Absorbing Membrane (SAM) and Stress Absorbing Membrane Interlayer (SAMI). SAM is a hot Asphalt-Rubber chip seal applied to a distressed, cracked surface. SAMI is a hot, asphalt-rubber chip seal applied to a surface followed by 1-1/2 to 2 inch asphalt- concrete overlay. SAMI's are generally used on major streets with a great number of utility cuts in addition to extensive cracking. Asphalt-rubber applications have allowed the city of Phoenix to incorporate existing pavement that were evaluated to be structurally inadequate. This resulted in substantial savings for the City.

The following guidelines, specifications, and conclusions were taken from the above mentioned publication:

Guidelines and specifications for use of asphalt-rubber chip seal: The following guidelines and specifications have been developed for the use and application of asphalt-rubber chip seal on city streets.

- Asphalt-rubber is produced with eighty percent (80%) hot asphalt cement and twenty percent (20%) coarse-ground recycled-tire rubber, heat digested at a temperature of about 400ºF (200ºC).

- Aggregates used are 3/8 inch (9.5 mm) or ¼ inch (4.75 mm) nominal and are hot precoated. [Precoating may not be necessary with ESCS].

- Asphalt-rubber is generally applied at a rate of 0.6 gallons per square yard.

- Hot-precoated normalweight chips are applied at a rate of 3-40 lbs/yd^2. (The volume of ESCS aggregate will be about the same, but the pounds per square yard will be considerably less [approximately 17 lbs/yd^2]. Consult the ESCS suppler).

The chip seal produces a unique paving material with superior engineering properties. The main advantage of the asphalt-rubber chip seal treatment has been virtually complete cessation of surface maintenance for twelve (12) years except for utility cuts. Cracks have not reflected through the seal on aged pavements. Continued observations on treated streets confirm the significant advantage of this method in preventing reflective cracking. Long term studies have shown cracks less than 0.25 inch wide do not generally reflect through the seal for 8 years, and in some cases for as many as 12 years. In occasional cases when reflection cracking occurred, there was no spalling or deterioration into potholes.

Transverse cracking has not been totally stopped by asphalt-rubber SAM or SAMI. However, secondary cracking that normally radiates off a primary transverse crack does not normally occur. Secondary cracking usually causes potholes at major cracks.

The greatest advantage in stopping reflective cracking has been in alligator type of cracks and shrinkage cracking. Any crack that is greater than 0.3 inches should be prepared and filled.

Conclusions on the use and advantages of asphalt-rubber chip seal in the city of Phoenix, Arizona: Chip seals have been very dependable maintenance treatment for city streets. They have added extra life to the pavements and enabled the city to delay reconstruction of the streets that would otherwise have been needed.

Asphalt-rubber seal coat SAM's and SAMI's have given the pavement-management system several advantages as summarized below:

1. Retards reflective cracking in paving materials with less than one-quarter-inch cracks for 8 to 12 years.
2. Stops secondary cracking up to 15 years.
3. Retards spalling of asphalt concrete around potholes and larger cracks.
4. Waterproofs the structure to obtain maximum stability.
5. Seals and preserves the in-place original quality of the asphalt cement and the asphalt concrete.
6. Reduces maintenance considerably due to all of the above factors.
7. Seals the subgrade to minimize volume changes that take place due to moisture changes.
8. Serves as a stress absorbing interlayer to reduce future maintenance.
9. Fills cracks and seals joints.
10. If another asphalt-rubber seal, fog seal, or rejuvenation seal were applied at the proper time, the pavement life can be extended.
11. Asphalt-rubber seals last two, to two-and-one-half times longer than most standard seals in Phoenix. If preventive seals were applied at the right time, the seals would last two to five times longer.

In spite of the successful use of asphalt-rubber, it must be used with careful considerations for the pavement structural condition, its absorption properties, the size of the cracks, and its intended use. Although asphalt-rubber absorbs pavement stresses and does seal, it does not stop cracking or failures in the existing pavement or subgrade-the cracks are still present although they do not come to the surface to cause problems. When used as a SAMI, experience has shown the minimum overlay thickness should be 1-1/2 inches (38 mm) to prevent reflection.

Appendix I, "International Surfacing Inc., Guide Specification for Asphalt-Rubber Stress Absorbing Treatments", provides helpful information and notes to engineers on asphalt-rubber chip seals.

Hot-Mixed Asphalt-Rubber Concrete Pavement (open, dense, and gap-graded)

International Surfacing, Inc., Publication, "Design Methods for Hot Mixed Asphalt-Rubber Concrete Paving Materials", by James G. Chehovits, Chief Engineer, Sealants; Crafco Inc., October 30-31, 1989, covers this subject in detail. The publication describes design procedures which have been developed since 1984 as the result of approximately 30 hot-mixed paving projects that used asphalt-rubber binder. Procedures for selecting the asphalt-rubber material proportions and resulting desire properties, mixture aggregates, and binder contents for dense, open, and gap-graded mixture types are presented along with suggested construction guidelines and specifications.

Appendix H provides the International Surfacing Inc., detailed "Guide Specification for Open, Dense, and Gap-Graded Asphalt Concrete Pavements with Asphalt-Rubber Binder", with helpful "Notes to Engineers".

The following two comments on aggregate from James Chehovits, *"Design Methods for Hot-Mixed Asphalt-Rubber Concrete Paving Materials"* are also helpful:

"**Aggregate for dense-graded asphalt-rubber concrete:** Dense-graded asphalt-rubber concrete pavements are composed of typical dense-graded type aggregates [ESCS Aggregate also works well] and appropriate asphalt-rubber binder. Aggregate should meet the same quality requirements as for conventional asphalt concrete which would be used in similar applications. Due to the presence of the rubber particles in the asphalt-rubber binder, the aggregate gradation for dense-graded mixtures should be maintained on the coarse sided of the gradation band. Gradations which plot between the maximum density line and the upper limit of the band should be avoided, (Fig. 14.24). Maintaining the gradation on the middle to coarse side of typical dense-graded bands is important to provide sufficient void spaces in the aggregate for the rubber particles. If the gradation is too fine, or the rubber particles are too large, compaction problems resulting from rubber interference between aggregate particles can result. This effect is indicated by two observations during the mixture design procedure. First, immediately after compaction and while hot, the mixture will appear to have a somewhat unstable and "spongy" characteristic if coarse aggregate particles are pressed into the mixture. Second, a relatively level trend in mixture air voids data will be noticed with increasing asphalt-rubber contents, instead of the typical decrease in air voids. Both of these effects can generally be reduced and eliminated by coarsening the gradation, or by reducing rubber particle size used. Suggested gradation limits for 3/8 inch (9.5 mm), ½ inch (12.5 mm), and ¾ inch (19 mm) maximum sized dense-graded mixtures for use with asphalt-rubber binder are listed in Appendix H.

"Aggregate for open-graded asphalt-rubber concrete: Aggregate used for open-grade Asphalt-Rubber concrete should meet the same quality requirements as for conventional asphalt concrete which would be used in similar applications. Recommended aggregate gradations are listed in Appendix H. These gradations are typical of many 3/8 and ½ inch open-graded mixtures used throughout the United States. For the 3/8 inch (19.5 mm) gradation, overlay thickness should not exceed 1 inch (25 mm). For the ½ inch (12.5 mm) gradation, maximum thickness should be 1-1/2 inches (38 mm)."

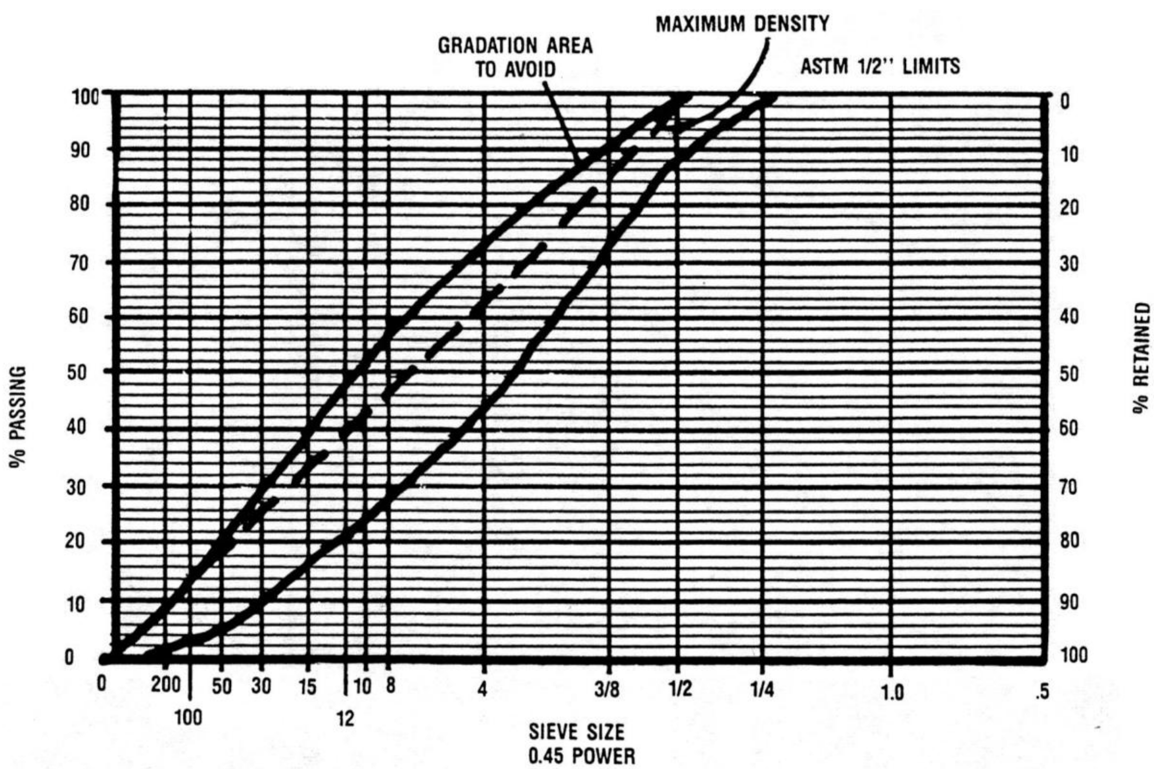


Figure 14.24 ***Illustration of gradation area to avoid with a typical dense-graded gradations when using asphalt-rubber binder.***

California I-15 asphalt rubber chip seal project:

In August 1996 Cal-Trans placed approximately 20 lane miles of asphalt-rubber chip seal project using a special gradation of ¾ inch (19 mm) expanded shale (ESCS) aggregate from Pacific Custom Material, Port Costa, California.

The project is on I-15 between Los Angeles and Las Vegas neat the Bell Mountain Wash area. An ESCS asphalt-rubber chip seal was selected to extend the life of the roadway by building up the surface and improving the friction resistance without creating motorist complaints caused by flying stones and windshield damage.

Some specific's about the project:

- Project size 4.8 miles (7.7 km) long, 4 lanes wide, 48 ft. (14.6 m), total area 135,170 yd^2 (113,000 m^2).

- ESCS aggregate was heated to about 300ºF (149ºC), and precoated at the rate of 2.5 to 3.0 percent by weight of ESCS with AR-4000 paving asphalt and then hauled 12 miles (19 km) to the job-site when it was spread at approximately 85 square yards per cubic yard.

- The hot-asphalt rubber mixture or binder composed of AR-4000 and up to 22% crumb rubber was pre-blended at a centralized job mix site. The binder was maintained at a temperature of approximately 400ºF (200ºC) and sprayed onto the pavement surface at the rate of between 0.55 and 0.65 gallons per square yard.

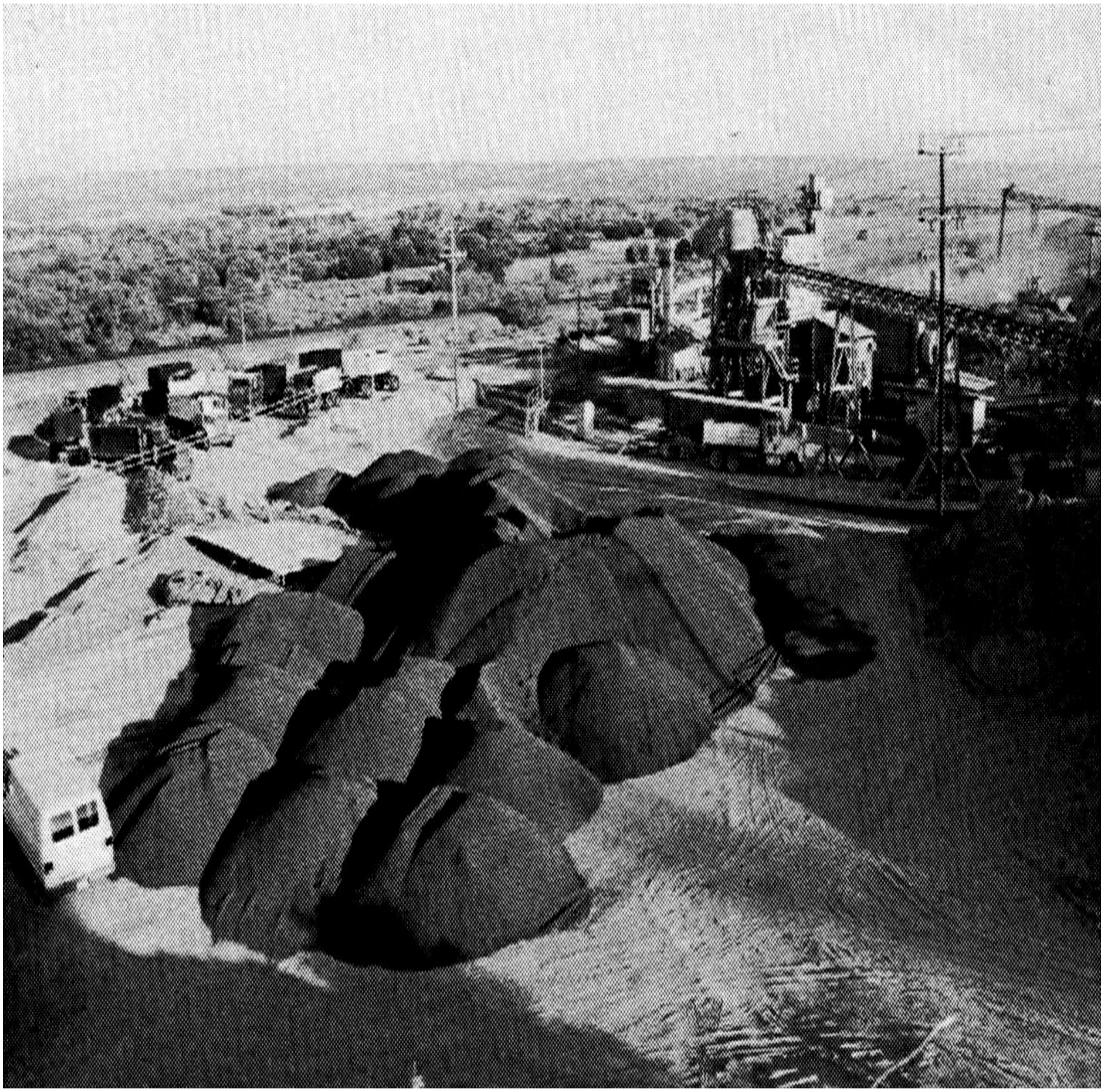


Figure 14.25 ***Prior to the start of the I-15 job, the ESCS (Baypor) ESCS aggregate was stockpiled at the Industrial Asphalt hot plant in Oro Grande, California. The aggregate was precoated at the rate of 2.5 to 3.0 percent by weight of lightweight aggregate with AR-4000 paving asphalt. It was then loaded into end dump trucks for about a 12 mile (19 km) trip to the jobsite.***

Figure 14.26 ***Asphalt-Rubber distributor truck***

Figure 14.27 ***I-15 Asphalt-rubber chip seal project showing chip spreader.***

Figure 14.28 ***I-15 Asphalt-rubber chip seal project showing three pneumatic rubber-tired rollers following the chip spreader.***

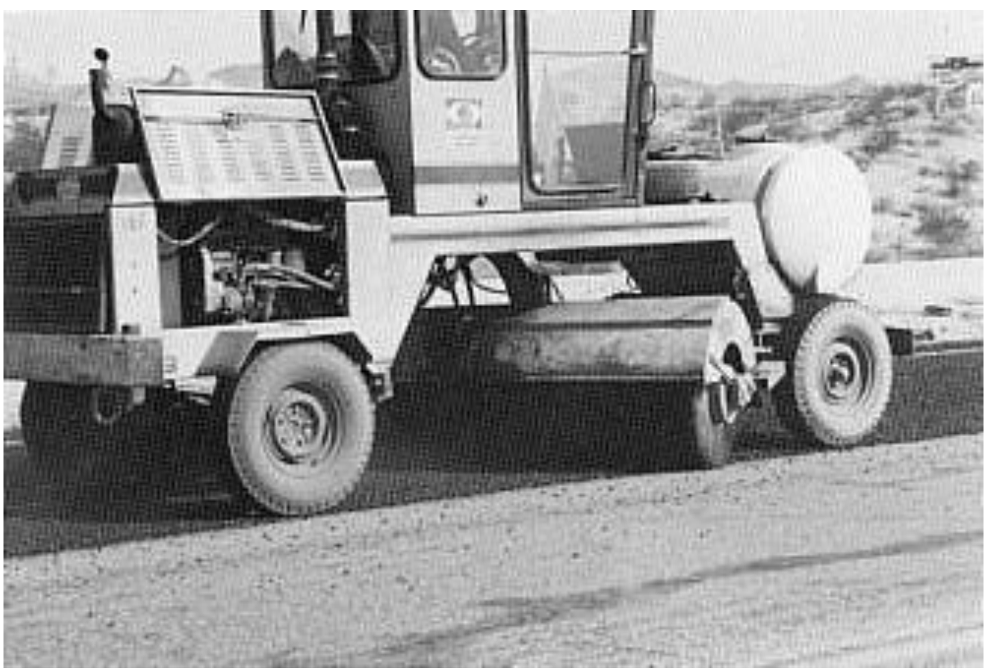


Figure 14.29 ***A self-propelled rotary "sidekick" sweeper broom removing loose aggregate from the pavement.***

Figure 14.30 ***Longitudinal edge joint showing excellent adhesion, embedment and distribution of the aggregate in the asphalt-rubber binder.***

Figure 14.31 ***Close up of finished surface with U.S. $.25 coin (quarter) as reference.***

Appendix 14A

State Specifications (Sections of)

• Colorado	Section 409	Seal Coat
	Section 702.04	Emulsified asphalt
	Section 703	Aggregates
• Kansas	Section 1109	Aggregates for cover material
• Louisiana	Section 507	Asphaltic surface treatment
	Section 1003	Aggregates
• Oklahoma		
• Texas		
	Item 303	Aggregate for surface treatment(lightweight)
	Item 316	Surface treatment
	Item 318	Hot asphalt-rubber surface treatments
	Item 334	Hot mix-cold laid asphaltic concrete pavement
	Item 340	Hot mix asphaltic concrete pavement
	Item 342	Plant mix seal
• Utah		
• Virginia		
	Section 206	Lightweight aggregate
	Section 311	Prime coat
	Section 312	Seal coat
	Section 313	Asphalt surface treatment
• Missouri/Kansas (Buildex Letter)		

State Department of Transportation
State of Colorado

Standard Specifications for Road and Bridge Construction

USING

INTERNATIONAL SYSTEM OF UNITS (SI)

(MODERNIZED METRIC)

1991
(WITH METRIC UNITS 1994)

No ....

REVISION OF SECTIONS 409, 702 AND 703
SEAL COAT

Sections 409, 702, and 703 of the Standard Specifications are hereby revised for this project as follows:

Subsection 409.08 shall include the following:

If cover coat material is lightweight aggregate it shall be moistened with water prior to spreading.

Delete subsection 409.09 and replace with the following:

Seal coat will be measured by the number of tons (metric tons) or cubic yards (cubic meters) of the designated type of cover coat aggregate.

Subsection 409.10 shall include the following:

Pay Item	Pay Unit
Cover Coat Material (Type__) (Lightweight)	Cubic Yard (Cubic Meter)

In subsection 702.04, Table 702-6, change the minimum demulsibility from 60 to 40.

Delete subsection 703.05(3) and Table 703-4 and replace with the following:

(3) For Type I, II, or IV cover coat material, 90 percent by weight of the particles retained on the No. 4 sieve shall have at least two fractured faces when tested in accordance with Colorado Procedure 45.

(4) Lightweight aggregate used for cover coat material shall be an aggregate prepared by expanding shale, clay, or slate in a rotary fired kiln. Lightweight aggregate shall have a dry loose unit weight of 35 to 55 pounds/cubic foot (560 to 880 kg/m³) determined in accordance with AASHTO T 19, Shoveling Procedure. The total mass of the test sample of lightweight aggregate used in AASHTO T 96 (Los Angles Abrasion) shall be 2000 g.

TABLE 703-4
Gradation Specifications for Cover Coat Aggregate

Sieve Size	Percent by Weight Passing Square Mesh Sieve		
	3/8"(9.5 mm) Type I	1/2"(12.5 mm) Type II	3/4"(19.0 mm) * Type IV
3/4"(19.0 mm)	...	...	100
1/2"(12.5 mm)	...	100	95-100
3/8"(9.5 mm)	100	70-100	60-80
No. 4	0-15	0-4	0-10
No. 200	0-1.0	0-1.0	0-1.0

*Type IV shall be used only with lightweight aggregates.

SECTION 409
SEAL COAT

DESCRIPTION

409.01 This work consists of furnishing and applying bituminous material and cover coat material on an existing surface, in accordance with these specifications and in conformity with the lines shown on the plans or established. When rejuvenating agent or emulsified asphalt is used as a fog seal, cover coat material will not be required.

MATERIALS

409.02 Bituminous Material. Emulsified asphalt shall be polymerized rapid set emulsified asphalt conforming to the requirements of subsection 702.04 for either CRS-2P or HFRS-2P.

Rejuvenating agent shall conform to the requirements of subsection 702.05.

409.03 Cover Coat Material. Cover coat material shall meet the requirements of subsection 703.05 for the type specified. The material will be accepted at the spreader.

CONSTRUCTION REQUIREMENTS

409.04 Weather Limitations. Bituminous material shall not be applied on a damp surface, when either the air or pavement surface temperature is below 21°C, or when weather conditions would prevent the proper construction of the seal coat.

409.05 Equipment. The following equipment or its equivalent shall be used:

(1) Bituminous distributor and equipment shall be capable of uniformly distributing bituminous material at even temperature and uniform pressure on variable widths of surface up to 4.5 m at readily determined and controlled rates from 0.2 to 9 L/m^2. The allowable variation from any specified rate shall not exceed plus or minus 0.09 L/m^2. The distributor's spreading capabilities. shall be computer controlled or it shall be calibrated to conform to the distributor manufacturer's procedure prior to applying the emulsified asphalt. Distributor equipment shall include a tachometer, pressure gauges, accurate volume measuring devices or a calibrated tank, and a thermometer for measuring temperatures of tank contents. Distributors shall be equipped with a power unit for the pump, and full circulation spray bars adjustable laterally and vertically. Distributors shall be equipped with an automatic heater capable of maintaining the bituminous material at the manufacturer's recommended application temperature or at 60°C, whichever is higher.

(2) A rotary power broom.

(3) A minimum of two pneumatic tire rollers, which weigh at least 9 metric tons each.

(4) One self-propelled aggregate spreader of approved design supported by at least four wheels equipped with pneumatic tires on two axles. The aggregate spreader shall be capable of applying the larger cover coat material to the surface ahead of the smaller cover coat material and with positive controls

so the required quantity of material is deposited uniformly over the full width of the bituminous material. Other types of aggregate spreaders may be used provided they accomplish equivalent results and are approved.

409.06 Preparation of Surface. The entire surface that is to receive a seal coat shall be cleaned of loose sand, dust, rock, mud, or any other debris that could prevent proper adhesion of the bituminous coating. The cleaning shall be accomplished by power broom, scraping, blading, or other approved measures. Seal coating operations shall not be started until the surface is approved.

409.07 Applying Bituminous Material. Bituminous material shall be applied by a pressure distributor in a uniform, continuous spread and within the temperature range specified. The distributor's spreading capability shall be computer controlled or calibrated to conform to the distributor manufacturer's procedure prior to applying the emulsified asphalt. If streaking occurs, the distributor operation shall be stopped immediately until the cause is determined and corrected. Streaking is alternating, narrow, longitudinal areas of excessive and then insufficient quantities of bituminous material. The quantity of bituminous material per square meter may vary from the rate shown in the Contract, as directed. A strip of building paper, at least 900 mm in width and with a length equal to that of the spray bar of the distributor plus 300 mm, shall be used at the beginning of each spread. If the distributor does not have a positive cut-off, the use of paper shall be required at the end of each spread. The paper shall be removed and disposed of in a satisfactory manner. The distributor shall be moving forward at proper application speed at the time the spray bar is opened, and skipped areas or deficiencies shall be corrected. Junctions of spreads shall be carefully made to assure a smooth riding surface.

The length of spread of bituminous material shall not be in excess of the area which trucks loaded with cover coat material can immediately cover.

The spread of bituminous material shall not be more than 150 mm wider than the width covered by the cover coat material from the spreading device. Under no circumstances shall operations proceed so bituminous material will be allowed to chill, set up, dry, or otherwise impair retention of the cover coat.

The distributor shall be parked so that bituminous material will not drip on the surface of the traveled way.

409.08 Application of Cover Coat Material. Immediately following the application of the bituminous material, cover coat material shall be spread in quantities as designated. The spreading rate may vary from the rate shown in the Contract when approved. Spreading shall be accomplished so the tires of the trucks or aggregate spreader do not contact the uncovered and newly applied bituminous material.

If directed, the cover coat material shall be moistened with water prior to spreading, to eliminate or reduce the dust coating of the aggregate.

Immediately after the cover coat material is spread, any deficient areas shall be covered with additional material. Rolling shall begin immediately behind the spreader and shall continue until three complete coverages are obtained. Rolling shall be completed the same day the bituminous material and cover coat materials are applied.

The completed roadway surface shall be lightly broomed the following morning to remove any excess material, without removing any imbedded material. The Contractor shall conduct additional brooming if so directed.

A fog seal shall be applied at the rate of 0.5 L/m^2 of diluted emulsion when directed. The emulsion shall be diluted with water at the rate of 50 percent water and 50 percent emulsion. The application rate and the dilution rate may be changed by the Engineer.

METHOD OF MEASUREMENT

(or Cubic yards)

409.09 Seal coat will be measured by the number of metric tons of the designated type of cover coat aggregate.

BASIS OF PAYMENT

409.10 The accepted quantities of seal coat will be paid for at the contract price per metric ton for cover coat material.

Payment will be made under:

Pay Item	**Pay Unit**
Cover Coat Material (Type______) (Lightweight)	Metric Ton Cubic yard (Cubic Meter)

Bituminous materials, including the bituminous material used for fog seal, will be measured and paid for in accordance with Section 411.

702.04 Emulsified Asphalts. Emulsified asphalts shall conform to AASHTO M 140 or M 208 for the designated types and grades. When grade CSS-1h or SS-1h emulsified asphalt is used for tack coat, residue penetration test values shall be between 40 and 120.

Polymerized rapid set emulsified asphalt for seal coat shall conform to the following requirements for either CRS-2P or HFRS-2P.

(a) CRS-2P (Cationic, Polymerized) shall be an emulsified blend of polymerized asphalt, water, and emulsifiers. The asphalt cement shall be polymerized prior to emulsification and shall contain a minimum of three percent polymer by mass of asphalt cement. The emulsion standing undisturbed for a minimum of 24 hours shall show no white, milky separation but shall be smooth and homogenous throughout. The emulsion shall be pumpable and suitable for application through a distributor. The emulsified blend shall conform to the requirements of Table 702-5.

TABLE 702-5

Property	Requirement Min.	Requirement Max.	AASHTO Test No.
Viscosity, Saybolt Furol at 50°C, s	50	450	T 59
Storage Stability Test, 24 hrs., %		1.0	T 59
Demulsibility, %	40		T 59
Particle Charge Test	Positive		T 59
Sieve Test, %		0.1	T 59
Oil Distillate by volume, %		3.0	T 59
Residue by distillation, %	65		T 59
Tests on residue: Penetration, 25°C, 100g, 5 s	70	150	T 49
Solubility in trichloroethylene, %	97.5		T 44
Toughness, 25°C, joules	7.9		*CP L-2210
Tenacity, 25°C, joules	5.1		*CP L-2210

*Colorado Procedure.

(b) HFRS-2P (Anionic, Polymerized, HighFloat) shall be an emulsified blend of polymerized asphalt, water, and emulsifiers. The asphalt cement shall be polymerized prior to emulsification and shall contain a minimum of three percent polymer by mass of asphalt cement. The emulsion, standing undisturbed for a minimum of 24 hours shall show no white, milky separation, but shall be smooth and homogenous throughout. The emulsion shall be pumpable and suitable for application through a distributor. The emulsified blend shall conform to the requirements of Table 702-6.

TABLE 702-6

Property	Requirement Min.	Requirement Max.	AASHTO Test No.
Viscosity, Saybolt Furol at 50°C, s	50	450	T 59
Storage Stability Test, 24 hrs., %		1.0	T 59
Sieve Test, %		0.1	T 59
Demulsibility, 0.02 N, $CaCl_2$,%	40 60		T 59
Oil Distillate by volume, %		3.0	T 59
Residue by distillation, %	65		T 59(1)
Tests on residue:			
Penetration, 25°C, 100g, 5 s	70	150	T 49
Float Test, 60°C, s	1200		T 50
Ductility, 25°C, 5 cm/min., cm	75		T 51
Solubility in Trichloroethylene, %	97.5		T 44
Elastic Recovery, 25°C, %	58		*CP L-2211

1 AASHTO T 59 with modifications to include a 205 ± 5°C maximum temperature to be held for 15 minutes.
* Colorado Procedure.

Emulsion for prime coat shall conform to the following requirements for either Asphalt Emulsion Prime in Table 702-7, or Penetrating Priming Stabilizer in Table 702-8.

TABLE 702-7
For Asphalt Emulsion Prime

Property	Requirement	AASHTO Test No.
Viscosity, Saybolt Furol, at 50°C, s	15-150	T 59
Settlement	1% max.	T 59
% Residue	65% min.	T 59 to 260°C
Oil Distillate by Volume, %	7% max.	T 78
Tests on Residue from Distillation: Solubility in Trichloroethylene, %	97.5 min.	T 44
Tests on Residue from Cutback Distillation to 360°C: Viscosity, 60°C, mm/s	3,000 min.	T 202

TABLE 703-3
Master Range Table
for Hot Bituminous Pavement

Sieve Size	Mass Percent Passing Square Mesh Sieves			
	Grading G	Grading C	Grading CX	Grading F
37.5 mm	100			
25.0 mm				100
19.0 mm	63-85	100		
12.5 mm	46-78	70-95	100	
9.5 mm		60-88	74-95	
#4	22-54	44-72	50-78	
#8	13-43	30-58	32-60	45-85
#30	4-22	12-34	12-34	
#200	1-8	3-9	3-9	7-13

703.05 Aggregate for Cover Coat Material. Aggregates for cover coat material shall be crushed stone, crushed slag, crushed gravel, or natural gravel. Aggregates shall be composed of clean, tough, durable fragments free from an excess of flat, elongated, soft, or disintegrated pieces and free from fragments coated with dirt or other objectionable matter. Slag shall be air-cooled blast-furnace slag reasonably uniform in density.

The aggregate shall conform to the following requirements:

(1) Percentage of wear, Los Angeles Test (AASHTO T 96), not more than 35.

(2) When blast-furnace slag is used, mass per cubic meter shall be at least 1120 kilograms.

(3) For Type I or Type II cover coat material, ~~100~~ percent by weight of the particles retained on the No. 4 sieve shall have at least two fractured faces when tested in accordance with Colorado Procedure 45. ~~Aggregate passing the No. 4 sieve shall be the product of fracture of crushing rock larger than 13 mm.~~

Only one type of aggregate shall be used on the project unless alternate types are approved.

When tested in accordance with AASHTO T 182, aggregate shall have a retained bituminous film above 95 percent. In order to meet this requirement, an approved additive meeting the requirements of subsection 712.10 may be added to the bituminous material.

TABLE 703-4
Gradation Specifications
for Cover Coat Aggregate

This section was replaced by 12/12/94 Revision.

	Sieve Size	Mass Percent Passing Square Mesh Sieve of the Indicated Size		
		9.5 mm Type I	12.5 mm Type II	Sand Type III
1/2"	12.5 mm	. . . . .	100	100
3/8"	9.5 mm	100	70-100	60-100
4.75mm	#4	0-15	0-4	0-30
75µm	#200	0-1.0	0-1.0	0-1.0

703.06 Mineral Filler. Mineral filler shall conform to the requirements of AASHTO M 17 and shall consist of rock dust, slag dust, hydrated lime, hydraulic cement, fly ash, or other suitable

STANDARD SPECIFICATIONS

FOR

STATE ROAD AND BRIDGE CONSTRUCTION

EDITION 1990

KANSAS DEPARTMENT OF TRANSPORTATION

TOPEKA, KANSAS

PRINTED BY
DIVISION OF PRINTING
DEPARTMENT OF ADMINISTRATION
TOPEKA, KANSAS
1994

SUBSECTION 1109

AGGREGATES FOR COVER MATERIAL

1109.01 DESCRIPTION.

This specification covers aggregates for cover material to be used for bituminous sealing. The type or types of cover material aggregate to be furnished will be shown on the Plans or in the contract for each project.

1109.02 REQUIREMENTS.

(a) Composition.

Aggregates for cover material shall be sand-gravel, lightweight aggregate, crushed limestone, crushed sandstone, crushed or uncrushed gravel or chat. Chat shall be material obtained from the mining of lead and zinc ores. Lightweight aggregate shall be expanded shale.

(b) Quality Requirements.

The aggregate shall meet the following quality requirements:

(1) *Soundness*, minimum	0.90
(2) *Wear*, maximum	
Sand-gravel, Gravel, Limestone or Chat	40%
Sandstone	45%
Lightweight aggregate	25%
(3) Absorption, maximum (all types except CM-L)	4.0%

(c) Product Control.

Material produced for use under this specification shall meet the following requirements.

(1) *Size Requirements.* The size requirements for the various cover material types shall be as shown in Table 7. The gradation factor shall be determined in accordance with the procedures listed in 1102.02(a)(2.3) and comply with the requirements of Table 7.

3/4 1/2 3/8 No. 4 No 8

TABLE 7—GRADATION REQUIREMENTS FOR AGGREGATES FOR COVER MATERIAL

Type	Composition	Percent Retained—Square Mesh Sieves (1) 19.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	600 µm	300 µm	Minimum Gradation Factor
CM-A	Sand-Gravel		0	0-20	30-100	85-100			
CM-B	Sand-Gravel		0	0-25		35-100		90-100	4.00
CM-C	Crushed Stone	0	0-12	40-100	95-100				
CM-D	Crushed Sandstone	0	0-5	20-35	45-100	95-100			
CM-E	Chat		0	0-15	45-100	90-100			
CM-F(3)	Chat		0	0-15	40-100	85-100	95-100		
CM-G	Chat, Sand-Gravel or Crushed Sandstone		0	0-15	45-100	95-100			
CM-H(2)	Crushed Stone	0	0-5		40-100	90-100			
CM-J(2)	Sand-Gravel	0	1-20			30-100		90-100	
CM-K	Crushed Limestone	0	0-5	20-35	45-85	95-100			
CM-L	Lightweight Aggregate	0	0-5	0-15	70-100	90-100			

(1) After removal of all deleterious substances.
(2) Types CM-H and CM-J shall not be specified for Federal Aid projects.
(3) County Projects only when specified.

(2) *Deleterious Substances.* Deleterious substances shall not exceed the following percentages by weight:

(2.1) Material Passing 75 µm Sieve.	
Type CM-G	1.0
Type CM-J	4.0
All other types	2.0
(2.2) Shale or Shale like material	1.5
(2.3) Soft or friable particles	
Type CM-G	1.5
Type CM-H and CM-J	4.0
All other types	3.0
(2.4) Coal	0.5
(2.5) Clay lumps	0.5
(2.6) Sticks (wet)	0.1

Any combination of deleterious substances as shown above shall not exceed the following.

Type CM-G dustless	2.0
CM-J (SG)	6.0
All other	5.0

(d) **Stockpiling.**

Stockpiling operations shall comply with the requirements of 1105.02(d).

1109.03 METHODS OF TEST.

Materials covered by this section shall be tested in accordance with the applicable provisions of subsection 1117.

1109.04 BASIS OF ACCEPTANCE.

The basis of acceptance for materials furnished under this specification shall be in accordance with the requirements of subsection 1101.

LOUISIANA STANDARD SPECIFICATIONS FOR ROADS AND BRIDGES 1992 EDITION

STATE OF LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT BATON ROUGE

This public document was published at a total cost of $11,527.72. Three thousand copies of this public document were published in the second printing at a cost of $11,527.72. The total cost of all printing of this document including reprint is $31,352.72. This document was published by the Department of Transportation and Development and printed by Rose Printing Company, Tallahassee, Florida, to provide the Department of Transportation and Development with revised specifications for the construction of the state transportation infrastructure under authority of Revised Statues 48:1 et seq., 38:2211 et seq., and 3:501 et seq. This material was printed in accordance with the standards for printing by state agencies established pursuant to Revised Statute 43:31. Printing of this material was purchased in accordance with the provisions of Title 43 of the Louisiana Revised Statutes.

Section 507
Asphaltic Surface Treatment

507.01 DESCRIPTION. This work consists of furnishing and constructing a wearing surface of aggregate and asphaltic material on a prepared base course or on existing pavement, in accordance with these specifications and in conformity with the lines, grades and typical sections shown on the plans or established.

Asphaltic surface treatment shall consist of one or more applications of each of the specified sizes of aggregate and the specified asphaltic material.

507.02 MATERIALS. The following combination of materials will be allowable depending on the Type of Asphaltic Surface Treatment (AST):

Type AST	Asphaltic Material	Friction Rating
A	CRS-2P	I, II
B	CRS-2P or CRS-2L	I, II or III
C	CRS-2P	I, II, III, or IV
D	CRS-2, CRS-2P, or CRS-2L	I, II, III, or IV

The asphaltic material shall conform to Section 1002. Aggregates shall conform to Section 1003.05.

507.03 EQUIPMENT. The contractor shall provide and maintain the necessary equipment for proper construction. The equipment shall have been approved before construction begins.

Storage tanks, piping, retorts, booster tanks, distributors and other equipment used in delivering, storing or handling asphaltic materials shall be kept clean and in good operating condition and shall be operated to avoid contamination of the contents with foreign materials.

Equipment shall consist of the following:

(a) Power distributor conforming to Subsection 503.07 amended as follows:

The distributor shall be capable of maintaining an allowable variation from any specified rate within ±0.02 gallon per square yard. The distributor shall be equipped with a height adjustable spray bar with spray nozzles recommended by the manufacturer which yield uniform double coverage. Each of the two end nozzles shall be specially designed to provide, a sharp line of asphaltic material on the roadway surface.

(b) Self-propelled pneumatic-tire rollers.

Pneumatic-tire rollers shall be self-propelled. Tires shall have smooth tread, shall be the same size and ply rating, shall be inflated to a uniform pressure not varying more than ±5 psi between tires. The contractor shall supply appropriate calibration charts to determine wheel load and contact pressure. Wheels shall not wobble and shall be aligned so that gaps between tires on one axle are covered by tires of the other axle. Tires shall be equipped with scrapers to prevent adhesion of material. The engineer may require additional cleaning apparatus on tires if material adhesion is detrimental to the surface treatment. Rollers shall be capable of applying a minimum of 50 psi contact pressure under each tire and shall be of such weight that no damage is caused to the underlying base course or surface treatment being applied.

(c) Power revolving broom or a power blower.

(d) Self-propelled, pneumatic-tire power spreader so designed, equipped, and operated to spread aggregate uniformly at the designated rate with application being defined at edges.

The aggregate spreader shall be capable of maintaining an allowable variation from the specified rate within ±0.5 pounds per square yard (±0.25 pounds per square yard for expanded clay aggregate).

(e) A vacuum-sweeper will be required when using expanded clay aggregate when there is a dusting problem.

507.04 WEATHER LIMITATIONS. Asphaltic material shall not be applied on a wet surface nor when the air temperature in the shade is less than 60°F.

Asphaltic surface treatment shall not be applied during November, December, January, February or March.

507.05 PREPARATION OF EXISTING SURFACE. Potholes and surface depressions not included in any other patching items shall be repaired by removing loose and defective material, tacking, and replacing with a patching mixture meeting the requirements of Section 724. The patching mixture shall be compacted to produce a tight surface conforming to the adjacent area.

Immediately prior to application of the asphaltic material, existing pavements shall be cleaned over the full width to be treated. The outer edges of the pavement to be treated shall be thoroughly cleaned. Raised pavement markers shall be removed before application of asphaltic surface treatment.

Excess asphalt on patches and joints in existing pavements, when not covered by a contract item, shall be removed by a method approved by the engineer. The pavement shall then be swept with a power broom to remove all loose material. Areas not reached by the power broom shall be cleaned by hand brooming.

Prime coat or curing membrane shall be satisfactorily cured and maintained in accordance with Sections 505 and 506 prior to application of asphaltic surface treatment. The surface shall be approved prior to application of asphaltic surface treatment.

507.06 APPLICATION. After the existing surface has been approved, asphaltic material and aggregates shall be applied in the amounts and sequence specified herein.

Application temperatures and sequence of application and spreading for asphaltic surfacing shall be as given in Table 5. The quantities of material given in Table 6 may be adjusted by the engineer as field conditions warrant. The type and condition of the surface being covered will affect the required rate of asphaltic material. The quantities to be used shall be as directed and shall be established during the first distributor application.

(a) Asphaltic Material: The quantities of asphaltic material per square yard of treated surface shown in Table 5 are based on a temperature of 60°F. Volumetric measurements shall be converted to this temperature in accordance with DOTD TR 321.

The length of spread of asphaltic material shall not exceed that which can be covered within 3 minutes with aggregate.

The rate of asphaltic material placed shall not vary by more than 10 percent either longitudinally or transversely from the beginning to the end of each pass of the distributor.

Asphaltic material for each application shall be applied uniformly for the full width of treatment unless, due to the impracticality of detouring traffic, the engineer directs that the material be applied to less than the full width of roadway at a time. When the contractor is unable to keep the application of asphaltic material consistently within ±0.02 gallons per square yard of the quantity directed, operations shall be discontinued. Operations shall not resume until the contractor can provide an operator of greater experience, a better distributor, or both, or shall provide such precautions as necessary to keep the application within allowable variations.

The height of the spray bar and the angle of the nozzles shall be adjusted so that individual spray fans do not interfere with each other and uniform double coverage is achieved.

The height of the spray bar shall be adjusted during operations as the asphaltic material is distributed to maintain the proper distance between the spray bar and the surface to maintain uniform double coverage. A minimum of 100 gallons of asphaltic material shall be maintained in the distributor during operation.

Each of the special spray nozzles at the ends of the spray bar shall be adjusted and maintained to provide a sharp edge for the asphaltic material on the roadway surface. When the application is less in width than the length of the spray bar, these special nozzles shall be moved to provide the specified edge lines.

When any nozzles become blocked during application of asphaltic material, the distributor and flow of material shall be immediately stopped and the nozzles cleaned. When the engineer directs that application be made over less than the full width of the roadway at a time, there shall be a slight longitudinal overlapping of adjacent treatments. The distributor shall be operated along a marked edge to keep the surface treatment in proper alignment.

To secure uniform distribution at the transverse junction of two treatments, the distributor shall be promptly stopped before the flow decreases. Building paper or other suitable material shall be placed over the end of the previous application. The joining application shall start on the building paper. Building paper so used shall be removed and disposed of satisfactorily. Burning of building paper will not be permitted within the right-of-way.

During application of asphaltic material, adjacent pavements, structures, and trees shall not be splattered with asphaltic material. The distributor shall not be cleaned or discharged into ditches, borrow pits, on shoulders or along the right-of-way.

Excess asphaltic material at the junction between distributor loads shall be removed and satisfactorily corrected. Areas of the surface to be treated which are not covered with asphaltic material directly from the distributor shall be covered by means of a hand-held spray bar equipped with nozzles.

(b) Aggregates: Aggregate spreading operations shall begin immediately after the application of the asphaltic materials. Asphaltic material shall be covered with aggregate material within 3 minutes.

Aggregate shall be uniformly spread over the full width of asphaltic material with one or more passes of spreading equipment with the application being sharply defined at edges. Equipment shall not be driven on uncovered asphaltic material. When necessary to obtain uniform coverage, the surface shall be hand broomed. The spread rate shall be established and checked during the first distributor application.

Hand spreading will be permitted in conjunction with self-propelled spreaders over areas inaccessible to spreaders. Asphaltic material shall be covered with the appropriate rate of aggregate before rolling is allowed.

(c) Multiple Applications: When multiple applications are to be placed, a minimum of 24 hours shall elapse between the application of each successive treatment.

507.07 ROLLING COVER MATERIAL. Immediately after spreading and brooming cover material, the surface shall be rolled with a power roller. Rolling shall proceed in a longitudinal direction, beginning at outer edges of the application. Each pass shall overlap the previous pass by 1/2 the roller width. The first rolling shall be completed within 1/2 hour after cover material has been spread. Deficiencies or damage in the aggregate cover detected during rolling shall be immediately corrected and rerolled as directed. Rolling cover material shall be continued until uniform coverage has been obtained. The remaining applications shall be rolled as specified for the first application.

507.08 PROTECTION. Traffic shall not be allowed on the surface until the aggregate has been placed and rolled. Each treatment shall be lightly broomed the next morning to remove loose aggregate.

When directed, the surface, shall be lightly broomed to remove loose material or otherwise maintained for 4 days. Maintenance of the surface shall include the distribution of aggregate material over the surface to absorb any free asphalt, covering any area deficient with aggregate material, and additional rolling as directed at no direct pay. Maintenance shall be conducted not to displace imbedded material. Excess material shall be swept from the entire surface by means of rotary brooms at the time determined.

When expanded clay aggregate is used, a vacuum sweeper without the sweeper engaged will be required to remove loose aggregate when a dusting problem occurs. Loose aggregate material will not be permitted on the surface during the 4-day maintenance period. Loose aggregate shall be removed and discarded by the contractor.

507.09 MEASUREMENT. The quantities of asphaltic material and aggregate incorporated in the completed and accepted asphaltic surface treatment will be measured separately. Aggregates will be measured by the square yard and asphaltic material will be measured by the gallon. Design quantities are based on horizontal dimensions. Design quantities will be adjusted when the engineer makes changes to adjust to field conditions. Each size aggregate will be measured by the square yard per application. Asphaltic material will be measured in the distributor by the gallon converted to gallons at 60°F in accordance with DOTD TR 321.

507.10 PAYMENT. Payment for placement and maintenance of asphaltic material and aggregates will be made at the contract unit prices, subject to the payment adjustment provisions of Section 1002 for specification deviations of asphaltic materials. The Materials and Testing Section will provide the payment adjustment percentage for asphaltic materials.

Payment will be made under:

Item No.	Pay Item	Pay Unit
507(01)	Asphaltic Material (Type)	Gallon
507(02)	Aggregate (Size)	Square Yard

TABLE 5
ASPHALTIC SURFACE TREATMENT (AST) REQUIREMENTS

TYPE AST	TYPE A[1]		TYPE B[1]		TYPE C[1]	TYPE D					
AGG. FRICTION RATING	I, II		I, II, III		I, II, III, IV	I, II, III, IV					
ASPHALTIC MATERIALS	CRS-2P		CRS-2P or CRS-2L		CRS-2P	CRS-2			CRS-2P or CRS-2L		
APPLICATION TEMP.											
MINIMUM	160°F		160°F		160°F	125°F			160°F		
MAXIMUM	175°F		175°F		175°F	175°F			175°F		
NUMBER OF APPLICATIONS	2	1	2	1	1	3	2	1	3	2	1
ASPHALTIC MATERIALS[2] 1	0.38	0.40	0.38	0.30	0.40	0.50	0.45	0.35	0.45	0.38	0.30
Application Rates 2	0.28	---	0.28	---	---	0.40	0.30	---	0.35	0.28	---
Per Course 3	---	---	---	---	---	0.30	---	---	0.25	---	---
AGGREGATE[3] 1	S2-0.0111	S2-0.0111	S2-0.0111	S3-0.0075	S2-0.0111	S1-0.0200	S2-0.0111	S3-0.0075	S1-0.0200	S2-0.0111	S3-0.0075
Application Rates 2	S3-0.0075	---	S3-0.0075	---	---	S2-0.0111	S3-0.0075	---	S2-0.0111	S3-0.0075	---
Per Course 3	---	---	---	---	---	S3-0.0075	---	---	S3-0.0075	---	---

[1]Only expanded clay, crushed slag or crushed stone shall be used for Types A, B or C Asphaltic Surface Treatment.
[2]Asphaltic material application rates are in gallons of asphaltic material at 60°F per square yard of AST.
[3]Size aggregate and application rates. For example, S2 is Size 2 aggregate and 0.0111 is the application rate in cubic yards of aggregate per square yard of AST.

Section 1003
Aggregates

1003.01 GENERAL: Aggregates shall be from an approved source. For a source to be approved, each sample shall conform to the requirements specified below and in the appropriate subsection. In addition to the test methods given in each subsection, the following methods shall be used in testing aggregates.

Property	Test Method
Deleterious Materials	DOTD TR 119
Foreign Matter in Shell	DOTD TR 109
Unit Weight	AASHTO T 19
Specific Gravity & Absorption of Fine Aggregate	AASHTO T 84
Specific Gravity and Absorption of Coarse Aggregate	AASHTO T 85
Polish Value	AASHTO T 278
Amount of Material Finer than the No. 200 Sieve	DOTD TR 112
Sieve Analysis (Gradation)	DOTD TR 113
Specific Gravity of Aggregate for Asphaltic Mixtures	DOTD TR 300
Liquid Limit and Plasticity Index	DOTD TR 428

When the No. 200 sieve is included in the gradation requirements, the results obtained by washing in accordance with DOTD TR 112 shall be added to that obtained by dry sieving in accordance with DOTD TR 113, unless otherwise specified.

(a) Source Approval:

(1) Soundness: The soundness loss of recycled portland cement concrete and aggregates listed in QPL 2 shall not exceed 15 percent when subjected to 5 cycles of the magnesium sulfate soundness test in accordance with AASHTO T 104.

(2) Abrasion: Coarse aggregate listed in QPL 2, and recycled portland cement concrete, except lightweight aggregate shall show an abrasion loss of not more than 40 percent when tested in accordance with AASHTO T 96.

Lightweight aggregate shall be expanded clay or expanded shale and shall show an abrasion loss of not more than 40 percent when tested in accordance with DOTD TR 111.

(3) Recycled portland cement concrete shall be approved in dedicated stockpiles and shall be free of asphaltic concrete overlay material, reinforcing steel, joint material, and other debris. After processing, recycled portland cement concrete shall conform to the requirements specified in the appropriate Subsections. When a stockpile has been approved no other material shall be added without prior approval.

(4) Reclaimed asphaltic pavement shall be cold planed in accordance with Section 509 or crushed. Reclaimed asphaltic concrete shall be approved either at the time of removal from the roadway or in stockpiles. Stockpiled materials shall be uniform and reasonably free of lightweight aggregate, asphaltic concrete friction course, debris, soil, and other foreign matter.

(5) During source approval, aggregates for use in portland cement concrete will be tested in accordance with ASTM C 33 Appendix XI for alkali reactivity properties. Aggregates found to be potentially reactive with cement alkalies will be restricted for use with cement or a combination of cement and fly ash containing 0.6 percent or less alkalies (sodium oxide equivalent).

Fine aggregate for portland cement concrete that produces a color darker than the Organic Color No. 3 when tested in accordance with AASHTO T 21, will be subjected to the mortar strength test in accordance with AASHTO T 71. The minimum compressive strength shall be at least 95 percent of the reference mortar compressive strength.

(b) Acceptance Testing: Acceptance of aggregates shall be based on compliance with the requirements shown in the following subsections provided the aggregates consistently conform to the requirements for source approval in Heading (a).

1003.05

1003.05 AGGREGATES FOR ASPHALTIC SURFACE TREATMENT. Aggregates for asphaltic surface treatment shall conform to Subsection 1003.01 and shall be either crushed gravel, crushed stone, crushed slag or lightweight aggregate and shall be assigned a Friction Rating in accordance with Subsection 1003.06(a). Aggregates shall conform to the gradation requirements in Table ~~X~~. 11.

Crushed gravel Size 1 and Size 2 shall have 60 percent minimum crushed retained on the No. 4 sieve. Crushed gravel Size 3 shall have 75 percent crushed retained on the No. 4 sieve. The percent crushed shall be determined in accordance with DOTD TR 306.

The maximum amounts of deleterious materials shall be as follows:

Property	Percent (Max.)
Clay Lumps	0.05
Total Clay Lumps and Friable Particles	3.0
Iron Ore	2.0
Glassy Particles in Slag	10.0
Flat or Elongated Particles	15.0
Coal and Lignite	1.0
Wood (Wet)	0.05
Total Clay Lumps and Friable Particles, Coal and Lignite, and Wood	5.0

TABLE 11
ASPHALTIC SURFACE TREATMENT AGGREGATES
PERCENT PASSING

	Size 1		Size 2	Size 3
U. S. Sieve	Slag or Stone Aggregate	Crushed Gravel or Lightweight Aggregate	All Aggregate	All Aggregate
1 1/2"	100	100	---	---
1"	90-100	95-100	---	---
3/4"	20-55	60-90	100	---
1/2"	0-10	---	90-100	100
3/8"	0-5	0-15	40-70	85-100
No. 4	---	0-5	0-15	10-40
No. 8	---	---	0-5	0-10
No. 16	---	---	---	0-5
No. 200	0-1	0-1	0-1	0-1

CHANDLER MATERIALS COMPANY
5805 EAST 15th STREET • TULSA, OKLAHOMA 74112-6404
TULSA (918) 836-9151 • FAX (918) 836-2002
PONCA CITY (405) 762-6601

12-23-96

To: John Ries, P. E.
Executive Director, ESCSI

From: Bill Martin, P. E.

Subject: Chip-Seal or Seal-Coat Specs

Dear John:

ODOT does not have a standard spec *for lightweight aggregate.* The ODOT Standard Specifications in the "Red Book" are written for normalweight aggregates, but may be modified slightly for each ESCS lightweight project. The maintenance department of each Division prepares a simple specification for an individual project.

A typical spec issued by a Division office could read similar to the following . . . . .

It shall comply with Section 703.02 - COVER AGGREGATES FOR BITUMINOUS SURFACE TREATMENTS, Subsections (b), (c), (d), and (f). Exceptions are:
Slivered shapes and coatings are not relevant to Chipping with lightweight aggregate. Absorbed moisture content is not relevant to Chipping with lightweight aggregate using emulsions.

The CRS-2 emulsion is normally used, with modified styrene CRS-2 sometimes used. If the old surface is in bad shape, it will be primed before application of the Chip-Seal. The local Koch Laboratory always develops the shot rate of the emulsion based on aggregate characteristics. If the old surface is going to be absorptive, the shot rate is usually 0.45 gal / sy. If it is not, the shot rate will be about 0.40.

The ODOT grade 3 aggregate size will be normally used:

	% passing
5/8"	100
1/2"	90-100
3/8"	40-75
#4	0-15
#8	0-5
#200	0-2
Dust Coating	0-1

The following wording has been used more than once by the Division offices of ODOT to differentiate ESCS from natural aggregates - -

> "Aggregate For Bituminous Surface Treatment (Lightweight) . . .
>
> Aggregates shall be composed of lightweight aggregate defined as aggregate prepared by expanding, calcining, or sintering. The dry loose unit weight of lightweight aggregate shall not be less than 35 pounds per cubic foot and shall not exceed 60 pounds per cubic foot."

The attached letter dated 12/18/96 from Ray Jordan, Tulsa County Engineer provides a brief outline of the County's 1996 lightweight seal coating program. The cover rate shown is high, but it includes waste *plus* some roads had two layers applied. The LITE-WATE aggregate is intentionally shipped damp.

Bill Martin

Tulsa County

County Engineer

A Department of the Board of County Commissioners
Tulsa County Administration Bldg. • 500 South Denver
Tulsa, Oklahoma 74103-3832 • (918) 596-5730

RAY JORDAN
COUNTY ENGINEER

December 18, 1996

Chandler Materials Company
5805 East 15th Street
Tulsa, Oklahoma 74112

ATTN: Mr. Bill Martin

Dear Mr. Martin:

Per your request, this office has reviewed Tulsa County's seal coating program completed this past summer. The following information is being provided for your review and use:

1. Materials used were lite wate aggregate provided by Chandler Materials and CRS-2-S emulsion provided by Koch Materials.

2. Tulsa County seal coated approximately 592,533 square yards of surface area, at an average cost of $0.76 per square yard which includes materials, labor and equipment.

I hope this information is useful. If further information is required, please feel free to contact this office.

Sincerely,

Ray Jordan

Ray Jordan

RJ:sc

xc: File

Standard Specifications

FOR

HIGHWAY CONSTRUCTION

OKLAHOMA
DEPARTMENT OF TRANSPORTATION

Edition of 1988

No. 6167

703.02. COVER AGGREGATES FOR BITUMINOUS SURFACE TREATMENTS.

(a) **Materials Covered.** This Section establishes the requirements for aggregate to be used in construction of bituminous surface treatment (Section 402):

(b) **General Requirements.** The aggregate for cover material shall consist of clean, sound and durable particles of mine chats, crushed gravel, or crushed stone. The cover material shall be of uniform quality throughout with not more than 5 percent of slate, shale or soft stone particles and shall be substantially free from organic matter, clay, loam, or objectionable coating. A minimum of 75 percent of the aggregate retained on the no. 4 sieve shall have 2 or more mechanically fractured faces.

The cover aggregate shall be reasonably dry when placed on the bituminous binder except when cationic emulsified asphalt is used.

After the work starts, the same kind of cover material shall be used throughout the project unless otherwise permitted in writing by the Engineer.

(c) **Physical Properties.** The cover aggregate shall conform to the following requirements:

Los Angeles Abrasion, % wear	40 max.
Durability, Dc Factor	40 min.
Flat or elongated pieces, % (length is greater than 5 times the average thickness)	15 max.

(d) **Gradation.** The gradation requirements for cover aggregates shall be as follows:

PERCENT PASSING

Sieve Size	No. 1 Aggregate	No. 2 Aggregate	No. 3 Aggregate
3/4 in.	100		
5/8 in.			100
1/2 in.	25-60	100	90-100
3/8 in.	0-15	90-100	40-75
No. 4	0-5	0-25	0-15
No. 8		0-5	0-5
No. 200	0-2	0-2	0-2
*Dust Coating	0-1	0-1	0-1

* Dust coating on aggregates retained on no. 8 sieve shall be determined by wash loss (AASHTO T 11) after dry sieving.

The specific gradation or gradations shall be as shown on the Plans or in the Proposal. The same kind of specified aggregates shall be used throughout the project unless otherwise permitted in writing by the Engineer.

(e) **Precoated Cover Aggregates.** When precoated material is specified, cover aggregate meeting the above Specification requirements shall be treated with bitumunious material meeting the requirements of Subsection 708.03. The application of bituminous material is to be within the range of 0.30 to 1.75 percent by weight of the untreated aggregate, depending on the type and grade of bituminous material applied. The quantity applied shall be sufficient

to satisfy the particular needs of surface absorption, dust dissipation and film coating of the aggregate to be treated. The coating shall be durable and free of scales and blisters. When applied to the road, it shall be free of excess binder or moisture which might hinder the handling, spreading or rolling operations. The producer shall obtain the approval of the Materials Engineer pertaining to the type, grade, and amount of asphalt treatment prior to starting production.

The producer shall consistently ascertain that the aggregate is free of surface or absorbed moisture which will interfere with binder absorption and adhesion, or cause blisters or subsequent scaling of the treatment. However, when it is advisable or necessary to facilitate uniform coating of the aggregate with the bituminous material, water may be added at the pugmill in an amount not to exceed 2 percent by weight of the aggregate. When heating is required, or elected by producer, he shall maintain the bituminous materials at temperatures below the flash points or damaging temperatures. The temperatures of asphalt materials shall be within the mixing range for the particular type and grade as shown in Subsection 708.03(c) during application of the asphalt material to the aggregate.

Flow quantities of the treated aggregate shall be such that it may be satisfactorily spread by approved mechanical spreading devices.

The required percent of asphalt for precoating the aggregate shall be determined by inspection of the type and grade of bituminous material and aggregate used.

(f) **Sampling and Testing.** Sampling and testing shall be conducted in accordance with the following AASHTO methods except as noted:

Sampling	T 2
Sieve Analysis	T 27
Los Angeles Abrasion	T 96
Dust Coating (Plus no. 8 material after dry sieving)	T 11
Durability, Dc Factor	T 210
Soft Particles	OHD L-38
Fractured Faces	OHD L-18

703.03. AGGREGATES FOR TRAFFIC BOUND SURFACE COURSE.

(a) **Materials Covered.** This Subsection covers the requirements and test methods for aggregates to be used in the construction of traffic bound surface course in Section 403.

(b) **General Requirements.** Traffic bound surface course material shall consist of an intimate mixture of graded aggregate, coarse and fine, and shall be practically free from vegetation or other deleterious substances. Coarse aggregate, material retained on a no. 10 sieve, shall consist of sound, tough, durable particles or fragments of gravel, stone, mine chats, disintegrated granite, or combination thereof, crushed to size if necessary. Fine aggregate shall consist of sand, stone dust, or other inert finely divided mineral matter.

(c) **Physical Properties.** The coarse aggregate retained on the 3/8 inch sieve of the finished mixture shall not have a percent wear of more than 40 when tested in accordance with the Los Angeles Abrasion Test.

Texas
Department
of Transportation

STANDARD SPECIFICATIONS FOR CONSTRUCTION AND MAINTENANCE OF HIGHWAYS, STREETS, AND BRIDGES

Adopted by the
Texas Department of Transportation

March 1, 1995

(2) **Storage and Heating of Precoating Material or Fluxing Material.** The precoating or fluxing material storage shall be ample to meet the requirements of the plant. The precoating material shall not be heated in storage above the maximum temperature set forth in Item 300, "Asphalts, Oils and Emulsions". All equipment used in the storage and handling of pre al or fluxing material shall be kept in a clean condition all be operated in such manner that there will be no cont ign matter.

(3) **H of Aggregate.** The feeding of various sizes of aggreg ural limestone rock asphalt, to the dryer or drum mixer through the cold aggregate bin and proportioning dev er that a uniform and constant flow of material in the requ ll be maintained. The aggregate shall be heated to the ten to produce a mixture meeting the requirements of Suba.

(4) **Proportion.** oning of the various materials entering into the mixtur cted by the Engineer and in accordance with these spec ate shall be proportioned by mass using the weigh box herein specified when the weigh-batch type of plant i ume using the aggregate proportioning device when the tch type, the continuous mixer type or drum mix plant oat material or fluxing material shall be proportioned by based on mass using the specified equipment.

(5) **Mixing.**

(a) **Weigh-Batch Type and Mo h Type Mixer.** In the charging of the weigh box and in t mixer from the weigh box, such methods or devices shall b ary to secure a uniform mixture. In introducing the batc e aggregate shall be introduced first; shall be mixed ected, to uniformly distribute the various sizes throug fore the precoat material or fluxing material is added; the fluxing material shall then be added and the mixing cont e that the aggregate is properly coated. This mixing per f, in the opinion of the Engineer, the mixture is not unif

(b) **Continuous or Drum Mix Type Mixe** of aggregate and precoat material or fluxing material ente mixer and the rate of travel through the mixer shall be so coordinated that a uniform mixture of the sp᾿ ᾿ng and percent by mass of precoat material or fluxing mater᾿ ed.

302.7. ı. ᾿ **Payment.** Aggregates provided in accordance with tı. ᾿vill be measured and paid for in accordance with the ᾿ ..ications for the items of construction in which these materials ..ı.

ITEM 303

AGGREGATE FOR SURFACE TREATMENTS (Lightweight)

303.1. Description. This Item shall govern for lightweight aggregate and precoated lightweight aggregate used in the construction of surface treatments.

303.2. Materials.

(1) **Aggregate.** Aggregate shall be composed of lightweight aggregate, defined as expanded shale, clay or slate produced by the rotary kiln method.

The dry loose unit weight of lightweight aggregate shall not be less than 560 kilograms per cubic meter and shall not exceed 960 kilograms per cubic meter unless otherwise shown on the plans. Furthermore, a shipment of lightweight aggregate shall be rejected if the dry loose unit weight of the shipment differs by more than 6 percent from that of the sample submitted for acceptance tests from that source. Tests shall be in accordance with Test Method Tex-404-A, Part C, and shall be performed on a sample of similar gradation to that of the acceptance sample.

The aggregate shall not contain more than 1.0 percent by mass of fine dust, clay-like particles and/or silt when tested in accordance with Test Method Tex-217-F, Part II.

The percentage of wear shall not exceed 35 percent when the aggregate is tested in accordance with Test Method Tex-410-A.

The freeze-thaw loss shall not exceed 7.0 percent when the aggregate is tested in accordance with Test Method Tex-432-A.

The pressure slaking value shall not exceed 4.0 percent when the aggregate is tested in accordance with Test Method Tex-431-A.

The water absorption in 24 hours shall not exceed 12.0 percent unless otherwise shown on the plans when the aggregate is tested in accordance with Test Method Tex-433-A.

The polish value for the aggregate used in the surface or finish course shall not be less than the value shown on the plans, when tested in accordance with Test Method Tex-438-A. Unless otherwise shown on the plans, the polish-value requirement will apply only to aggregate used on travel lanes. When aggregates requiring polish value are supplied from a source that is rated by the Materials and Tests Division, the Rated Source Polish Value (RSPV) for that source will be used to meet this requirement. When aggregates are supplied from a source that is not rated, the aggregate will be sampled and tested prior to use. The procedures will be in accordance with Test Methods Tex-400-A and Tex-438-A, Part I.

If blending aggregate from two or more sources, material from each source shall meet the requirements of this Item.

(2) **Precoated Aggregate.** Precoated aggregate shall be aggregate of the type and grade specified, coated with 0.5 to 3.0 percent, by mass, of residual bitumen from the precoating material.

The grade of aggregate specified shall meet all requirements of Article 303.2 and 303.4 prior to the application of the precoat material.

The materials may be mixed on the job or at a central mixing plant and shipped ready for use. Mixes that do not maintain flow qualities such that the precoated aggregate may be satisfactorily spread by approved mechanical spreading devices will not be acceptable.

Materials that are not uniformly and/or properly coated, in the opinion of the Engineer, will not be accepted for use.

(3) **Asphaltic Material.** The precoating material shall meet the requirements of Item 300, "Asphalts, Oils and Emulsions". Unless otherwise shown on the plans, any of the types and grades shown in Item 300, "Asphalts, Oils and Emulsions", may be used.

303.3. Types. The aggregate types are identified as follows:

Type L. Type L shall consist of lightweight aggregate.
Type PL. Type PL shall consist of precoated lightweight aggregate.

303.4. Grades. When tested by Test Method Tex-200-F, Part I, the gradation requirements shall be as follows:

		Percent by Mass
Grade 3:	Retained on 19.0 mm sieve	0
	Retained on 16.0 mm sieve	0 - 2
	Retained on 12.5 mm sieve	10 - 25
	Retained on 9.5 mm sieve	60 - 80
	Retained on 6.3 mm sieve	95 - 100
	Retained on 2.00 mm sieve	98 - 100
Grade 4:	Retained on 16.0 mm sieve	0
	Retained on 12.5 mm sieve	0 - 5
	Retained on 9.5 mm sieve	20 - 40
	Retained on 4.75 mm sieve	95 - 100
	Retained on 2.00 mm sieve	98 - 100
Grade 5:	Retained on 12.5 mm sieve	0
	Retained on 9.5 mm sieve	0 - 2
	Retained on 4.75 mm sieve	60 - 80
	Retained on 2.00 mm sieve	98 - 100

303.5. Equipment. Equipment shall meet the requirements of Article 302.5, except that other equipment which will consistently produce satisfactory results will be allowed.

303.6. Storage, Proportions and Mixing. Storage, proportions, and mixing shall meet the requirements of Article 302.6.

303.7. Measurement and Payment. Aggregates provided in accordance with this specification will be measured and paid for in accordance with the governing specifications for the items of construction in which these materials are used.

2. **Materials.** All materials shall conform to the pertinent of the following Items:

m 204, "Sprinkling"
300, "Asphalts, Oils and Emulsions"

emulsified asphalt in the mixture, expressed as a perc total mixture, shall be within the limits and shall be of hown on the plans.

3. **Methods.** Unless otherwise permitted by the Engineer, seals shall not be applied when the air temperature falling, but may be applied when the air temperature is sing, the air temperature being taken in the shade and a eat. Asphaltic material shall not be placed when gener , in the opinion of the Engineer, are not suitable.

The emulsified ixture shall be applied by an approved self-propelled p operated as to distribute the material at the rate directe venly and smoothly, under a pressure necessary for prop

The Contractor shall prov ilities and equipment for determining the temperature terial in all of the heating equipment and in the distrib the rate at which it is applied, and for securing unit on of two (2) distributor loads.

The distributor tank, when used for have been calibrated within three (3) years from the date project. The tank calibration procedure shall be in acc Method Tex-922-K, Part I, and shall be signed and tered professional engineer. Unless otherwise shown on t tor shall provide the tank calibration record and shall fu n accurate and satisfactory calibration record prior to t The Engineer may at any time verify calibration accur with Test Method Tex-922-K, Part II, and may perfo recalibration if the calibration is found to be in error.

The Engineer will select the temperature of applica Contractor shall apply the emulsified asphalt mixture at a temperatu hin 8°C of the temperature selected.

The treated surface shall be opened to traffic when directed by the Engineer.

315.4. Measurement. This Item will be measured by the liter of emulsified asphalt used in the emulsified asphalt and water mixture.

315.5. Payment. The work performed and the materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Emulsified Asphalt Seal" of the type and grade specified. This price shall be full compensation for furnishing all required materials, including mixing water for application; for all hauling, mixing, heating, and distributing the mixture as specified; and for all manipulation, tools, labor, equipment and incidentals necessary to complete the work.

ITEM 316

SURFACE TREATMENTS

316.1. Description. This Item shall govern for the construction of a surface treatment composed of a single, double or triple application of asphaltic material, each covered with aggregate, constructed on existing pavements or on the prepared base course or surface in accordance with these specifications. This Item shall also govern for the furnishing of Aggregates (Stockpiled). Quantities for the different types of surfaces and materials will be as shown on the Basis of Estimate in the plans.

316.2. Materials. All materials shall be of the type(s) and grade(s) shown on the plans and shall conform to the pertinent material requirements of the following Items:

Item 300, "Asphalts, Oils and Emulsions"
Item 302, "Aggregate for Surface Treatments"
Item 303, "Aggregate for Surface Treatments (Lightweight)"

316.3. Equipment.

(1) Distributor. The distributor shall be a self-propelled pressure type, equipped with an asphaltic material heater and a distributing pump capable of pumping the material at the specified rate through the distributor spray bar. The distributor spray bar shall be capable of fully circulating the asphaltic material. The distributor spray bar shall contain nipples and valves so constructed that the nipples will not become partially plugged with congealing asphaltic material, in order to prevent streaking or irregular distribution of asphaltic material. Distributor equipment shall include a tachometer, pressure gauges, volume measuring devices, and a thermometer for reading the temperature of tank contents.

The distributor tank, when used for pay purposes, shall have been calibrated within three (3) years from the date it is first used on this project. The tank calibration procedure shall be in accordance with Test Method Tex-922-K, Part I, and shall be signed and sealed by a registered professional engineer. Unless otherwise shown on the plans, the Contractor shall provide the tank calibration and shall furnish the Engineer an accurate and satisfactory calibration record prior to beginning the work. The Engineer may at any time verify calibration accuracy in accordance with Test Method Tex-922-K, Part II, and may perform the required recalibration if the calibration is found to be in error.

When a uniform application of asphaltic material is not being achieved, the Engineer may require that the spray bars on the distributor be controlled by an operator riding in such a position at the rear of the distributor that the operation of all sprays is in full view.

(2) **Aggregate Spreader.** A self-propelled continuous-feed aggregate spreader shall be used which will uniformly spread aggregate at the rate specified by the Engineer.

(3) **Rollers.** Rolling equipment shall meet the governing specifications for Item 210, "Rolling (Flat Wheel)" and Item 213, "Rolling (Pneumatic Tire)".

(4) **Broom.** The broom shall be a rotary, self-propelled power broom for cleaning existing surfaces.

(5) **Asphalt Storing and Handling Equipment.** All equipment used in storing or handling asphaltic material shall be kept clean and in good operating condition at all times and shall be operated in such a manner that there will be no contamination of the asphaltic material. The Contractor shall provide and maintain a recording thermometer to continuously indicate the temperature of the asphaltic material at the storage heating unit when storing of asphalt is permitted.

(6) Vehicles used for hauling aggregate shall be of uniform capacity unless otherwise authorized by the Engineer.

316.4. Construction Methods.

(1) **General.** Temporary stockpiling of aggregates on the right of way will be permitted, provided that the stockpiles are so placed as to allow for the safety of the traveling public and not obstruct traffic or sight distance, and do not interfere with access from abutting property, nor with roadway drainage.

The aggregate placement sites will be subject to the approval of the Engineer.

Location of stockpiles shall be either a minimum of ten (10) meters from the edge of the travel lanes or shall be signed and barricaded as shown on the plans.

When shown on the plans, the Department will furnish aggregate to the Contractor without cost for designated sections of the project. The aggregate will be in stockpiles at locations or within limits shown on the plans. The Contractor shall load, haul, distribute and apply the stockpiled aggregate in accordance with specification requirements governing for this Item. The stockpile areas and remaining stockpiles shall be left in a neat condition satisfactory to the Engineer.

Surface treatments shall not be applied when the air temperature is below 15°C and is falling, but may be applied when the air temperature is above 10°C and is rising, the air temperature being taken in the shade and away from artificial heat. Surface treatments shall not be applied when the temperature of the surface on which the surface treatment is to be applied is below 15°C. When latex modified asphalt cement is specified, surface treatments shall not be applied when the air temperature is below 25°C and is falling, but may be applied when the air temperature is above 20°C and is rising and shall not be applied when the temperature of the surface on which the surface treatment is to be applied is below 20°C. When cutback asphalt or asphaltic materials designed for cool weather placement are used, application may occur whenever the air and surface temperatures are acceptable to the Engineer. Asphaltic material shall not be placed when general weather conditions, in the opinion of the Engineer, are not suitable.

The area to be treated shall be cleaned of dirt, dust or other deleterious matter by sweeping or other approved methods. If it is found necessary by the Engineer, the surface shall be lightly sprinkled with water just prior to the first application of asphaltic material.

The rates shown on the plans for asphalt and aggregate are for estimating purposes only. The rates may be varied as directed by the Engineer.

The Engineer will select the temperature of application within the limits recommended in Item 300, "Asphalts, Oils and Emulsions". The Contractor shall apply the asphalt at a temperature within 8°C of the temperature selected.

The width of each application of asphaltic material shall be such to allow uniform application and immediate covering with aggregate. The Contractor shall be responsible for uniform application of asphaltic material at the junction of distributor loads. Paper or other suitable material shall be used to prevent overlapping of transverse joints. Longitudinal joints shall match lane lines unless otherwise authorized by the Engineer. Application of asphaltic material will be measured as necessary to determine the rate of application.

The finished surface shall be cleared of any surplus aggregate by the Contractor by sweeping or other approved methods after all rolling is completed.

Prior to final acceptance of the project, aggregate stockpiles deemed undesirable by the Engineer shall be removed by the Contractor. The temporary stockpile areas shall be left in a neat condition satisfactory to the Engineer. Aggregate stockpiles remaining on the State's right of way 30 days after the final acceptance of the project will become the property of the Texas Department of Transportation.

When plans include "Aggregate (Stockpiled)", aggregate(s) of the type(s) and grade(s) specified shall be stockpiled within the limits of the project at sites designated by the Engineer.

(2) **One Course Surface Treatments or First Course of a Multiple Surface Treatment.** Asphaltic material shall be applied by an approved distributor so operated as to distribute the material under a pressure necessary for uniform distribution.

The Contractor shall protect the existing raised pavement markers by any means acceptable to the Engineer for one course surface treatments, unless otherwise shown on the plans.

Aggregates shall be immediately and uniformly applied and spread by the specified aggregate spreader, unless otherwise authorized by the Engineer.

After applying the aggregate, the entire surface shall then be broomed, bladed or raked as required by the Engineer and shall be thoroughly rolled with the type or types of rollers specified herein or as shown on the plans.

The Contractor shall be responsible for the maintenance of the surface treatment until the work is accepted by the Engineer. All holes or failures in the surface shall be repaired by use of additional asphalt and aggregate. All fat or bleeding surfaces shall be covered with approved cover material in such a manner that the asphaltic material will not adhere to or be picked up by the wheels of vehicles.

(3) **Two Course or Three Course Surface Treatments.** It is the intent of this specification that the application of asphalt and aggregate for multiple courses be applied within the same day or immediately thereafter and prior to opening the roadway to traffic.

The asphaltic material for each course of the surface treatment shall be applied and covered with aggregate in the same manner specified for the first application. Each surface shall then be broomed, bladed or raked as required by the Engineer and thoroughly rolled as specified for the first course. Asphaltic material and aggregate for each course shall be applied at the rates directed by the Engineer.

The Contractor shall be responsible for the maintenance of each course until covered by the succeeding courses or until the work is accepted by the Engineer. All holes or failures in the surface shall be repaired by use of additional asphalt and aggregate. All fat or bleeding surfaces shall be covered with approved cover material in such a manner that the asphaltic material will not adhere to or be picked up by the wheels of vehicles.

316.5. Measurement.

(1) **Asphaltic Material.** Asphaltic material will be measured as follows and as specified on the plans.

(a) **Volume.** Asphaltic material will be measured at point of application on the road in liters at the applied temperature. The quantity to be measured for payment shall be the number of liters used, as directed, in the accepted surface treatment.

(b) Mass. Asphaltic material will be measured in megagrams at the point of origin. Weighing will be done by a certified public weigher and the transporting vehicle shall have a seal attached to the draining device and other openings. At the Contractor's expense, the Engineer may require random checking by reweighing on public scales to verify mass accuracy. An asphalt storage tank shall not be permitted unless approved by the Engineer. If an asphalt storage tank is used, the Contractor shall provide an acceptable means of measuring the amount of asphaltic material received to assure that all material measured at the point of origin is received and used on the project. Upon completion or temporary suspension of the prescribed work, any remaining asphaltic material will be weighed by a certified public weigher or shall be measured by volume in a calibrated distributor or calibrated tank and the quantity converted to megagrams with respect to the measured temperature. The quantity to be measured for payment shall be the number of megagrams received minus the number of megagrams remaining after all directed work is complete and minus the amount used for other items.

(2) Aggregates. Aggregate will be measured by the cubic meter in vehicles as applied on the road.

Aggregate (Stockpiled), if required to be furnished, will be measured by the cubic meter of material in vehicles at the point of stockpiling or by the cubic meter in the stockpile as computed by the method of average end areas.

When "Loading, Hauling and Distributing Aggregate" is a bid Item, it will be measured by the cubic meter in vehicles as applied on the road.

316.6. Payment. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit prices bid for "Asphalt", "Aggregate" and "Aggregate (Stockpiled)", if required, of the type and grade specified. These prices shall each be full compensation for cleaning and sprinkling the existing surface; for furnishing, preparing, hauling, and placing all materials; for protecting existing pavement markers; for rolling, removing excess aggregate, and cleaning up stockpiles; for all freight and heating involved; and for all manipulations, labor, tools, equipment and incidentals necessary to complete the work.

When "Loading, Hauling and Distributing Aggregate" is a bid Item, the work performed and measured as provided for herein will be paid for at the unit price bid for "Loading, Hauling, and Distributing Aggregate". This price shall be full compensation for loading, hauling, applying and distributing aggregate; for protecting existing pavement markers; for rolling, removing excess aggregate, and cleaning up stockpiles; and for all manipulation, labor, tools, equipment and incidentals necessary to complete the work.

When "Driveways and Turnouts" is included in the contract as a bid Item, the work performed and materials furnished for driveways and turnouts will be paid for in accordance with Item 530, "Driveways and Turnouts".

ITEM 318

HOT ASPHALT-RUBBER SURFACE TREATMENTS

318.1. Description. This Item shall govern for the construction of a surface treatment composed of a single or double application of hot asphalt-rubber material, each covered with aggregate, constructed on existing pavements or on the prepared base course or surface in accordance with these specifications.

318.2. Materials. All materials shall conform to the pertinent material requirements of the following Items:

Item 300, "Asphalts, Oils and Emulsions"
Item 302, "Aggregate for Surface Treatments"
Item 303, "Aggregate for Surface Treatments (Lightweight)"

(1) Asphaltic Materials.

(a) Asphalt Cement. The asphalt cement shall be of the type and grade shown on the plans or designated by the Engineer.

(b) Tack Coat. Cut-back asphalt may not be diluted with gasoline and/or kerosene. Emulsions may be diluted with the addition of water, with the approval of the Engineer.

= Total mass of limestone rock asphalt mixture in kilograms
Average actual specific gravity of three molded specimens as prepared by Test Method Tex-206-F ›nd determined in accordance with Test Method Tex-`7-F

Y ς of water and light hydrocarbon volatiles in ıms in excess of 4.0 percent of total mass of ıme of weighing

332.8. ı

(1) The wor. naterials furnished in accordance with this Item and measure der "Measurement" will be paid for at the unit price bid for ʾock Asphalt Pavement (Class B)" of the type specified.

Measurement Method		Unit of Measure
Mass	Lin. Asph. ss B)	Megagram
Volumetric	Limeston. Asphalt Pa	Cubic Meter

The payment, based on the unit bid price ›pensation for quarrying, furnishing all materials, additives, 'ved; for all heating, mixing, hauling, cleaning the existing ›avement, tack coat, placing limestone rock asphalt mixture, . ·ng; and for all manipulations, labor, tools, equipment and . ary to complete the work.

(2) All templates, straightedges, scales and oth measuring devices necessary for the proper construction, checking of the work shall be furnished, operated and main Contractor at his expense.

ITEM 334

HOT MIX-COLD LAID ASPHALTIC CONCRETE PAVEMENT

334.1. Description. This Item shall govern for the construction of a base course, a level-up course, a surface course or any combination of these courses as shown on the plans, each course being composed of a compacted mixture of aggregate and asphaltic material mixed hot in a mixing plant, in accordance with the details shown on the plans and the requirements herein.

The mixture covered by this Item has been designed for cold placement. Should the placement temperature of the mixture be 79°C or greater, the mixture is not considered as being placed cold and shall be designed, mixed, placed and compacted in accordance with Item 340, "Hot Mix Asphaltic Concrete Pavement", to include any applicable requirements for the use of reclaimed asphalt pavement.

334.2. Materials. The Contractor shall furnish materials to the project meeting the following requirements prior to mixing. Additional test requirements affecting the quality of individual materials or the paving mixture shall be required when indicated on the plans.

(1) **Aggregate.** The aggregate shall be composed of a coarse aggregate, a fine aggregate, and if required or allowed, a mineral filler. Samples of each aggregate shall be submitted for approval in accordance with Item 6, "Control of Materials".

Aggregate from each stockpile shall meet the quality requirements of Table 1 and other requirements as specified herein.

(a) **Coarse Aggregate.** Coarse aggregate is defined as that part of the aggregate retained on a 2.00 millimeter sieve. The aggregate shall be natural, lightweight or manufactured, and be of uniform quality throughout. When specified on the plans, certain coarse aggregate material may be allowed, required or prohibited.

Lightweight aggregate is defined as expanded shale, clay or slate produced by the rotary kiln method. Manufactured aggregate is defined as any aggregate other than natural or lightweight.

Lightweight or manufactured materials with the same or similar gradation, whose unit weight vary by more than 6.0 percent from that used in the mixture design, may require a redesign.

Gravel from each source shall be so crushed as to have a minimum of 85 percent of the particles retained on the 4.75 millimeter sieve with two or more mechanically induced crushed faces, as determined by Test Method Tex-460-A (Part I). The material passing the 4.75 millimeter sieve and retained on the 2.00 millimeter sieve must be the product of crushing aggregate that was originally retained on the 4.75 millimeter sieve.

The polish value for the coarse aggregate used in the surface or finish course shall not be less than the value shown on the plans, when tested in accordance with Test Method Tex-438-A. Unless otherwise shown on the plans, the polish value requirement will apply only to aggregate used on travel lanes. For rated sources, the Materials and Tests Division's Rated Source Polish Value (RSPV) catalog will be used to determine polish value compliance. Unless otherwise shown on the plans, coarse aggregates may be blended in accordance with Test Method Tex-438-A, Part II, Method B, to meet the polish value requirement. When blending is allowed, the blended aggregates shall contain non-polishing aggregates of not less than the percent by volume of the critical size shown below for the specified mixture.

	Type C	Type D	Type F
Retained on the 4.75 mm sieve	50%	50%	
Retained on the 2.00 mm sieve			50%

(b) Fine Aggregate. The fine aggregate is defined as that part of the aggregate passing the 2.00 millimeter sieve and shall be of uniform quality throughout. When specified on the plans, certain fine aggregate material may be allowed, required or prohibited. However, a maximum of 15 percent of the total aggregate may be field sand or other uncrushed fine aggregate.

Screenings shall be supplied from sources whose coarse aggregate meets the Los Angeles abrasion and magnesium sulfate soundness loss requirements shown in Table 1, unless otherwise shown on the plans.

1. Unless otherwise shown on the plans, stone screenings are required and shall be the result of a rock crushing operation and meet the following gradation requirements, when tested in accordance with Test Method Tex-200-F, Part I.

	Percent by Mass
Passing the 9.5 mm sieve	100
Passing the 2.00 mm sieve	70-100
Passing the 75 μm sieve	0-15

2. Crushed gravel screenings may be used with, or in lieu of, stone screenings when shown on the plans. Crushed gravel screenings must be

the product of crushing aggregate that was originally retained on the 4.75 millimeter sieve and meet the gradation for stone screenings shown above.

(c) **Mineral Filler.** Mineral filler shall consist of thoroughly dried stone dust, portland cement, lime, fly ash, or other mineral dust approved by the Engineer. The mineral filler shall be free from foreign matter.

When a specific type of mineral filler is specified on the plans, fines collected by the baghouse or other air cleaning or dust collecting equipment shall not be used to meet this requirement. When mineral filler is not specifically required, the addition of baghouse or other collected fines will be permitted if the mixture quality is not adversely affected in the opinion of the Engineer. In no case shall the amount of material passing the 75 micrometer sieve exceed the tolerances of the job-mix formula or the master gradation limits.

When mineral filler is specified or allowed by the Engineer, or baghouse fines are permitted to be added to the mixture, it shall be proportioned into the mix by a vane meter or an equivalent measuring device acceptable to the Engineer. A hopper or other acceptable storage system shall be required to maintain a constant supply of mineral filler to the measuring device.

The measuring device for adding mineral filler shall be tied into the automatic plant controls so that the supply of mineral filler will be automatically adjusted to plant production and provide a consistent percentage to the mixture. When shown on the plans, the measuring device for adding baghouse fines shall have controls in the plant control room which will allow manual adjustment of feed rates to match plant production rate adjustments.

When tested in accordance with Test Method Tex-200-F (Part I or Part III, as applicable), the mineral filler shall meet the following gradation requirements, unless otherwise shown on the plans. Baghouse fines are not required to meet the gradation requirements.

	Percent by Mass or Volume
Passing the 600 μm sieve	95-100
Passing the 180 μm sieve, not less than	75
Passing the 75 μm sieve, not less than	55

TABLE 1
AGGREGATE
QUALITY REQUIREMENTS *

Requirement	Test Method	Manufactured or Natural Aggregate	Lightweight Aggregate
COARSE AGGREGATE			
Dry Loose Unit Weight, kg/m^3 minimum	Tex-404-A	-	560
Pressure Slaking Value, maximum	Tex-431-A	-	4.0
Freeze Thaw Loss, percent, max.	Tex-432-A	-	7.0
24 Hour Water Absorption, percent, maximum	Tex-433-A	-	12.0
Deleterious Material, percent, maximum	Tex-217-F Part I	1.5	1.5
Decantation, percent, maximum	Tex-217-F Part II	1.5	1.5
Los Angeles Abrasion, percent, maximum	Tex-410-A	40	35
Magnesium Sulfate Soundness Loss, 5 cycle, percent, maximum	Tex-411-A	30**	-
FINE AGGREGATE			
Linear Shrinkage, maximum	Tex-107-E Part II	3	3
COMBINED AGGREGATES * **			
Sand Equivalent Value, minimum	Tex-203-F	45	45

* Sampled during delivery to the plant or from the stockpile, unless otherwise shown on the plans.

** Unless otherwise shown on the plans.

*** Aggregates, without added mineral filler, or additives, combined as used in the job-mix formula.

(2) **Asphaltic Material.**

(a) **Paving Mixture.** Asphalt for the paving mixture shall be of the type shown on the plans or designated by the Engineer and shall meet the requirements of Item 300, "Asphalts, Oils and Emulsions". The Contractor shall notify the Engineer of the source of the asphaltic material prior to design of the asphaltic mixture. This source shall not be changed during the course of the project without the authorization of the Engineer. Should the source of asphaltic material be changed, the moisture resistance of the new material combination will be evaluated to verify that the requirements of Subarticle 334.3(1) are met.

(b) **Primer.** Asphalt primer shall be a blend of asphalt cement and hydrocarbon volatiles meeting with the approval of the Engineer.

(c) **Tack Coat.** Asphaltic materials, shown on the plans or approved by the Engineer, shall meet the requirements of Item 300, "Asphalts, Oils and Emulsions".

(3) **Additives.** Additives to facilitate mixing and/or improve the quality of the asphaltic mixture or tack coat shall be used when noted on the plans or may be used with the authorization of the Equipment.

Unless otherwise shown on the plans, the Contractor may choose to use either lime or a liquid antistripping agent to reduce the moisture susceptibility of the aggregate. The evaluation and addition of antistripping agents will be in accordance with Item 301, "Asphalt Antistripping Agents".

334.3. Paving Mixtures. The paving mixtures shall consist of a uniform mixture of aggregate, asphaltic material, and primer, additives and water if allowed or required. The materials may be mixed on the job or at a central mixing plant and shipped ready to use. Mixtures that do not remain workable a sufficient period of time to permit loading, unloading, hauling, placing, and compacting will not be acceptable.

An asphalt mixture design is a laboratory process which includes the determination of the quality of the asphaltic materials and the individual aggregates, the development of the job-mix formula, and the testing of the combined mixture.

The job-mix formula lists the quantity of each component to be used in the mix and the combined gradation of the aggregates used.

(1) **Mixture Design.** The Contractor shall furnish the Engineer with representative samples of the materials to be used in production. Using these materials, the mix shall be designed by the Engineer in accordance with Test Method Tex-204-F to conform with the requirements herein. The amount of primer and water, if allowed or required, will be selected by the Engineer to meet the other mix requirements. The Engineer may accept a design from the Contractor which was derived using these design procedures.

The second and subsequent mixture designs, or partial designs, for each type of paving mixture which are necessitated by changes in the material or at the request of the Contractor will be charged to the Contractor when a rate is shown on the plans.

The bulk specific gravity will be determined for each aggregate to be used in the design mixture. If the determined values vary by 0.300 or more, the Volumetric Method, Test Method Tex-204-F, Part II, will be used.

When properly proportioned for the type specified, the blend of aggregates shall produce an aggregate gradation which will conform to the limits of the master grading shown in Table 2. Unless otherwise shown on the plans, the gradation of the aggregate will be determined in accordance with Test Method Tex-200-F, Part I (Dry Sieve Analysis), to develop the job-mix formula.

The master grading limits for the appropriate type and the proposed job-mix formula will be plotted on a gradation chart with sieve sizes raised to the 0.45 power. This plot must show that the proposed job-mix formula is within the limits of the master grading. Gaps in gradation shown by this plot should be avoided.

The voids in the mineral aggregate (VMA) will be determined as a mixture design requirement only, in accordance with Test Method Tex-207-F, and shall not be less than the value indicated in Table 2.

Unless otherwise shown on the plans, the mixture of aggregate, asphaltic material and additives proposed for use will be evaluated in the design stage for moisture susceptibility, in accordance with Item 301, "Asphalt Antistripping Agents". The Engineer may waive this test if a similar design, using the same ingredients, has proven satisfactory.

To substantiate the design, trial mixtures shall be produced and tested using all of the proposed project materials and equipment prior to any placement. The Engineer may waive trial mixtures if similar designs have proven satisfactory.

(2) **Density.** The mixture shall be designed to produce an acceptable mixture at an optimum density of 95.0 percent, when tested in accordance with Test Method Tex-207-F and Test Method Tex-227-F. The operating range for control of laboratory density during production shall be optimum density plus or minus 1.5 percent.

Laboratory density is a mixture design and process control parameter. If the laboratory density of the mixture produced has a value outside the range specified above, the Contractor shall investigate the cause and take corrective action. If three (3) consecutive test results fall outside the specified range, production shall cease unless test results or other information indicate, to the satisfaction of the Engineer, that the next mixture to be produced will be within the specified range.

(3) **Stability.** The materials used in the mixture design shall produce a mixture with a stability value of at least 35, unless otherwise shown on the plans, when tested in accordance with Test Method Tex-208-F.

If, during production, the stability value falls below the specified minimum, the Engineer and the Contractor shall closely evaluate other test result values for specification compliance such as gradation, asphalt content, moisture content, crushed faces, etc., to determine the cause and take corrective action. If three (3) consecutive test results fall below the minimum value specified, production shall cease unless test results or other information indicate, to the satisfaction of the Engineer, that the next material to be produced will meet the minimum value specified.

(4) **Job-Mix Formula Field Adjustments.** The Contractor shall produce a mixture of uniform composition closely conforming to the approved job-mix formula.

If, during initial days of production, it is determined that adjustments to the mixture design job-mix formula are necessary to achieve the specified requirements, or to more nearly match the aggregate production, the Engineer may allow adjustment of the mixture design job-mix formula within the following limits without a laboratory redesign of the mixture.

The adjusted job-mix formula shall not exceed the limits of the master grading for the type of mixture specified nor shall the adjustments exceed five (5) percent on any one sieve, 12.5 millimeter size and larger, or three (3) percent on the sieve sizes below the 12.5 millimeter sieve.

When the considered adjustments exceed either the five (5) or three (3) percent limits, and the Engineer determines that the impact of these changes may adversely affect pavement performance, a new laboratory mixture design will be required.

The asphalt content will be adjusted as deemed necessary by the Engineer to maintain desirable laboratory density near the optimum value while achieving other mix requirements.

(5) Types. The aggregate gradation of the job-mix formula shall conform to the master grading limits shown in Table 2 for the type mix specified on the plans.

TABLE 2
Master Grading
Percent Passing by Mass or Volume

Sieve Size	Type				
	A Coarse Base	B Fine Base	C Coarse Surface	D Fine Surface	F Fine Mixture
37.5 mm	100				
31.5 mm	95-100				
25.0 mm		100			
22.4 mm	70-90	95-100	100		
16.0 mm		75-95	95-100		
12.5 mm	50-70			100	
9.5 mm		60-80	70-85	85-100	100
6.3 mm					95-100
4.75 mm	30-50	40-60	43-63	50-70	
2.00 mm	20-34	27-40	30-40	32-42	32-42
425 μm	5-20	10-25	10-25	11-26	9-24
180 μm	2-12	3-13	3-13	4-14	3-13
75 μm	1-6*	1-6*	1-6*	1-6*	1-6*
VMA % minimum	11	12	13	14	15

* 2 - 8 when Test Method Tex-200-F, Part II (Washed Sieve Analysis) is used.

(6) **Asphalt Primer.** When approved by the Engineer, the use of an asphalt primer will be permitted. In the event an asphalt primer is used, the hydrocarbon volatile content of the asphaltic concrete, as determined by Test Method Tex-213-F, shall not exceed 0.6 percent of the mixture by mass. The asphalt content of the primer shall be included in the total asphalt content of the paving mixture.

When used, the primer shall be added as directed by the Engineer during mixing.

(7) **Water.** When approved by the Engineer, water in an amount not to exceed 4.0 percent by mass of the mixture, as determined by Test Method Tex-212-F, may be used in preparing the mixture. In the event water is used in the mixing operation, adequate measuring devices as approved by the Engineer shall be used.

When used, the water shall be added as directed by the Engineer during the mixing.

(8) **Tolerances.** The gradation of the aggregate and the asphalt cement content of the produced mixture shall not vary from the job-mix formula by more than the tolerances allowed herein. When within applied tolerances, the gradation of the produced mixture may fall outside the master grading limits for any of the sieve sizes from the largest sieve size on which aggregate may be retained down through the 180 micrometer sieve. Only the quantity of aggregate passing the 75 micrometer sieve is further restricted to conform to the master grading limitations shown in Table 2 or as modified in Test Method Tex-229-F. A tolerance of two (2) percent is allowed on the sieve size for each mixture type which shows 100 percent passing in Table 2.

	Tolerance, Percent by Mass or Volume as Applicable
Passing the 31.5 mm to 2.00 mm sieve	Plus or Minus 5
Passing the 425 μm to 75 μm sieve	Plus or Minus 3
Asphalt, mass	Plus or Minus 0.5
Asphalt, volume	Plus or Minus 1.2

The mixture will be tested in accordance with Test Method Tex-210-F, or Test Method Tex-228-F will be used in conjunction with combined cold feed belt samples tested in accordance with Test Method Tex-229-F. Other methods of proven accuracy may be used. The methods of test will be determined by the Engineer. However, mixtures produced by weigh-batch plants will be tested for gradation in accordance with Test Method Tex-210-F. If three (3) consecutive tests indicate that the material produced exceeds the above tolerances on any individual sieve, or if two (2) consecutive tests indicate that the asphalt content tolerance is exceeded, production shall stop and not resume until test results or other information indicate, to the satisfaction of the Engineer, that the next mixture to be produced will be within the above tolerances.

When disagreements concerning determination of specification compliance occur between allowed sampling and testing procedures, extracted aggregate testing shall take precedence over cold feed belt testing.

When cold feed belt samples are used for job control, the Engineer will select the sieve analysis method that corresponds with the one used to determine the mixture design gradation. The tolerances will be adjusted as outlined in Test Method Tex-229-F.

334.4. Equipment.

(1) **General.** All equipment for the handling of all materials, mixing, placing and compacting of the mixture shall be maintained in good repair and operating condition and subject to the approval of the Engineer. Any equipment found to be defective and potentially having a negative effect on the quality of the paving mixture or ride quality will not be allowed.

(2) **Mixing Plants.** Mixing plants may be the weigh-batch type, the modified weigh-batch type or the drum-mix type. All plants shall be equipped with satisfactory conveyors, power units, mixing equipment, aggregate handling equipment, bins and dust collectors.

Automatic proportioning devices are required for all plants and shall be in accordance with Item 520, "Weighing and Measuring Equipment".

It shall be the Contractor's responsibility to provide safe and accurate means to enable inspection forces to take all required samples, to provide permanent means for checking the output of any specified metering device, and to perform calibration and mass checks as required by the

Engineer. When cold feed belt sampling is to be used for gradation testing, occasional stoppage of the belt may be necessary unless other means of sampling are approved by the Engineer.

When using fuel oil heavier than Grade No. 2, or waste oil, the Contractor shall insure that the fuel delivered to the burner is at a viscosity of 100 SSU or less, when tested in accordance with Test Method Tex-534-C, to insure complete burning of the fuel. Higher viscosities will be allowed if recommended by the burner manufacturer. If necessary, the Contractor shall preheat the oil to maintain the required viscosity.

The Contractor shall provide means for obtaining a sample of the fuel, just prior to entry into the burner, in order to perform the viscosity test. The Contractor shall perform this test or provide a laboratory test report that will establish the temperature of the fuel necessary to meet the viscosity requirements. There shall be an in-line thermometer to check the temperature of the fuel delivered to the burner.

Regardless of the burner fuel used, the burner or combination of burners and types of fuel used shall provide a complete burn of the fuel and not leave any fuel residue that will adhere to the heated aggregate or become mixed with the asphalt.

(a) **Weigh-Batch Type.**

Cold Aggregate Bin Unit and Proportioning Device. The cold aggregate bin unit shall have at least four bins of sufficient size to store the amount of aggregate required to keep the plant in continuous operation and of proper design to prevent overflow of material from one bin to another. There shall be vertical partitions between each bin and on each end of the bins of sufficient height so that any overflow will be to the front and back, and not allow overflow to the sides or between bins. Overflow that might occur shall not fall onto any feeder belt. The proportioning device shall provide a uniform and continuous flow of aggregate in the desired proportion to the dryer. Each aggregate shall be proportioned from a separate bin.

When mineral filler is used, as specified in Section 334.2.(1)(c), an additional bin shall be provided.

Dryer. The dryer shall continually agitate the aggregate during heating. The temperature shall be controlled so that the aggregate will not be damaged in the drying and heating operations. The dryer shall be of sufficient size to keep the plant in continuous operation.

Screening and Proportioning. The screening capacity and size of the hot aggregate bins shall be sufficient to screen and store the amount of aggregate required to properly operate the plant and keep the plant in continuous operation at full capacity. The hot bins shall be constructed so that oversize and overloaded material will be discarded through overflow chutes. Provisions shall be made to enable inspection forces to have easy and safe access to the proper location on the mixing plant where representative samples may be taken from the hot bins for testing. The aggregate shall be separated into at least four bins when producing Type "A", Type "B" or Type "C" mixtures, at least three bins when producing Type "D" mixture and at least two bins when producing Type "F" mixture. These bins shall contain the following sizes of aggregates, in percentages by mass or by volume, as applicable.

Type "A" (Coarse-Graded Base Course):

Bin No. 1 - Shall contain aggregates of which 85 to 100 percent will pass the 2.00 mm sieve.

Bin No. 2 - Shall contain aggregates of which at least 85 percent will be of such size as to pass the 12.5 mm sieve and be retained on the 2.00 mm sieve.

Bin No. 3 - Shall contain aggregates of which at least 85 percent will be of such size as to pass the 22.4 mm sieve and be retained on the 9.5 mm sieve.

Bin No. 4 - Shall contain aggregates of which at least 85 percent will be of such size as to pass the 37.5 mm sieve and be retained on the 22.4 mm sieve.

Type "B" (Fine-Graded Base Course):

Bin No. 1 - Shall contain aggregates of which 85 to 100 percent will pass the 2.00 mm sieve.

Bin No. 2 - Shall contain aggregates of which at least 70 percent will be of such size as to pass the 4.75 mm sieve and be retained on the 2.00 mm sieve.

Bin No. 3 - Shall contain aggregates of which at least 75 percent will be of such size as to pass the 9.5 mm sieve and be retained on the 4.75 mm sieve.

Bin No. 4 - Shall contain aggregates of which at least 75 percent will be of such size as to pass the 25.0 mm sieve and be retained on the 9.5 mm sieve.

Type "C" (Coarse-Graded Surface Course):

Bin No. 1 - Shall contain aggregates of which 85 to 100 percent will pass the 2.00 mm sieve.

Bin No. 2 - Shall contain aggregates of which at least 70 percent will be of such size as to pass the 4.75 mm sieve and be retained on the 2.00 mm sieve.

Bin No. 3 - Shall contain aggregates of which at least 75 percent will be of such size as to pass the 9.5 mm sieve and be retained on the 4.75 mm sieve.

Bin No. 4 - Shall contain aggregates of which at least 75 percent will be of such size as to pass the 22.4 mm sieve and be retained on the 9.5 mm sieve.

Type "D" (Fine-Graded Surface Course):

Bin No. 1 - Shall contain aggregates of which 85 to 100 percent will pass the 2.00 mm sieve.

Bin No. 2 - Shall contain aggregates of which at least 70 percent will be of such size as to pass the 4.75 mm sieve and be retained on the 2.00 mm sieve.

Bin No. 3 - Shall contain aggregates of which at least 75 percent will be of such size as to pass the 12.5 mm sieve and be retained on the 4.75 mm sieve.

Type "F" (Fine-Graded Mixture):

Bin No. 1 - Shall contain aggregates of which 85 to 100 percent will pass the 2.00 mm sieve.

Bin No. 2 - Shall contain aggregates of which at least 75 percent will be of such size as to pass the 9.5 mm sieve and be retained on the 2.00 mm sieve.

Aggregate Weigh Box and Batching Scale. The aggregate weigh box and batching scales shall be of sufficient capacity to hold and weigh a complete batch of aggregate. The weigh box and scales shall conform to the requirements of Item 520, "Weighing and Measuring Equipment".

Asphaltic Material Measuring System. If an asphaltic material bucket and scales are used, they shall be of sufficient capacity to hold and weigh the necessary asphaltic material for one batch. The bucket and scales shall conform to the requirements of Item 520, "Weighing and Measuring Equipment".

If a pressure type flow meter is used to measure the asphaltic material, the requirements of Item 520, "Weighing and Measuring Equipment", shall apply. This system shall include an automatic temperature compensation device to insure a constant percent by mass of asphaltic material in the mixture.

Provisions of a permanent nature shall be made for checking the accuracy of the asphaltic material measuring device. The asphalt line to the measuring device shall be protected with a jacket of hot oil or other approved means to maintain the temperature of the line near the temperature specified for the asphaltic material.

Mixer. The mixer shall be of the pugmill type and shall have a capacity of not less than 1350 kilograms (of natural-aggregate mixture) in a single batch, unless otherwise shown on the plans. Any mixer that has a tendency to segregate the aggregate or fails to secure a thorough and uniform mixture with the asphaltic material shall not be used. All mixers shall be provided with an automatic timer that will lock the discharge doors of the mixer for the required mixing period. The dump door or doors and the shaft seals of the mixer shall be tight enough to prevent spilling of aggregate or mixture from the pugmill. Provisions shall be made for introducing primer and water into the mixer when required or approved by the Engineer. The method and equipment shall meet with the approval of the Engineer.

Surge-Storage System and Scales. A surge-storage system may be used to minimize the production interruptions during the normal day's operations. A device such as a gob hopper or other device approved by the Engineer to prevent segregation in the surge-storage bin shall be used. The mixture shall be weighed at a point designated by the Engineer.

When a surge-storage system is used, scales shall be standard platform truck scales or other equipment such as weigh hopper (suspended) scales and shall conform to Item 520, "Weighing and Measuring Equipment". If truck scales are used, they shall be placed at a location approved by the Engineer. If other weighing equipment is used, the Engineer may require mass checks by truck scales for the basis of approval of the equipment.

Recording Device and Record Printer. The mixture shall be weighed for payment. If a surge-storage system is used, an automatic recording device and a digital record printer shall be provided to indicate the date, project identification number, vehicle identification, total mass of the load, tare mass of the vehicle, the mass of asphaltic mixture in each load and the number of loads for the day, unless otherwise indicated on the plans or designated by the Engineer. When surge-storage is not used, batch mass will be used as the basis for payment and automatic recording devices and automatic digital record printers in accordance with Item 520, "Weighing and Measuring Equipment", shall be required.

(b) Modified Weigh-Batch Type.

General. This plant is similar to the weigh-batch type plant. The hot bin screens shall be removed and the aggregate control is placed at the cold feeds. The cold feed bins shall be the same as those required for the drum-mix type plant.

Cold-Aggregate Bin Unit and Feed System. The number of bins in the cold-aggregate bin unit shall be equal to or greater than the number of stockpiles of individual materials to be used.

The bins shall be of sufficient size to store the amount of aggregate required to keep the plant in continuous operation and of proper design to prevent overflow of material from one bin to another. There shall be vertical partitions between each bin and on each end of the bins of sufficient height so that any overflow will be to the front and back and not allow overflow to the sides or between bins. Overflow that might occur shall not fall onto any feeder belt. When required by the Engineer, an approved stationary scalping screen shall be placed on top of the field sand bin to eliminate roots and other objectionable material. The feed system shall provide a uniform and continuous flow of aggregate in the desired proportion to the dryer. The Contractor shall furnish a chart indicating the calibration of each cold bin in accordance with the manufacturer's recommendations or in a method acceptable to the Engineer.

When mineral filler is used, as specified in Section 334.2.(1)(c), an additional bin shall be provided.

Scalping Screen. A scalping screen shall be required after the cold feeds and ahead of the hot aggregate surge bins.

Dryer. The dryer shall continually agitate the aggregate during heating. The temperature shall be controlled so that the aggregate will not be damaged in the drying and heating operations. The dryer shall be of sufficient size to keep the plant in continuous operation.

Screening and Proportioning. The hot aggregate shall not be separated into sizes after being dried. There shall be one or more surge bins provided between the dryer and the weigh hopper. Surge bins shall be of sufficient size to hold enough combined aggregate for one complete batch of mixture.

Aggregate Weigh Box and Batching Scale. The aggregate weigh box and batching scales shall be of sufficient capacity to hold and weigh a complete batch of aggregate. The weigh box and scales shall conform to the requirements of Item 520, "Weighing and Measuring Equipment".

Asphaltic Material Measuring System. If an asphaltic material bucket and scales are used, they shall be of sufficient capacity to hold and weigh the necessary asphaltic material for one batch. The bucket and scales shall conform to the requirements of Item 520, "Weighing and Measuring Equipment".

If a pressure type flow meter is used to measure the asphaltic material, the requirements of Item 520, "Weighing and Measuring Equipment", shall apply. This system shall include an automatic temperature compensation device to insure a constant percent by mass of asphaltic material in the mixture.

Provisions of a permanent nature shall be made for checking the accuracy of the asphaltic material measuring device. The asphalt line to the measuring device shall be protected with a jacket of hot oil or other approved means to maintain the temperature of the line near the temperature specified for the asphaltic material.

Provisions shall be made to measure and distribute uniformly any required primer and water approved by the Engineer. The method and equipment shall meet with the approval of the Engineer.

Mixer. The mixer shall be of the pugmill type and shall have a capacity of not less than 1350 kilograms (of natural-aggregate mixture) in a single batch, unless otherwise shown on the plans. Any mixer that has a tendency to segregate the aggregate or fails to secure a thorough and uniform mixture with the asphaltic material shall not be used. All mixers shall be provided with an automatic timer that will lock the discharge doors of the mixer for the required mixing period. The dump door or doors and the shaft seals of the mixer shall be tight enough to prevent spilling of aggregate or mixture from the pugmill. Provisions shall be made for introducing primer and water into the mixer when these materials are required or approved by the Engineer. The method and equipment shall meet with the approval of the Engineer.

Surge-Storage System and Scales. A surge-storage system may be used to minimize the production interruptions during the normal day's operations. A device such as a gob hopper or other device approved by the Engineer to prevent segregation in the surge-storage bin shall be used. The mixture shall be weighed at a point designated by the Engineer.

When a surge-storage system is used, scales shall be standard platform truck scales or other equipment such as weigh hopper (suspended) scales and shall conform to Item 520, "Weighing and Measuring Equipment". If truck scales are used, they shall be placed at a location approved by the Engineer. If other weighing equipment is used, the Engineer may require mass checks by truck scales for the basis of approval of the equipment.

Recording Device and Record Printer. The mixture shall be weighed for payment. If a surge-storage system is used, an automatic recording device and a digital record printer shall be provided to indicate the date, project identification number, vehicle identification, total mass of the load, tare mass of the vehicle, the mass of asphaltic mixture in each load and the number of loads for the day, unless otherwise indicated on the plans or designated by the Engineer. When surge-storage is not used, batch mass will be used as the basis for payment and automatic recording devices and automatic digital record printers in accordance with Item 520, "Weighing and Measuring Equipment", shall be required.

(c) **Drum-Mix Type.**

General. The plant shall be adequately designed and constructed for the process of mixing aggregates and asphalt. The plant shall be equipped with satisfactory conveyors, power units, aggregate-handling equipment and feed controls.

Cold-Aggregate Bin Unit and Feed System. The number of bins in the cold-aggregate bin unit shall be equal to or greater than the number of stockpiles of individual materials to be used.

The bins shall be of sufficient size to store the amount of aggregate required to keep the plant in continuous operation and of proper design to prevent overflow of material from one bin to another. There shall be vertical partitions between each bin and on each end of the bins of sufficient height so that any overflow will be to the front and back and not allow overflow to the sides or between bins. Overflow that might occur shall not fall onto any feeder belt. When required by the Engineer, an approved stationary scalping screen shall be placed on top of the field sand bin to eliminate roots and other objectionable material. The feed system shall provide a uniform and continuous flow of aggregate in the desired proportion to the mixer. The Contractor shall furnish a chart indicating the calibration of each cold bin in accordance with the manufacturer's recommendations or in a method acceptable to the Engineer.

The system shall provide positive mass measurement of the combined cold-aggregate feed by use of belt scales or other approved devices. Provisions of a permanent nature shall be made for checking the accuracy of the measuring device as required by Item 520, "Weighing and Measuring Equipment". When a belt scale is used, mixture production shall be maintained so that the scale normally operates between 50 percent and 100 percent of its rated capacity. Belt scale operation below 50 percent of the rated capacity may be allowed by the Engineer if accuracy checks show the scale to meet the requirements of Item 520, "Weighing and Measuring Equipment", at the selected rate. It shall be satisfactorily demonstrated to the Engineer that mixture uniformity and quality have not been adversely affected.

Scalping Screen. A scalping screen shall be required after the cold feeds and ahead of the combined aggregate belt scales.

Asphaltic Material Measuring System. An asphaltic material measuring device meeting the requirements of Item 520, "Weighing and Measuring Equipment", shall be placed in the asphalt line leading to the mixer so that the cumulative amount of asphalt used can be accurately determined. Provisions of a permanent nature shall be made for checking the accuracy of the measuring device output. The asphalt line to the measuring device shall be protected with a jacket of hot oil or other approved means to maintain the temperature of the line near the temperature specified for the asphaltic material. The measuring system shall include an automatic temperature compensation device to maintain a constant percent by mass of asphaltic material in the mixture.

Provisions shall be made to measure and distribute uniformly any required primer and water approved by the Engineer. The method and equipment shall meet with the approval of the Engineer.

Synchronization Equipment for Feed-Control Systems. The asphaltic material, primer and water feed-controls shall be coupled with the total aggregate mass measuring device to automatically vary these feed rates in order to maintain the required proportion.

Mixing System. The mixing system shall control the temperature so that the aggregate and asphalt will not be damaged in the drying, heating and mixing operations. A continuously recording thermometer shall be provided which will indicate the temperature of the mixture as it leaves the mixer.

Surge-Storage System and Scales. A surge-storage system shall be used to minimize the production interruptions during the normal day's operations. A device such as a gob hopper or other device approved by the Engineer to prevent segregation in the surge-storage bin shall be used. The mixture shall be weighed at a point designated by the Engineer.

Scales shall be standard platform truck scales or other equipment such as weigh hopper (suspended) scales and shall conform to Item 520, "Weighing and Measuring Equipment". If truck scales are used, they shall be placed at a location approved by the Engineer. If other weighing equipment is used, the Engineer may require mass checks by truck scales for the basis of approval of the equipment.

Recording Device and Record Printer. Automatic recording devices and automatic digital record printers shall be provided to indicate the date, project identification number, vehicle identification, total mass of the load, tare mass of the vehicle, the mass of asphaltic mixture in each load and the number of loads for the day in accordance with Item 520, "Weighing and Measuring Equipment", unless otherwise shown on the plans, or designated by the Engineer.

(3) Asphaltic Material Heating Equipment. Asphaltic material heating equipment shall be adequate to heat the required amount of asphaltic material to the desired temperature. The heating apparatus shall be equipped with a continuously recording thermometer with a 24-hour chart that will record the temperature of the asphaltic material at the location of highest temperature.

(4) Spreading and Finishing Machine. The spreading and finishing machine shall be approved by the Engineer and shall meet the requirements indicated below.

(a) Screed Unit. The spreading and finishing machine shall be equipped with a compacting screed. It shall produce a finished surface meeting the requirements of the typical cross sections and the surface tests.

Extensions added to the screed shall be provided with the same compacting action as the main screed unit, except for use on variable depth tapered areas and/or as approved by the Engineer.

The spreading and finishing machine shall be equipped with an approved automatic dual longitudinal screed control system and automatic transverse screed control system. The longitudinal controls shall be capable of operating from any longitudinal grade reference including a stringline, ski, mobile stringline, or matching shoe.

The Contractor shall furnish all equipment required for grade reference. It shall be maintained in good operating condition by personnel trained in the use of this type of equipment.

The grade reference used by the Contractor may be of any type approved by the Engineer. Control points, if required by the plans, shall be established for the finished profile in accordance with Item 5, "Control of the Work". These points shall be set at intervals not to exceed 15 meters. The Contractor shall set the grade reference from the control points. The grade reference shall have sufficient support so that the maximum deflection shall not exceed two (2) millimeters between supports.

(b) Tractor Unit. The tractor unit shall be equipped with a hydraulic hitch sufficient in design and capacity to maintain contact between the rear wheels of the hauling equipment and the pusher rollers of the finishing machine while the mixture is being unloaded.

No portion of the mass of hauling equipment, other than the connection, shall be supported by the asphalt paver. No vibrations or other motions of the loading equipment, which could have a detrimental effect on the riding quality of the completed pavement, shall be transmitted to the paver.

The use of any vehicle which requires dumping directly into the finishing machine and which the finishing machine cannot push or propel to obtain the desired lines and grades without resorting to hand finishing will not be allowed.

(5) Material Transfer Equipment. Equipment to transfer mixture from the hauling units or the roadbed to the spreading and finishing machine will be allowed unless otherwise shown on the plans. A specific type of material transfer equipment shall be required when shown on the plans.

(a) Windrow Pick-Up Equipment. Windrow pick-up equipment shall be constructed in such a manner that substantially all the mixture deposited on the roadbed is picked up and loaded into the spreading and finishing machine. The mixture shall not be contaminated with foreign material. The loading equipment shall be designed so that it does not interfere with the spreading and finishing machine in obtaining the required line, grade and surface without resorting to hand finishing.

(b) Material Feeding System. Material feeding systems shall be designed to provide a continuous flow of uniform mixture to the spreading and finishing machine. When use of a material feeding system is required on the plans, it shall meet the storage capacity, remixing capability, or other requirements shown on the plans.

(6) Motor Grader. The motor grader, when used, shall be a self-propelled power motor grader and shall be equipped with smooth tread pneumatic tired wheels unless otherwise directed. It shall have a blade length of not less than 3.6 meters and a wheelbase of not less than 4.8 meters.

(7) **Rollers.** Rollers provided shall meet the requirements for their type as follows:

(a) **Pneumatic-Tire Roller.** The roller shall be an acceptable medium pneumatic tire roller conforming to the requirements of Item 213, "Rolling (Pneumatic Tire)", Type B, unless otherwise specified on the plans. Pneumatic-tire rollers used for compaction shall provide a ground contact pressure acceptable to the Engineer.

(b) **Two-Axle Tandem Roller.** This roller shall be an acceptable self-propelled tandem roller weighing not less than 7.2 megagrams.

(c) **Three-Wheel Roller.** This roller shall be an acceptable self-propelled three wheel roller weighing not less than 9.1 megagrams.

(d) **Three-Axle Tandem Roller.** This roller shall be an acceptable self-propelled three axle roller weighing not less than 9.1 megagrams.

(e) **Trench Roller.** This roller shall be an acceptable self-propelled trench roller equipped with a sprinkler for keeping the wheels wet and an adjustable road wheel so that the roller may be kept level during rolling. The drive wheel shall be not less than 500 millimeters wide. The roller under working conditions shall produce not less than 5803 kilograms per meter of roller width and be so geared that a speed of approximately three (3) kilometers per hour is obtained in low gear.

(f) **Vibratory Steel-Wheel Roller.** This roller shall have a minimum mass of 5.4 megagrams. The compactor shall be equipped with amplitude and frequency controls and shall be specifically designed to compact the material on which it is used.

(8) **Straightedges and Templates.** When directed by the Engineer, the Contractor shall provide acceptable three (3) meter straightedges for surface testing. Satisfactory templates shall be provided as required by the Engineer.

(9) **Alternate Equipment.** When permitted by the Engineer, equipment other than that specified herein which will consistently produce satisfactory results may be used.

334.5. **Stockpiling, Storage and Mixing.**

(1) **Stockpiling of Aggregates.**

(a) **Weigh-Batch Plant.** Prior to stockpiling of aggregates, the area shall be cleaned of trash, weeds, grass and shall be relatively smooth and well drained. The stockpiling shall be done in a manner that will minimize aggregate degradation, segregation, mixing of one stockpile with another, and will not allow contamination with foreign material.

The plant shall have at least a two-day supply of aggregates on hand before production can begin and at least a two-day supply shall be maintained through the course of the project, unless otherwise directed by the Engineer.

No stockpile shall contain aggregate from more than one source.

Coarse aggregates for mixture Types "A", "B" and "C" shall be separated into at least two stockpiles of different gradation, such as a large-coarse-aggregate and a small-coarse-aggregate stockpile.

When shown on the plans, coarse aggregates for Type "D" mixtures shall also be separated into at least two stockpiles.

No coarse-aggregate stockpile shall contain more than 15 percent by mass of material that will pass a 2.00 millimeter sieve.

Fine-aggregate stockpiles may contain coarse aggregate in amounts up to 20 percent by mass. This requirement does not apply to stone screenings stockpiles, which must meet the gradation requirements shown in Section 334.2.(1)(b), unless otherwise shown on the plans.

When required by the Engineer, additional material shall not be added to stockpiles that have previously been sampled for approval.

Equipment of an acceptable size and type shall be furnished to work the stockpiles and prevent segregation and degradation of the aggregates.

(b) **Modified Weigh-Batch Plant.** The stockpiling requirements for aggregate shall be the same as required for a drum-mix type plant.

(c) **Drum-Mix Plant.** When a drum-mix plant is used, the following stockpiling requirements for coarse aggregates shall apply in addition to the aggregate stockpiling requirements listed under Section 334.5.(1)(a).

Once a job-mix formula has been established in accordance with Article 334.3, the coarse aggregates delivered to the stockpiles shall not vary on any grading size fraction by more than plus or minus 8 percentage points from the percentage found in the samples submitted by the Contractor and upon which the job-mix formula was based. Should the gradation of coarse aggregates in the stockpiles vary by more than the allowed tolerance, the Engineer may stop production. If production is stopped, new aggregates shall be furnished that meet the gradations of the aggregates submitted for the job-mix formula, or a new mix design shall be formulated in accordance with Article 334.3.

When the volume of production from a commercial plant makes sampling of all coarse aggregate delivered to the stockpiles impractical, cold feeds will be sampled to determine stockpile uniformity. Should this sampling prove the stockpiles non-uniform beyond the acceptable tolerance, separate stockpiles which meet these specifications may be required.

(2) Storage and Heating of Asphaltic Materials. The asphaltic material storage capacity shall be ample to meet the requirements of the plant. Asphalt shall not be heated to a temperature in excess of that specified in Item 300, "Asphalts, Oils and Emulsions". All equipment used in the storage and handling of asphaltic material shall be kept in a clean condition at all times and shall be operated in such a manner that there will be no contamination with foreign matter.

(3) Feeding and Drying of Aggregate. The feeding of various sizes of aggregate to the dryer shall be done through the cold aggregate bins and the proportioning device in such a manner that a uniform and constant flow of materials in the required proportions will be maintained. The aggregate shall be dried and heated to the temperature necessary to produce a mixture having the specified temperature.

(4) Mixing and Storage.

(a) Weigh-Batch Plant. In introducing the batch into the mixer, all aggregate shall be introduced first and shall be mixed thoroughly for a minimum period of 5 seconds to uniformly distribute the various sizes throughout the batch before the asphaltic material is added. The asphaltic material shall then be added and the mixing continued for a wet mixing period of not less than 15 seconds. The mixing period shall be increased if, in the opinion of the Engineer, the mixture is not uniform or the aggregates are not properly coated.

The asphaltic mixture may be stored either in a surge-storage system or in a stockpile. If the asphaltic mixture is stored in a stockpile, the area shall be cleaned of trash, weeds and grass and be relatively smooth and well drained. The stockpiling shall be done in a manner that will minimize degradation, segregation and not allow contamination with foreign material. Equipment of an acceptable size and type shall be furnished to work the stockpiles and shall not segregate or degrade the asphaltic mixture.

(b) **Modified Weigh-Batch Plant.** The mixing and storage requirements shall be the same as is required for a standard weigh-batch plant.

(c) **Drum-Mix Plant.** The amount of aggregate and asphaltic material entering the mixer and the rate of travel through the mixing unit shall be so coordinated that a uniform mixture of the specified grading and asphalt content will be produced.

The asphaltic mixture may be stored either in a surge-storage system or in a stockpile. If the asphaltic mixture is stored in a stockpile, the area shall be cleaned of trash, weeds and grass and be relatively smooth and well drained. The stockpiling shall be done in a manner that will minimize degradation, segregation and not allow contamination with foreign material. Equipment of an acceptable size and type shall be furnished to work the stockpiles and shall not segregate or degrade the asphaltic mixture.

(d) **Discharge Temperature.** The Engineer will select the target discharge temperature of the mixture between 65°C and 135°C. The mixture, when discharged from the mixer, shall not vary from this selected temperature more than 15°C.

(e) **Moisture Content.** The mixture produced from each type of mixer shall have a moisture content not greater than one (1) percent by mass when discharged from the mixer, unless otherwise shown on the plans and/or approved by the Engineer. The moisture content shall be determined in accordance with Test Method Tex-212-F.

334.6. Construction Methods.

(1) **General.** It shall be the responsibility of the Contractor to produce, transport, place and compact the specified paving mixture in accordance with the requirements herein.

The asphaltic mixture and the tack coat shall not be placed when the air temperature is below 15°C and is falling, but it may be placed when the air temperature is above 10°C and is rising.

The air temperature shall be taken in the shade away from artificial heat. It is further provided that the tack coat or asphaltic mixture shall be placed only when the humidity, general weather conditions and temperature and moisture condition of the base, in the opinion of the Engineer, are suitable.

(2) **Tack Coat.** The surface upon which the tack coat is to be placed shall be cleaned thoroughly to the satisfaction of the Engineer. The surface shall be given a uniform application of tack coat using asphaltic materials of this specification. This tack coat shall be applied, as directed by the Engineer, with an approved sprayer at a rate not to exceed 0.2 liter residual asphalt per square meter of surface. Where the mixture will adhere to the surface on which it is to be placed without the use of a tack coat, the tack coat may be eliminated by the Engineer. All contact surfaces of curbs and structures and all joints shall be painted with a thin uniform application of tack coat. During the application of tack coat, care shall be taken to prevent splattering of adjacent pavement, curb and gutter and structures. The tack coat shall be rolled with a pneumatic tire roller when directed by the Engineer.

(3) **Transporting Asphaltic Concrete.** The asphaltic mixture shall be hauled to the work site in tight vehicles previously cleaned of all foreign material.

(4) **Placing.**

(a) The asphaltic mixture shall be dumped and spread on the approved prepared surface with the spreading and finishing machine. When properly compacted, the finished pavement shall be smooth, of uniform texture and density and shall meet the requirements of the typical cross sections and the surface tests. In addition, the placing of the asphaltic mixture shall be done without tearing, shoving, gouging or segregating the mixture and without producing streaks in the mat.

Unloading into the finishing machine shall be controlled so that bouncing or jarring the spreading and finishing machine shall not occur and the required lines and grades shall be obtained without resorting to hand finishing, except as shown under Section 334.6.(4)(d).

Unless otherwise shown on the plans, dumping of the asphaltic mixture in a windrow and then placing the mixture in the finishing machine with windrow pick-up equipment will be permitted. The windrow pick-up equipment shall be operated in such a manner that substantially all the mixture deposited on the roadbed is picked up and loaded into the finishing machine without contamination by foreign material. The windrow pick-up equipment will be so operated that the finishing machine will obtain the required line, grade and surface without resorting to hand finishing. Any operation of the windrow pick-up equipment resulting in the accumulation and subsequent shedding of accumulated material into the asphaltic mixture will not be permitted.

In placing the material with a spreading and finishing machine, rolling shall be deferred for a period of time, as directed by the Engineer, to allow for volatilization.

Where more than one course of pavement is to be placed, no succeeding course shall be placed until the preceding course has been in place for a sufficient period of time to allow the preceding course to dry and cure. The drying and curing period shall be not less than 45 days unless authorized by the Engineer.

(b) Alternate Method of Placing. When shown on the plans or allowed by the Engineer, the mixture may be spread with a motor grader. The mixture shall be thoroughly aerated and then spread into place with a power motor grader in a uniform layer of such depth that after compaction is complete, the requirements of the typical cross section will have been fulfilled. Hand spreading will be permitted where the mixture is placed on narrow strips or small irregular areas.

Where more than one course of pavement is to be placed, no succeeding course shall be placed until the preceding course has been in place for a sufficient period of time to allow the preceding course to dry and cure. The drying and curing period shall be not less than 45 days unless authorized by the Engineer.

(c) The spreading and finishing machine shall be operated at a uniform forward speed consistent with the plant production rate, hauling capability, and roller train capacity to result in a continuous operation. The speed shall be slow enough that stopping between trucks is not ordinarily required. If, in the opinion of the Engineer, sporadic delivery of material is adversely affecting the mat, the Engineer may require paving operations to cease until acceptable methods are provided to minimize starting and stopping of the paver.

The hopper flow gates of the spreading and finishing machine shall be adjusted to provide an adequate and consistent flow of material. These shall result in enough material being delivered to the augers so that they are operating approximately 85 percent of the time or more. The augers shall provide means to supply adequate flow of material to the center of the paver. Augers shall supply an adequate flow of material for the full width of the mat, as approved by the Engineer. Augers should be kept approximately one-half to three-quarters full of mixture at all times during the paving operation.

(d) When the asphaltic mixture is placed in a narrow strip along the edge of an existing pavement, or used to level up small areas of an existing pavement, or placed in small irregular areas where the use of a finishing machine is not practical, the finishing machine may be eliminated when authorized by the Engineer.

(e) Adjacent to flush curbs, gutters and structures, the surface shall be finished uniformly high so that when compacted it will be slightly above the edge of the curb or structure.

(f) Construction joints of successive courses of asphaltic material shall be offset at least 150 millimeters. Construction joints on surface courses shall coincide with lane lines, or as directed by the Engineer.

(g) If a pattern of surface irregularities or segregation is detected, the Contractor shall make an investigation into the causes and immediately take the necessary corrective action. With the approval of the Engineer, placement may continue for no more than one full production day from the time the Contractor is first notified and while corrective actions are being taken. If the problem still exists after that time, paving shall cease until the Contractor further investigates the causes and the Engineer approves further corrective action to be taken.

(5) **Compacting.**

(a) The pavement shall be compacted thoroughly and uniformly with the necessary rollers to obtain the compaction and cross section of the finished paving mixture meeting the requirements of the plans and specifications.

(b) When rolling with the three-wheel, tandem or vibratory rollers, rolling shall start by first rolling the joint with the adjacent pavement and then continue by rolling longitudinally at the sides and proceed toward the center of the pavement, overlapping on successive trips by at least 300 millimeters, unless otherwise directed by the Engineer. Alternate trips of the roller shall be slightly different in length. On super-elevated curves, rolling shall begin at the low side and progress toward the high side, unless otherwise directed by the Engineer.

When rolling with vibratory steel-wheel rollers, equipment operation shall be in accordance with Item 217, "Rolling (Vibratory)", and the manufacturer's recommendations, unless otherwise directed by the Engineer. Vibratory rollers shall not be left vibrating while not rolling or when changing directions. Unless otherwise shown on the plans or approved by the Engineer, vibratory rollers shall not be allowed in the vibrating mode on mats with a plan depth of less than 40 millimeters.

The motion of the rollers shall be slow enough to avoid other than usual initial displacement of the mixture. If any displacement occurs, it shall be corrected to the satisfaction of the Engineer. The roller shall not be allowed to stand on pavement which has not been fully compacted. When necessary to prevent adhesion of the surface mixture to the steel-wheel rollers, the wheels shall be kept thoroughly moistened with water, but an excess of water will not be permitted. Necessary precautions shall be taken to prevent the dropping of diesel, gasoline, oil, grease or other foreign matter on the pavement, either when the rollers are in operation or when standing.

(c) The edges of the pavement along curbs, headers and similar structures, and all places not accessible to the roller, or in such positions as will not allow thorough compaction with the rollers, shall be thoroughly compacted with lightly oiled tamps.

(d) Rolling with a trench roller will be required on widened areas, in trenches and other limited areas where satisfactory compaction cannot be obtained with the approved rollers.

(6) In-Place Compaction Control. The Contractor shall furnish one (1) three-wheel roller, one (1) pneumatic-tire roller, and one (1) tandem roller for each compaction operation except as provided below or approved by the Engineer. The use of a tandem roller may be waived by the Engineer when the surface is already adequately smooth. With the approval of the Engineer, the Contractor may substitute a vibratory roller for the three-wheel roller and/or the tandem roller. Use of at least one (1) pneumatic-tire roller is required. Additional or heavier rollers shall be furnished if required by the Engineer.

Rolling patterns shall be established by the Contractor as outlined in Test Method Tex-207-F, Part IV, to achieve the maximum compaction, unless otherwise directed by the Engineer. The selected rolling pattern shall be followed unless changes in the mixture or placement conditions occur which affect compaction. When changes in the mixture or placement conditions occur, a new rolling pattern shall be established.

(7) Ride Quality. Unless otherwise shown on the plans, Ride Quality will be required in accordance with Item 585, "Ride Quality for Pavement Surfaces".

(8) Opening to Traffic. The pavement shall be opened to traffic when directed by the Engineer. The Contractor's attention is directed to the fact that all construction traffic allowed on the pavement open to the public will be subject to the State laws governing traffic on highways.

If the surface ravels, flushes, ruts or deteriorates in any manner prior to final acceptance of the work, it will be the Contractor's responsibility to correct this condition at his expense, to the satisfaction of the Engineer and in conformance with the requirements of this specification.

334.7. Measurement. The quantity of hot mix-cold laid asphaltic concrete will be measured by the composite mass or composite volumetric method.

(1) Composite Mass Method. Asphaltic concrete will be measured by the megagram of the composite "Hot Mix-Cold Laid Asphaltic Concrete" of the type actually used in the completed and accepted work in accordance with the plans and specifications for the project. The composite asphaltic concrete mixture is hereby defined as the asphalt, primer, aggregate, additives as noted in the plans and/or approved by the Engineer, and any residual moisture which is not designated to be deducted.

If mixing is done by a drum-mix plant, measurement will be made on scales as specified herein.

If mixing is done by a weigh-batch plant or modified weigh-batch plant, measurement will be determined on the batch scales unless surge-storage or stockpiling is used. Records of the number of batches, batch design and the mass of the composite "Hot Mix-Cold Laid Asphaltic Concrete" shall be kept. Where surge-storage or stockpiling is used, measurement of the material taken from the surge-storage bin or stockpile will be made on truck scales or suspended hopper scales.

(2) Composite Volumetric Method. The asphaltic concrete will be measured by the cubic meter of compacted "Hot Mix-Cold Laid Asphaltic Concrete" of the type actually used in the completed and accepted work in accordance with the plans and specifications for the project. The composite asphaltic concrete mixture is hereby defined as the asphalt, primer, aggregate, additives as noted in the plans and/or approved by the Engineer, and any residual moisture which is not designated to be deducted. The volume of the composite asphaltic concrete mixture shall be calculated by the following formula:

$$V = \frac{W}{1000\,G_a}$$

V = Cubic meters of compacted "Hot Mix-Cold Laid Asphaltic Concrete"
W = Total mass of asphaltic concrete in kilograms
G_a = Average actual specific gravity of three molded specimens as prepared by Test Method Tex-206-F and determined in accordance with Test Method Tex-207-F

If mixing is done by a drum-mix plant, measurement will be made on scales as specified herein.

If mixing is done by a weigh-batch plant or modified weigh-batch plant, measurement will be determined on the batch scales unless surge-storage or stockpiling is used. Records of the number of batches, batch design and the mass of the composite "Hot Mix-Cold Laid Asphaltic Concrete" shall be kept. Where surge-storage or stockpiling is used, measurement of the material taken from the surge-storage bin or stockpile will be made on truck scales or suspended hopper scales.

(3) **Ride Quality.** Ride quality will be measured as described in Item 585, "Ride Quality for Pavement Surfaces".

334.8. Payment.

(1) The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for the "Hot Mix-Cold Laid Asphaltic Concrete" of the type specified.

Measurement Method	Bid Item	Unit of Measure
Composite Mass	Hot Mix-Cold Laid Asphaltic Concrete	Megagram
Composite Volumetric	Hot Mix-Cold Laid Asphaltic Concrete	Cubic Meter

The payment based on the unit bid price shall be full compensation for quarrying, furnishing all materials, additives, freight involved, for all heating, mixing, hauling, cleaning the existing base course or pavement, tack coat, placing, rolling and finishing hot mix-cold laid asphaltic concrete mixture, and for all manipulations, labor, tools, equipment and incidentals necessary to complete the work. The unit bid price shall include full compensation for asphalt primer and water, when used.

(2) When surface Test Type-B, as specified in Item 585, "Ride Quality for Pavement Surfaces", is used, a bonus or deduction for each 0.1609 kilometer section of each travel lane will be calculated in dollars and cents. A running total of this will be determined for each day's placement. The bonus or deduction for ride quality will be paid for separately from the payment for the material placed.

(3) All templates, straightedges, scales and other weighing and measuring devices necessary for the proper construction, measuring and checking of the work shall be furnished, operated and maintained by the Contractor at his expense.

ITEM 340

HOT MIX ASPHALTIC CONCRETE PAVEMENT

340.1. Description. This Item shall govern for the construction of a base course, a level-up course, a surface course or any combination of these courses as shown on the plans, each course being composed of a compacted mixture of aggregate and asphalt cement mixed hot in a mixing plant, in accordance with the details shown on the plans and the requirements herein.

340.2. Materials. The Contractor shall furnish materials to the project meeting the following requirements prior to mixing. Additional test requirements affecting the quality of individual materials or the paving mixture shall be required when indicated on the plans.

(1) Aggregate. The aggregate shall be composed of a coarse aggregate, a fine aggregate, and if required or allowed, a mineral filler and may include reclaimed asphalt pavement (RAP). The use of RAP may be required on the plans. RAP use will be allowed in all mixtures except as specifically excluded herein or on the plans. Samples of each aggregate shall be submitted for approval in accordance with Item 6, "Control of Materials".

Aggregate from each stockpile shall meet the quality requirements of Table 1 and other requirements as specified herein. The aggregate contained in RAP will not be required to meet Table 1 requirements except as shown on the plans.

(a) Coarse Aggregate. Coarse aggregate is defined as that part of the aggregate retained on a 2.00 millimeter sieve. The aggregate shall be natural, lightweight or manufactured, and be of uniform quality throughout. When specified on the plans, certain coarse aggregate material may be allowed, required or prohibited.

Lightweight aggregate is defined as expanded shale, clay or slate produced by the rotary kiln method. Manufactured aggregate is defined as any aggregate other than natural or lightweight.

Lightweight or manufactured materials with the same or similar gradation whose unit weight vary by more than 6.0 percent from that used in the mixture design may require a redesign.

Gravel from each source shall be so crushed as to have a minimum of 85 percent of the particles retained on the 4.75 millimeter sieve with two or more mechanically induced crushed faces, as determined by Test Method Tex-460-A (Part I). The material passing the 4.75 millimeter sieve and retained on the 2.00 millimeter sieve must be the product of crushing aggregate that was originally retained on the 4.75 millimeter sieve.

The polish value for the virgin (not previously used in construction) coarse aggregate used in the surface or finish course shall not be less than the value shown on the plans, when tested in accordance with Test Method Tex-438-A. Unless otherwise shown on the plans, the polish value requirement will apply only to aggregate used on travel lanes. For rated sources, the Materials and Tests Division's Rated Source Polish Value (RSPV) catalog will be used to determine polish value compliance. Unless otherwise shown on the plans, virgin coarse aggregates may be blended in accordance with Test Method Tex-438-A, Part II, Method B, to meet the polish value requirement. When blending is allowed, the blended virgin aggregates shall contain non-polishing aggregates of not less than the percent by volume of the critical size shown below for the specified mixture.

	Type C	Type D	Type F
Retained on the 4.75 mm sieve	50%	50%	
Retained on the 2.00 mm sieve			50%

The polish value of RAP aggregate will not be used in any determination of polish value specification compliance.

(b) Reclaimed Asphalt Pavement (RAP). RAP is defined as a salvaged, milled, pulverized, broken or crushed asphaltic pavement. The RAP to be used in the mix shall be crushed or broken to the extent that 100 percent will pass the 50 millimeter sieve.

The stockpiled RAP shall not be contaminated by dirt or other objectionable materials. Unless otherwise shown on the plans, stockpiled, crushed RAP must have either a decantation of no more than five (5) percent or a plasticity index of no more than eight (8), when tested in accordance with Test Method Tex-406-A, Part I, or Test Method Tex-106-E, respectively. This requirement applies to stockpiled RAP from which the asphalt has not been removed by extraction.

State-owned RAP sources that are designated on the plans will be available for use by the Contractor. Only RAP from state-owned sources will be allowed in mixes using more than 20 percent RAP, unless otherwise shown on the plans. When RAP sources are designated, either in stockpile or existing pavements, the approximate gradation, asphalt content, and asphalt cement properties of this material will be shown on the plans for material existing in pavements, or in a special provision "Local Material Sources for Reclaimed Asphaltic Pavement" for material in existing stockpiles.

Any Contractor-owned RAP that is to be used on this project shall remain the property of the Contractor while stockpiled and shall not be intermingled with State-owned RAP stockpiles. Any unused Contractor-owned RAP material shall be removed from the project site upon completion of the project.

Only RAP from designated sources may be used in surface courses.

Excess RAP removed from designated sources will remain the property of the State and will be delivered to stockpile locations shown on the plans.

(c) Fine Aggregate. The fine aggregate is defined as that part of the aggregate passing the 2.00 millimeter sieve and shall be of uniform quality throughout. When specified on the plans, certain fine aggregate material may be allowed, required or prohibited. However, a maximum of 15 percent of the total virgin aggregate may be field sand or other uncrushed fine aggregate.

Screenings shall be supplied from sources whose coarse aggregate meets the Los Angeles abrasion and magnesium sulfate soundness loss requirements shown in Table 1, unless otherwise shown on the plans.

1. Unless otherwise shown on the plans, stone screenings are required and shall be the result of a rock crushing operation and meet the following gradation requirements, when tested in accordance with Test Method Tex-200-F, Part I.

	Percent by Mass
Passing the 9.5 mm sieve	100
Passing the 2.00 mm sieve	70-100
Passing the 75 μm sieve	0-15

2. Crushed gravel screenings may be used with, or in lieu of, stone screenings when shown on the plans. Crushed gravel screenings must be the product of crushing aggregate that was originally retained on the 4.75 millimeter sieve and meet the gradation for stone screenings shown above.

(d) Mineral Filler. Mineral filler shall consist of thoroughly dried stone dust, portland cement, lime, fly ash, or other mineral dust approved by the Engineer. The mineral filler shall be free from foreign matter.

When a specific type of mineral filler is specified on the plans, fines collected by the baghouse or other air cleaning or dust collecting equipment shall not be used to meet this requirement. When mineral filler is not specifically required, the addition of baghouse or other collected fines will be permitted if the mixture quality is not adversely affected in the opinion of the Engineer. In no case shall the amount of material passing the 75 micrometer sieve exceed the tolerances of the job-mix formula or the master gradation limits.

When mineral filler is specified or allowed by the Engineer, or baghouse fines are permitted to be added to the mixture, it shall be proportioned into the mix by a vane meter or an equivalent measuring device acceptable to the Engineer. A hopper or other acceptable storage system shall be required to maintain a constant supply of mineral filler to the measuring device.

The measuring device for adding mineral filler shall be tied into the automatic plant controls so that the supply of mineral filler will be automatically adjusted to plant production and provide a consistent percentage to the mixture. When shown on the plans, the measuring device for adding baghouse fines shall have controls in the plant control room which will allow manual adjustment of feed rates to match plant production rate adjustments.

When tested in accordance with Test Method Tex-200-F (Part I or Part III, as applicable), the mineral filler shall meet the following gradation requirements, unless otherwise shown on the plans. Baghouse fines are not required to meet the gradation requirements.

	Percent by Mass or Volume
Passing the 600 μm sieve	95-100
Passing the 180 μm sieve, not less than	75
Passing the 75 μm sieve, not less than	55

TABLE 1
AGGREGATE
QUALITY REQUIREMENTS *

Requirement	Test Method	Manufactured or Natural Aggregate	Lightweight Aggregate
COARSE AGGREGATE			
Dry Loose Unit Weight, kg/m^3 minimum	Tex-404-A	-	560
Pressure Slaking Value, maximum	Tex-431-A	-	4.0
Freeze Thaw Loss, percent, max.	Tex-432-A	-	7.0
24 Hour Water Absorption, percent, maximum	Tex-433-A	-	12.0
Deleterious Material, percent, maximum	Tex-217-F Part I	1.5	1.5
Decantation, percent, maximum	Tex-217-F Part II	1.5	1.5
Los Angeles Abrasion, percent, maximum	Tex-410-A	40	35
Magnesium Sulfate Soundness Loss, 5 cycle, percent, maximum	Tex-411-A	30**	-
FINE AGGREGATE			
Linear Shrinkage, maximum	Tex-107-E Part II	3	3
COMBINED AGGREGATES ***			
Sand Equivalent Value, minimum	Tex-203-F	45	45

* Sampled during delivery to the plant or from the stockpile, unless otherwise shown on the plans.

** Unless otherwise shown on the plans.

*** Aggregates, without added mineral filler, RAP, or additives, combined as used in the job-mix formula.

(2) **Asphaltic Material.**

(a) **Paving Mixture.** Asphalt cement for the paving mixture shall be of the grade shown on the plans or designated by the Engineer and shall meet the requirements of Item 300, "Asphalts, Oils and Emulsions". The Contractor shall notify the Engineer of the source of the asphaltic material prior to design of the asphaltic mixture. This source shall not be changed during the course of the project without the authorization of the Engineer. Should the source of asphaltic material be changed, the moisture resistance of the new material combination will be evaluated to verify that the requirements of Subarticle 340.3(1) are met.

(b) **RAP Paving Mixture.** When more than 20 percent RAP is used in the produced mixture, the asphalt in the RAP shall be restored to the properties indicated below. Restoration will be made by adding asphalt recycling agent and/or virgin asphalt cement meeting the requirements of Item 300, "Asphalts, Oils and Emulsions".

The mixture design will include recovery of asphalt from the RAP in accordance with Test Method Tex-211-F. The recovered asphalt shall be blended in the laboratory with the amount of asphalt cement and/or asphalt recycling agent selected for the project. The following tests shall be performed on the laboratory blend:

1. Viscosity, 60°C, Pa•s - Test Method Tex-528-C
2. Thin Film Oven Aging Test - Test Method Tex-510-C
3. Viscosity, 60°C, Pa•s, on residue from the Thin Film Oven Aging Test - Test Method Tex-528-C
4. Penetration at 25°C, 100 g, 5 s, (0.1 mm), on residue from the Thin Film Oven Aging Test - Test Method Tex-502-C

The viscosity in poises equivalent to the residue penetration at 25°C shall be calculated as set forth in Test Method Tex-535-C. The viscosity index of the residue shall then be calculated as follows:

$$\text{Residue Viscosity Index} = \frac{\text{Residue Viscosity, Pa}\bullet\text{s, equivalent to Penetration at }25^\circ\text{C, (0.1 mm)}}{\text{Residue Viscosity, }60^\circ\text{C, Pa}\bullet\text{s}}$$

The aging index of the laboratory blended asphalt shall be determined as follows:

$$\text{Aging Index} = \frac{\text{Residue Viscosity, 60°C, Pa}\bullet\text{s}}{\text{Original Viscosity, 60°C, Pa}\bullet\text{s}}$$

The laboratory blended asphalt shall meet the following requirements:

Residue Viscosity Index, maximum 1500
Aging Index, maximum 3.0

Samples of asphalt recovered from plant produced mixture shall show the asphalt to meet the following requirements when tested in accordance with Test Methods Tex-211-F and Tex-502-C.

	Minimum	Maximum
Penetration, 25°C, 100 g, 5 s, (0.1 mm)	30	55

(c) Tack Coat. Asphaltic materials, shown on the plans or approved by the Engineer, shall meet the requirements of Item 300, "Asphalts, Oils and Emulsions".

(3) Additives. Additives to facilitate mixing and/or improve the quality of the asphaltic mixture or tack coat shall be used when noted on the plans or may be used with the authorization of the Engineer.

Unless otherwise shown on the plans, the Contractor may choose to use either lime or a liquid antistripping agent to reduce the moisture susceptibility of the aggregate. The evaluation and addition of antistripping agents will be in accordance with Item 301, "Asphalt Antistripping Agents".

340.3. Paving Mixtures. The paving mixtures shall consist of a uniform mixture of aggregate, hot asphalt cement, and additives if allowed or required.

An asphalt mixture design is a laboratory process which includes the determination of the quality of the asphalt and the individual aggregates, the development of the job-mix formula, and the testing of the combined mixture.

The job-mix formula lists the quantity of each component to be used in the mix and the combined gradation of the aggregates used.

(1) Mixture Design. The Contractor shall furnish the Engineer with representative samples of the materials to be used in production. Using these materials, the mix shall be designed in accordance with Test Method Tex-204-F to conform with the requirements herein. Unless otherwise shown on the plans, the Engineer will furnish the mix design for mixtures when using 20 percent or less RAP. The Engineer may accept a design from the Contractor which was derived using these design procedures.

The second and subsequent mixture designs, or partial designs, for each type of paving mixture which are necessitated by changes in the material or at the request of the Contractor will be charged to the Contractor when a rate is shown on the plans.

The Contractor shall furnish the mixture design for all mixtures containing more than 20 percent RAP. This mixture design shall include, in addition to the results of the tests required for virgin mixes, the results of tests run on the proposed asphalt blend. The Contractor shall furnish the Engineer with representative samples of all materials to be used in the proposed mixture. The Engineer will verify the proposed mixture design. Should the Engineer's tests find that the proposed mixture design does not meet the requirements of this specification, the Contractor shall furnish another mixture design.

The bulk specific gravity will be determined for each aggregate to be used in the design mixture. If the determined values vary by 0.300 or more, the Volumetric Method, Test Method Tex-204-F, Part II, will be used. The bulk specific gravity of aggregates in RAP will be determined on extracted aggregates.

When properly proportioned, for the type specified, the blend of aggregates shall produce an aggregate gradation which will conform to the limits of the master grading shown in Table 2. Unless otherwise shown on the plans, the gradation of the aggregate will be determined in accordance with Test Method Tex-200-F, Part I (Dry Sieve Analysis), to develop the job-mix formula.

The master grading limits for the appropriate type and the proposed job-mix formula will be plotted on a gradation chart with sieve sizes raised to the 0.45 power. This plot must show that the proposed job-mix formula is within the limits of the master grading. Gaps in gradation shown by this plot should be avoided.

The voids in the mineral aggregate (VMA) will be determined as a mixture design requirement only, in accordance with Test Method Tex-207-F, and shall not be less than the value indicated in Table 2.

Unless otherwise shown on the plans, the mixture of aggregate, asphalt and additives proposed for use will be evaluated in the design stage for moisture susceptibility, in accordance with Item 301, "Asphalt Antistripping Agents". The Engineer may waive this test if a similar design, using the same ingredients, has proven satisfactory.

To substantiate the design, trial mixtures shall be produced and tested using all of the proposed project materials and equipment prior to any placement. The Engineer may waive trial mixtures if similar designs have proven satisfactory.

(2) Density. The mixture shall be designed to produce an acceptable mixture at an optimum density of 96.0 percent, when tested in accordance with Test Method Tex-207-F and Test Method Tex-227-F. The operating range for control of laboratory density during production shall be optimum density plus or minus 1.5 percent.

Laboratory density is a mixture design and process control parameter. If the laboratory density of the mixture produced has a value outside the range specified above, the Contractor shall investigate the cause and take corrective action. If three (3) consecutive test results fall outside the specified range, production shall cease unless test results or other information indicate, to the satisfaction of the Engineer, that the next mixture to be produced will be within the specified range.

(3) Stability. The materials used in the mixture design shall produce a mixture with a stability value of at least 35, unless otherwise shown on the plans, when tested in accordance with Test Method Tex-208-F.

If, during production, the stability value falls below the specified minimum, the Engineer and the Contractor shall closely evaluate other test result values for specification compliance such as gradation, asphalt content, moisture content, crushed faces, etc., to determine the cause and take corrective action. If three (3) consecutive test results fall below the minimum value specified, production shall cease unless test results or other information indicate, to the satisfaction of the Engineer, that the next material to be produced will meet the minimum value specified.

(4) Job-Mix Formula Field Adjustments. The Contractor shall produce a mixture of uniform composition closely conforming to the approved job-mix formula.

If, during initial days of production, it is determined that adjustments to the mixture design job-mix formula are necessary to achieve the specified requirements, or to more nearly match the aggregate production, the Engineer may allow adjustment of the mixture design job-mix formula within the following limits without a laboratory redesign of the mixture. The adjusted job-mix formula shall not exceed the limits of the master grading for the type of mixture specified nor shall the adjustments exceed five (5) percent on any one sieve, 12.5 millimeter size and larger, or three (3) percent on the sieve sizes below the 12.5 millimeter sieve.

When the considered adjustments exceed either the five (5) or three (3) percent limits, and the Engineer determines that the impact of these changes may adversely affect pavement performance, a new laboratory mixture design will be required.

The asphalt content will be adjusted as deemed necessary by the Engineer to maintain desirable laboratory density near the optimum value while achieving other mix requirements.

(5) Types. The aggregate gradation of the job-mix formula shall conform to the master grading limits shown in Table 2 for the type mix specified on the plans.

TABLE 2
Master Grading
Percent Passing by Mass or Volume

Sieve Size	Type				
	A Coarse Base	B Fine Base	C Coarse Surface	D Fine Surface	F Fine Mixture
37.5 mm	100				
31.5 mm	95-100				
25.0 mm		100			
22.4 mm	70-90	95-100	100		
16.0 mm		75-95	95-100		
12.5 mm	50-70			100	
9.5 mm		60-80	70-85	85-100	100
6.3 mm					95-100
4.75 mm	30-50	40-60	43-63	50-70	
2.00 mm	20-34	27-40	30-40	32-42	32-42
425 µm	5-20	10-25	10-25	11-26	9-24
180 µm	2-12	3-13	3-13	4-14	3-13
75 µm	1-6*	1-6*	1-6*	1-6*	1-6*
VMA % minimum	11	12	13	14	15

* 2 - 8 when Test Method Tex-200-F, Part II (Washed Sieve Analysis) is used.

(6) Tolerances. The gradation of the aggregate and the asphalt cement content of the produced mixture shall not vary from the job-mix formula by more than the tolerances allowed herein. When within applied tolerances, the gradation of the produced mixture may fall outside the master grading limits for any of the sieve sizes from the largest sieve size on which aggregate may be retained down through the 180 micrometer sieve. Only the quantity of aggregate passing the 75 micrometer sieve is further restricted to conform to the master grading limitations shown in Table 2 or as modified in Test Method Tex-229-F. A tolerance of two (2) percent is allowed on the sieve size for each mixture type which shows 100 percent passing in Table 2.

	Tolerance, Percent by Mass or Volume as Applicable
Passing the 31.5 mm to 2.00 mm sieve	Plus or Minus 5
Passing the 425 μm to 75 μm sieve	Plus or Minus 3
Asphalt, mass	Plus or Minus 0.5
Asphalt, volume	Plus or Minus 1.2

The mixture will be tested in accordance with Test Method Tex-210-F, or Test Method Tex-228-F will be used in conjunction with combined cold feed belt samples tested in accordance with Test Method Tex-229-F. Other methods of proven accuracy may be used. The methods of test will be determined by the Engineer. However, mixtures produced by weigh-batch plants and all mixtures containing RAP will be tested for gradation in accordance with Test Method Tex-210-F. If three (3) consecutive tests indicate that the material produced exceeds the above tolerances on any individual sieve, or if two (2) consecutive tests indicate that the asphalt content tolerance is exceeded, production shall stop and not resume until test results or other information indicate, to the satisfaction of the Engineer, that the next mixture to be produced will be within the above tolerances.

When disagreements concerning determination of specification compliance occur between allowed sampling and testing procedures, extracted aggregate testing shall take precedence over cold feed belt testing.

When cold feed belt samples are used for job control, the Engineer will select the sieve analysis method that corresponds with the one used to determine the mixture design gradation. The tolerances will be adjusted as outlined in Test Method Tex-229-F.

340.4. Equipment.

(1) **General.** All equipment for the handling of all materials, mixing, placing and compacting of the mixture shall be maintained in good repair and operating condition and subject to the approval of the Engineer. Any equipment found to be defective and potentially having a negative effect on the quality of the paving mixture or ride quality will not be allowed.

(2) **Mixing Plants.** Mixing plants may be the weigh-batch type, the modified weigh-batch type, the drum-mix type, or the specialized recycling type. All plants shall be equipped with satisfactory conveyors, power units, mixing equipment, aggregate handling equipment, bins and dust collectors.

Automatic proportioning devices are required for all plants and shall be in accordance with Item 520, "Weighing and Measuring Equipment".

It shall be the Contractor's responsibility to provide safe and accurate means to enable inspection forces to take all required samples, to provide permanent means for checking the output of any specified metering device, and to perform calibration and mass checks as required by the Engineer. When cold feed belt sampling is to be used for gradation testing, occasional stoppage of the belt may be necessary unless other means of sampling are approved by the Engineer.

When using fuel oil heavier than Grade No. 2, or waste oil, the Contractor shall insure that the fuel delivered to the burner is at a viscosity of 100 SSU or less, when tested in accordance with Test Method Tex-534-C, to insure complete burning of the fuel. Higher viscosities will be allowed if recommended by the burner manufacturer. If necessary, the Contractor shall preheat the oil to maintain the required viscosity.

The Contractor shall provide means for obtaining a sample of the fuel, just prior to entry into the burner, in order to perform the viscosity test. The Contractor shall perform this test or provide a laboratory test report that will establish the temperature of the fuel necessary to meet the viscosity requirements. There shall be an in-line thermometer to check the temperature of the fuel delivered to the burner.

Regardless of the burner fuel used, the burner or combination of burners and types of fuel used shall provide a complete burn of the fuel and not leave any fuel residue that will adhere to the heated aggregate or become mixed with the asphalt.

(a) Weigh-Batch Type.

Cold Aggregate Bin Unit and Proportioning Device. The cold aggregate bin unit shall have at least four bins of sufficient size to store the amount of aggregate required to keep the plant in continuous operation and of proper design to prevent overflow of material from one bin to another. There shall be vertical partitions between each bin and on each end of the bins of sufficient height so that any overflow will be to the front and back, and not allow overflow to the sides or between bins. Overflow that might occur shall not fall onto any feeder belt. The proportioning device shall provide a uniform and continuous flow of aggregate in the desired proportion to the dryer. Each aggregate shall be proportioned from a separate bin.

If RAP is used, a separate cold bin shall be required. The RAP feed system shall be equipped with a scalping screen to remove particles over 50 millimeters in size. The cold bin system shall supply the proper amount of RAP to the weigh box. RAP will not be allowed in the hot bins.

When mineral filler is used, as specified in Section 340.2.(1)(d), an additional bin shall be provided.

Dryer. The dryer shall continually agitate the aggregate during heating. The temperature shall be controlled so that the aggregate will not be damaged in the drying and heating operations. The dryer shall be of sufficient size to keep the plant in continuous operation.

Screening and Proportioning. The screening capacity and size of the hot aggregate bins shall be sufficient to screen and store the amount of aggregate required to properly operate the plant and keep the plant in continuous operation at full capacity. The hot bins shall be constructed so that oversize and overloaded material will be discarded through overflow chutes. Provisions shall be made to enable inspection forces to have easy and safe access to the proper location on the mixing plant where representative samples may be taken from the hot bins for testing. The aggregate shall be separated into at least four bins when producing Type "A", Type "B" or Type "C" mixtures, at least three bins when producing Type "D" mixture and at least two bins when producing Type "F" mixture. These bins shall contain the following sizes of aggregates, in percentages by mass or by volume, as applicable.

Type "A" (Coarse-Graded Base Course):

Bin No. 1 - Shall contain aggregates of which 85 to 100 percent will pass the 2.00 mm sieve.

Bin No. 2 - Shall contain aggregates of which at least 85 percent will be of such size as to pass the 12.5 mm sieve and be retained on the 2.00 mm sieve.

Bin No. 3 - Shall contain aggregates of which at least 85 percent will be of such size as to pass the 22.4 mm sieve and be retained on the 9.5 mm sieve.

Bin No. 4 - Shall contain aggregates of which at least 85 percent will be of such size as to pass the 37.5 mm sieve and be retained on the 22.4 mm sieve.

Type "B" (Fine-Graded Base Course):

Bin No. 1 - Shall contain aggregates of which 85 to 100 percent will pass the 2.00 mm sieve.

Bin No. 2 - Shall contain aggregates of which at least 70 percent will be of such size as to pass the 4.75 mm sieve and be retained on the 2.00 mm sieve.

Bin No. 3 - Shall contain aggregates of which at least 75 percent will be of such size as to pass the 9.5 mm sieve and be retained on the 4.75 mm sieve.

Bin No. 4 - Shall contain aggregates of which at least 75 percent will be of such size as to pass the 25.0 mm sieve and be retained on the 9.5 mm sieve.

Type "C" (Coarse-Graded Surface Course):

Bin No. 1 - Shall contain aggregates of which 85 to 100 percent will pass the 2.00 mm sieve.

Bin No. 2 - Shall contain aggregates of which at least 70 percent will be of such size as to pass the 4.75 mm sieve and be retained on the 2.00 mm sieve.

Bin No. 3 - Shall contain aggregates of which at least 75 percent will be of such size as to pass the 9.5 mm sieve and be retained on the 4.75 mm sieve.

Bin No. 4 - Shall contain aggregates of which at least 75 percent will be of such size as to pass the 22.4 mm sieve and be retained on the 9.5 mm sieve.

Type "D" (Fine-Graded Surface Course):

Bin No. 1 - Shall contain aggregates of which 85 to 100 percent will pass the 2.00 mm sieve.

Bin No. 2 - Shall contain aggregates of which at least 70 percent will be of such size as to pass the 4.75 mm sieve and be retained on the 2.00 mm sieve.

Bin No. 3 - Shall contain aggregates of which at least 75 percent will be of such size as to pass the 12.5 mm sieve and be retained on the 4.75 mm sieve.

Type "F" (Fine-Graded Mixture):

Bin No. 1 - Shall contain aggregates of which 85 to 100 percent will pass the 2.00 mm sieve.

Bin No. 2 - Shall contain aggregates of which at least 75 percent will be of such size as to pass the 9.5 mm sieve and be retained on the 2.00 mm sieve.

Aggregate Weigh Box and Batching Scale. The aggregate weigh box and batching scales shall be of sufficient capacity to hold and weigh a complete batch of aggregate. The weigh box and scales shall conform to the requirements of Item 520, "Weighing and Measuring Equipment".

Asphaltic Material Measuring System. If an asphaltic material bucket and scales are used, they shall be of sufficient capacity to hold and weigh the necessary asphaltic material for one batch. The bucket and scales shall conform to the requirements of Item 520, "Weighing and Measuring Equipment".

If a pressure type flow meter is used to measure the asphaltic material, the requirements of Item 520, "Weighing and Measuring Equipment", shall apply. This system shall include an automatic temperature compensation device to insure a constant percent by mass of asphaltic material in the mixture.

Provisions of a permanent nature shall be made for checking the accuracy of the asphaltic material measuring device. The asphalt line to the measuring device shall be protected with a jacket of hot oil or other approved means to maintain the temperature of the line near the temperature specified for the asphaltic material.

Mixer. The mixer shall be of the pugmill type and shall have a capacity of not less than 1350 kilograms (of natural-aggregate mixture) in a single batch, unless otherwise shown on the plans. Any mixer that has a tendency to segregate the aggregate or fails to secure a thorough and uniform mixture with the asphaltic material shall not be used. All mixers shall be provided with an automatic timer that will lock the discharge doors of the mixer for the required mixing period. The dump door or doors and the shaft seals of the mixer shall be tight enough to prevent spilling of aggregate or mixture from the pugmill.

Surge-Storage System and Scales. A surge-storage system may be used to minimize the production interruptions during the normal day's operations. A device such as a gob hopper or other device approved by the

Engineer to prevent segregation in the surge-storage bin shall be used. The mixture shall be weighed upon discharge from the surge-storage system.

When a surge-storage system is used, scales shall be standard platform truck scales or other equipment such as weigh hopper (suspended) scales and shall conform to Item 520, "Weighing and Measuring Equipment". If truck scales are used, they shall be placed at a location approved by the Engineer. If other weighing equipment is used, the Engineer may require mass checks by truck scales for the basis of approval of the equipment.

Recording Device and Record Printer. The mixture shall be weighed for payment. If a surge-storage system is used, an automatic recording device and a digital record printer shall be provided to indicate the date, project identification number, vehicle identification, total mass of the load, tare mass of the vehicle, the mass of asphaltic mixture in each load and the number of loads for the day, unless otherwise indicated on the plans. When surge-storage is not used, batch mass will be used as the basis for payment and automatic recording devices and automatic digital record printers in accordance with Item 520, "Weighing and Measuring Equipment", shall be required.

(b) Modified Weigh-Batch Type.

General. This plant is similar to the weigh-batch type plant. The hot bin screens shall be removed and the aggregate control is placed at the cold feeds. The cold feed bins shall be the same as those required for the drum-mix type plant.

Cold-Aggregate Bin Unit and Feed System. The number of bins in the cold-aggregate bin unit shall be equal to or greater than the number of stockpiles of individual materials to be used.

The bins shall be of sufficient size to store the amount of aggregate required to keep the plant in continuous operation and of proper design to prevent overflow of material from one bin to another. There shall be vertical partitions between each bin and on each end of the bins of sufficient height so that any overflow will be to the front and back and not allow overflow to the sides or between bins. Overflow that might occur shall not fall onto any feeder belt. When required by the Engineer, an approved stationary scalping screen shall be placed on top of the field sand bin to eliminate roots and other objectionable material. The feed system shall provide a uniform and continuous flow of aggregate in the desired proportion to the dryer. The Contractor shall furnish a chart indicating the calibration of each cold bin in accordance with the manufacturer's recommendations or in a method acceptable to the Engineer.

When mineral filler is used, as specified in Section 340.2.(1)(d), an additional bin shall be provided.

If RAP is used, a separate cold bin shall be required. The RAP feed system shall be equipped with a scalping screen to remove particles over 50 millimeters in size. The cold bin system shall supply a uniform and proper amount of RAP to the mixture. The RAP may be added at the weigh box. If not added at the weigh box, the system shall include means acceptable to the Engineer to verify that the correct amount of RAP is continuously being fed.

Scalping Screen. A scalping screen shall be required after the cold feeds and ahead of the hot aggregate surge bins.

Dryer. The dryer shall continually agitate the aggregate during heating. The temperature shall be controlled so that the aggregate will not be damaged in the drying and heating operations. The dryer shall be of sufficient size to keep the plant in continuous operation.

Screening and Proportioning. The hot aggregate shall not be separated into sizes after being dried. There shall be one or more surge bins provided between the dryer and the weigh hopper. Surge bins shall be of sufficient size to hold enough combined aggregate for one complete batch of mixture.

Aggregate Weigh Box and Batching Scale. The aggregate weigh box and batching scales shall be of sufficient capacity to hold and weigh a complete batch of aggregate. The weigh box and scales shall conform to the requirements of Item 520, "Weighing and Measuring Equipment".

Asphaltic Material Measuring System. If an asphaltic material bucket and scales are used, they shall be of sufficient capacity to hold and weigh the necessary asphaltic material for one batch. The bucket and scales shall conform to the requirements of Item 520, "Weighing and Measuring Equipment".

If a pressure type flow meter is used to measure the asphaltic material, the requirements of Item 520, "Weighing and Measuring Equipment", shall apply. This system shall include an automatic temperature compensation device to insure a constant percent by mass of asphaltic material in the mixture.

Provisions of a permanent nature shall be made for checking the accuracy of the asphaltic material measuring device. The asphalt line to the measuring device shall be protected with a jacket of hot oil or other approved means to maintain the temperature of the line near the temperature specified for the asphaltic material.

Mixer. The mixer shall be of the pugmill type and shall have a capacity of not less than 1350 kilograms (of natural-aggregate mixture) in a single batch, unless otherwise shown on the plans. Any mixer that has a tendency to segregate the aggregate or fails to secure a thorough and uniform mixture with the asphaltic material shall not be used. All mixers shall be provided with an automatic timer that will lock the discharge doors of the mixer for the required mixing period. The dump door or doors and the shaft seals of the mixer shall be tight enough to prevent spilling of aggregate or mixture from the pugmill.

Surge-Storage System and Scales. A surge-storage system may be used to minimize the production interruptions during the normal day's operations. A device such as a gob hopper or other device approved by the Engineer to prevent segregation in the surge-storage bin shall be used. The mixture shall be weighed upon discharge from the surge-storage system.

When a surge-storage system is used, scales shall be standard platform truck scales or other equipment such as weigh hopper (suspended) scales and shall conform to Item 520, "Weighing and Measuring Equipment". If truck scales are used, they shall be placed at a location approved by the Engineer. If other weighing equipment is used, the Engineer may require mass checks by truck scales for the basis of approval of the equipment.

Recording Device and Record Printer. The mixture shall be weighed for payment. If a surge-storage system is used, an automatic recording device and a digital record printer shall be provided to indicate the date, project identification number, vehicle identification, total mass of the load, tare mass of the vehicle, the mass of asphaltic mixture in each load and the number of loads for the day, unless otherwise indicated on the plans. When surge-storage is not used, batch mass will be used as the basis for payment and automatic recording devices and automatic digital record printers in accordance with Item 520, "Weighing and Measuring Equipment", shall be required.

(c) Drum-Mix Type.

General. The plant shall be adequately designed and constructed for the process of mixing aggregates and asphalt. The plant shall be equipped with satisfactory conveyors, power units, aggregate-handling equipment and feed controls.

Cold-Aggregate Bin Unit and Feed System. The number of bins in the cold-aggregate bin unit shall be equal to or greater than the number of stockpiles of individual materials to be used.

The bins shall be of sufficient size to store the amount of aggregate required to keep the plant in continuous operation and of proper design to prevent overflow of material from one bin to another. There shall be vertical partitions between each bin and on each end of the bins of sufficient height so that any overflow will be to the front and back and not allow overflow to the sides or between bins. Overflow that might occur shall not fall onto any feeder belt. When required by the Engineer, an approved stationary scalping screen shall be placed on top of the field sand bin to eliminate roots and other objectionable material. The feed system shall provide a uniform and continuous flow of aggregate in the desired proportion to the mixer. The Contractor shall furnish a chart indicating the calibration of each cold bin in accordance with the manufacturer's recommendations or in a method acceptable to the Engineer.

The system shall provide positive mass measurement of the combined cold-aggregate feed by use of belt scales or other approved devices. Provisions of a permanent nature shall be made for checking the accuracy of the measuring device as required by Item 520, "Weighing and Measuring Equipment". When a belt scale is used, mixture production shall be maintained so that the scale normally operates between 50 percent and 100 percent of its rated capacity. Belt scale operation below 50 percent of the rated capacity may be allowed by the Engineer if accuracy checks show the scale to meet the requirements of Item 520, "Weighing and Measuring Equipment", at the selected rate. It shall be satisfactorily demonstrated to the Engineer that mixture uniformity and quality have not been adversely affected.

If RAP is used, a separate cold bin shall be required. The RAP feed system shall be equipped with a scalping screen to remove particles over 50 millimeters in size prior to the weighing device. There shall be adequate cold bin controls to provide a uniform amount of RAP to the mixture.

When RAP is used, positive mass measurement of RAP shall be provided by the use of belt scales or other approved devices.

Scalping Screen. A scalping screen shall be required after the cold feeds and ahead of the combined aggregate belt scales.

Asphaltic Material Measuring System. An asphaltic material measuring device meeting the requirements of Item 520, "Weighing and Measuring Equipment", shall be placed in the asphalt line leading to the mixer so that the cumulative amount of asphalt used can be accurately determined. Provisions of a permanent nature shall be made for checking the accuracy of the measuring device output. The asphalt line to the measuring device shall be protected with a jacket of hot oil or other approved means to maintain the temperature of the line near the temperature specified for the asphaltic material. The measuring system shall include an automatic temperature compensation device to maintain a constant percent by mass of asphaltic material in the mixture.

Synchronization Equipment for Feed-Control Systems. The asphaltic material feed-control shall be coupled with the total aggregate mass measuring device to automatically vary the asphalt-feed rate in order to maintain the required proportion.

Mixing System. The mixing system shall control the temperature so that the aggregate and asphalt will not be damaged in the drying, heating and mixing operations. A continuously recording thermometer shall be provided which will indicate the temperature of the mixture as it leaves the mixer.

Surge-Storage System and Scales. A surge-storage system shall be used to minimize the production interruptions during the normal day's operations. A device such as a gob hopper or other device approved by the Engineer to prevent segregation in the surge-storage bin shall be used. The mixture shall be weighed upon discharge from the surge-storage system.

Scales shall be standard platform truck scales or other equipment such as weigh hopper (suspended) scales and shall conform to Item 520, "Weighing and Measuring Equipment". If truck scales are used, they shall be placed at a location approved by the Engineer. If other weighing equipment is used, the Engineer may require mass checks by truck scales for the basis of approval of the equipment.

Recording Device and Record Printer. Automatic recording devices and automatic digital record printers shall be provided to indicate the date, project identification number, vehicle identification, total mass of the load, tare mass of the vehicle, the mass of asphaltic mixture in each load and the number of loads for the day in accordance with Item 520, "Weighing and Measuring Equipment", unless otherwise shown on the plans.

(d) Specialized Recycling Type.

General. Alternate methods of heating may be used which will not abnormally age the asphalt cement. This type of plant shall be capable of continually producing a minimum of 136 megagrams per hour of completed asphalt mixture that will meet all the requirements of this specification.

Cold-Aggregate Bin Unit and Feed System. The cold-aggregate feed system and controls shall meet all the requirements as listed under the drum-mix type plant.

Scalping Screen. A scalping screen shall be required after the cold feeds and ahead of the combined aggregate belt scales.

Dryer. The dryer shall continually agitate the RAP and aggregate during heating. The temperature shall be controlled so that the aggregate and asphalt will not be damaged in the drying and heating operations. The dryer shall be of sufficient size to keep the plant in continuous operation.

Asphalt Material Measuring System. An asphaltic material measuring device meeting the requirements of Item 520, "Weighing and Measuring Equipment", shall be placed in the asphalt line leading to the mixer so that the cumulative amount of asphalt used can be accurately determined. Provisions of a permanent nature shall be made for checking the accuracy of the measuring device output. The asphalt line to the measuring device shall be protected with a jacket of hot oil or other approved means to maintain the temperature of the line near the temperature specified for the asphaltic material. The measuring system shall include an automatic temperature compensation device to maintain a constant percent by mass of asphaltic material in the mixture.

Synchronization Equipment for Feed-Control Systems. The asphaltic material feed-control shall be coupled with the total aggregate mass measuring device to automatically vary the asphalt-feed rate in order to maintain the required proportion.

Mixer. The mixer shall be of the continuous mechanical mixing type. Any mixer that has a tendency to segregate the mixture or fails to secure a thorough and uniform mixture shall not be used. A continuously recording thermometer shall be provided which will indicate the temperature of the mixture as it leaves the mixer.

Surge-Storage System and Scales. A surge-storage system shall be used to minimize the production interruptions during the normal day's operations. A device such as a gob hopper or other device approved by the Engineer to prevent segregation in the surge-storage bin shall be used. The mixture shall be weighed upon discharge from the surge-storage system.

Scales shall be standard platform truck scales or other equipment such as weigh hopper (suspended) scales and shall conform to Item 520, "Weighing and Measuring Equipment". If truck scales are used, they shall be placed at a location approved by the Engineer. If other weighing equipment is used, the Engineer may require mass checks by truck scales for the basis of approval of the equipment.

Recording Device and Record Printer. Automatic recording devices and automatic digital record printers shall be provided to indicate the date, project identification number, vehicle identification, total mass of the load, tare mass of the vehicle, the mass of asphaltic mixture in each load and the number of loads for the day in accordance with Item 520, "Weighing and Measuring Equipment", unless otherwise shown on the plans.

(3) Asphaltic Material Heating Equipment. Asphaltic material heating equipment shall be adequate to heat the required amount of asphaltic material to the desired temperature. The heating apparatus shall be equipped with a continuously recording thermometer with a 24-hour chart that will record the temperature of the asphaltic material at the location of highest temperature.

(4) Spreading and Finishing Machine. The spreading and finishing machine shall be approved by the Engineer and shall meet the requirements indicated below.

(a) Screed Unit. The spreading and finishing machine shall be equipped with a heated compacting screed. It shall produce a finished surface meeting the requirements of the typical cross sections and the surface tests.

Extensions added to the screed shall be provided with the same compacting action and heating capability as the main screed unit, except for use on variable depth tapered areas and/or as approved by the Engineer.

The spreading and finishing machine shall be equipped with an approved automatic dual longitudinal screed control system and automatic transverse screed control system. The longitudinal controls shall be capable of operating from any longitudinal grade reference including a stringline, ski, mobile stringline, or matching shoe.

The Contractor shall furnish all equipment required for grade reference. It shall be maintained in good operating condition by personnel trained in the use of this type of equipment.

The grade reference used by the Contractor may be of any type approved by the Engineer. Control points, if required by the plans, shall be established for the finished profile in accordance with Item 5, "Control of the Work". These points shall be set at intervals not to exceed 15 meters. The Contractor shall set the grade reference from the control points. The grade reference shall have sufficient support so that the maximum deflection shall not exceed two (2) millimeters between supports.

(b) Tractor Unit. The tractor unit shall be equipped with a hydraulic hitch sufficient in design and capacity to maintain contact between the rear wheels of the hauling equipment and the pusher rollers of the finishing machine while the mixture is being unloaded.

No portion of the mass of hauling equipment, other than the connection, shall be supported by the asphalt paver. No vibrations or other motions of the loading equipment, which could have a detrimental effect on the riding quality of the completed pavement, shall be transmitted to the paver.

The use of any vehicle which requires dumping directly into the finishing machine and which the finishing machine cannot push or propel to obtain the desired lines and grades without resorting to hand finishing will not be allowed.

(5) Material Transfer Equipment. Equipment to transfer mixture from the hauling units or the roadbed to the spreading and finishing machine will be allowed unless otherwise shown on the plans. A specific type of material transfer equipment shall be required when shown on the plans.

(a) Windrow Pick-Up Equipment. Windrow pick-up equipment shall be constructed in such a manner that substantially all the mixture deposited on the roadbed is picked up and loaded into the spreading and finishing machine. The mixture shall not be contaminated with foreign material. The loading equipment shall be designed so that it does not interfere with the spreading and finishing machine in obtaining the required line, grade and surface without resorting to hand finishing.

(b) Material Feeding System. Material feeding systems shall be designed to provide a continuous flow of uniform mixture to the spreading and finishing machine. When use of a material feeding system is required on the plans, it shall meet the storage capacity, remixing capability, or other requirements shown on the plans.

(6) Motor Grader. The motor grader, when used, shall be a self-propelled power motor grader and shall be equipped with smooth tread pneumatic tired wheels unless otherwise directed. It shall have a blade length of not less than 3.6 meters and a wheelbase of not less than 4.8 meters.

(7) Rollers. Rollers provided shall meet the requirements for their type as follows:

(a) Pneumatic-Tire Roller. The roller shall be an acceptable medium pneumatic tire roller conforming to the requirements of Item 213, "Rolling (Pneumatic Tire)", Type A, unless otherwise specified on the plans. Pneumatic-tire rollers used for compaction shall provide a minimum 550 kilopascals ground contact pressure. When used for kneading and sealing the surface only, they shall provide a minimum of 380 kilopascals ground contact pressure.

(b) Two-Axle Tandem Roller. This roller shall be an acceptable self-propelled tandem roller weighing not less than 7.2 megagrams.

(c) Three-Wheel Roller. This roller shall be an acceptable self-propelled three wheel roller weighing not less than 9.1 megagrams.

(d) Three-Axle Tandem Roller. This roller shall be an acceptable self-propelled three axle roller weighing not less than 9.1 megagrams.

(e) Trench Roller. This roller shall be an acceptable self-propelled trench roller equipped with a sprinkler for keeping the wheels wet and an adjustable road wheel so that the roller may be kept level during rolling. The drive wheel shall be not less than 500 millimeters wide. The roller under working conditions shall produce not less than 5800 kilograms per meter of roller width and be so geared that a speed of approximately three (3) kilometers per hour is obtained in low gear.

(f) Vibratory Steel-Wheel Roller. This roller shall have a minimum mass of 5.4 megagrams. The compactor shall be equipped with amplitude and frequency controls and shall be specifically designed to compact the material on which it is used.

(8) Straightedges and Templates. When directed by the Engineer, the Contractor shall provide acceptable 3-meter straightedges for surface testing. Satisfactory templates shall be provided as required by the Engineer.

(9) Alternate Equipment. When permitted by the Engineer, equipment other than that specified herein which will consistently produce satisfactory results may be used.

340.5. Stockpiling, Storage and Mixing.

(1) Stockpiling of Aggregates.

(a) Weigh-Batch Plant. Prior to stockpiling of aggregates, the area shall be cleaned of trash, weeds, grass and shall be relatively smooth and well drained. The stockpiling shall be done in a manner that will minimize aggregate degradation, segregation, mixing of one stockpile with another, and will not allow contamination with foreign material.

The plant shall have at least a two-day supply of aggregates on hand before production can begin and at least a two-day supply shall be maintained through the course of the project, unless otherwise directed by the Engineer.

No stockpile shall contain aggregate from more than one source.

Coarse aggregates for mixture Types "A", "B" and "C" shall be separated into at least two stockpiles of different gradation, such as a large-coarse-aggregate and a small-coarse-aggregate stockpile, except when the use of large percentages of RAP preclude the need for two virgin coarse aggregate stockpiles.

When shown on the plans, coarse aggregates for Type "D" mixtures shall also be separated into at least two stockpiles.

No coarse-aggregate stockpile shall contain more than 15 percent by mass of material that will pass a 2.00 millimeter sieve.

Fine-aggregate stockpiles may contain coarse aggregate in amounts up to 20 percent by mass. This requirement does not apply to stone screenings stockpiles, which must meet the gradation requirements shown in Section 340.2.(1)(c), unless otherwise shown on the plans.

Prior to starting RAP stockpiling operations, the Contractor shall develop and submit in writing to the Engineer an acceptable stockpile production procedure and management plan which will ensure that a homogeneous stockpile of RAP is available. Stockpiles of contractor-owned RAP material shall be completely established at the plant site prior to submission of mixture design samples and shall be of sufficient quantity to meet the material requirements of the project for which they are prepared. When shown on the plans, plant site stockpiles composed of RAP from designated sources shall be of the minimum size shown on the plans prior to submission of mixture design samples.

When required by the Engineer, additional material shall not be added to stockpiles that have previously been sampled for approval.

Equipment of an acceptable size and type shall be furnished to work the stockpiles and prevent segregation and degradation of the aggregates.

(b) Modified Weigh-Batch Plant. The stockpiling requirements for aggregate shall be the same as required for a drum-mix type plant.

(c) Drum-Mix Plant. When a drum-mix plant is used, the following stockpiling requirements for coarse aggregates shall apply in addition to the aggregate stockpiling requirements listed under Section 340.5.(1)(a).

Once a job-mix formula has been established in accordance with Article 340.3, the virgin coarse aggregates delivered to the stockpiles shall not vary on any grading size fraction by more than plus or minus eight (8) percentage points from the percentage found in the samples submitted by the Contractor and upon which the job-mix formula was based. Should the gradation of virgin coarse aggregates in the stockpiles vary by more than the allowed tolerance, the Engineer may stop production. If production is stopped, new aggregates shall be furnished that meet the gradations of the aggregates submitted for the job-mix formula, or a new mix design shall be formulated in accordance with Article 340.3.

When the volume of production from a commercial plant makes sampling of all coarse aggregate delivered to the stockpiles impractical, cold feeds will be sampled to determine stockpile uniformity. Should this sampling prove the stockpiles non-uniform beyond the acceptable tolerance, separate stockpiles which meet these specifications may be required.

(d) Specialized Recycling Plant. The stockpiling requirements for aggregate shall be the same as required for drum-mix type plant.

(2) Storage and Heating of Asphaltic Materials. The asphaltic material storage capacity shall be ample to meet the requirements of the plant. Asphalt shall not be heated to a temperature in excess of that specified in Item 300, "Asphalts, Oils and Emulsions". All equipment used in the storage and handling of asphaltic material shall be kept in a clean condition at all times and shall be operated in such a manner that there will be no contamination with foreign matter.

(3) Feeding and Drying of Aggregate. The feeding of various sizes of aggregate and RAP, if applicable, to the dryer shall be done through the cold aggregate bins and the proportioning device in such a manner that a uniform and constant flow of materials in the required proportions will be maintained. The aggregate shall be dried and heated to the temperature necessary to produce a mixture having the specified temperature.

(4) Mixing and Storage.

(a) Weigh-Batch Plant. In introducing the batch into the mixer, all aggregate shall be introduced first and shall be mixed thoroughly for a minimum period of five (5) seconds to uniformly distribute the various sizes throughout the batch before the asphaltic material is added. The asphaltic material shall then be added and the mixing continued for a wet mixing period of not less than 15 seconds. The mixing period shall be increased if, in the opinion of the Engineer, the mixture is not uniform or the aggregates are not properly coated.

Temporary storing or holding of the asphaltic mixture by the surge-storage system will be permitted during the normal day's operation. Overnight storage will not be permitted unless authorized in the plans or by the Engineer. The mixture coming out of the surge-storage bin shall be of equal quality to that coming out of the mixer.

(b) Modified Weigh-Batch Plant. The mixing and storage requirements shall be the same as is required for a standard weigh-batch plant.

(c) Drum-Mix Plant. The amount of aggregate and asphaltic material entering the mixer and the rate of travel through the mixing unit shall be so coordinated that a uniform mixture of the specified grading and asphalt content will be produced.

Temporary storing or holding of the asphaltic mixture by the surge-storage system will be required during the normal day's operation. Overnight storage will not be permitted unless authorized in the plans or by the Engineer. The mixture coming out of the surge-storage bin shall be of equal quality to that coming out of the mixer.

(d) Specialized Recycling Plant. The mixing and storage requirements shall be the same as that stated for the drum-mix plant.

(e) Discharge Temperature. The Engineer will select the target discharge temperature of the mixture between 120°C and 175°C. The mixture, when discharged from the mixer, shall not vary from this selected temperature more than 15°C, but in no case shall the temperature exceed 180°C.

(f) Moisture Content. The mixture produced from each type of mixer shall have a moisture content not greater than one (1) percent by mass when discharged from the mixer, unless otherwise shown on the plans and/or approved by the Engineer. The moisture content shall be determined in accordance with Test Method Tex-212-F.

(g) RAP. If RAP is used, it shall be mixed and blended so that there is no evidence of unseparated particles in the mixture as it leaves the mixer.

340.6. Construction Methods.

(1) General. It shall be the responsibility of the Contractor to produce, transport, place and compact the specified paving mixture in accordance with the requirements herein.

The asphaltic mixture, when placed with a spreading and finishing machine, or the tack coat shall not be placed when the air temperature is below 10°C and is falling, but it may be placed when the air temperature is above 5°C and is rising.

The asphaltic mixture, when placed with a motor grader, shall not be placed when the air temperature is below 15°C and is falling, but may be placed when the air temperature is above 10°C and is rising.

The air temperature shall be taken in the shade away from artificial heat.

Mat thicknesses of 40 millimeters and less shall not be placed when the temperature of the surface on which the mat is to be placed is below 10°C.

Mixtures with lightweight coarse aggregate shall not be placed when the temperature of the surface on which the mat is to be placed is below 10°C.

Additional surface temperature requirements may be shown on the plans.

It is further provided that the tack coat or asphaltic mixture shall be placed only when the humidity, general weather conditions and temperature and moisture condition of the base, in the opinion of the Engineer, are suitable.

If, after being discharged from the mixer and prior to placing, the temperature of the asphaltic mixture is 10°C or more below the selected discharge temperature established by the Engineer, all or any part of the load may be rejected and payment will not be made for the rejected material.

(2) Tack Coat. The surface upon which the tack coat is to be placed shall be cleaned thoroughly to the satisfaction of the Engineer. The surface shall be given a uniform application of tack coat using asphaltic materials of this specification. This tack coat shall be applied, as directed by the Engineer, with an approved sprayer at a rate not to exceed 0.2 liter residual asphalt per square meter of surface. Where the mixture will adhere to the surface on which it is to be placed without the use of a tack coat, the tack coat may be eliminated by the Engineer. All contact surfaces of curbs and structures and all joints shall be painted with a thin uniform application of tack coat. During the application of tack coat, care shall be taken to prevent splattering of adjacent pavement, curb and gutter and structures. The tack coat shall be rolled with a pneumatic tire roller when directed by the Engineer.

(3) Transporting Asphaltic Concrete. The asphaltic mixture shall be hauled to the work site in tight vehicles previously cleaned of all foreign material. The dispatching of the vehicles shall be arranged so that all material delivered is placed and all rolling completed during daylight hours unless otherwise shown on the plans. In cool weather or for long hauls, covering and insulating of the truck bodies may be required. If necessary, to prevent the mixture from adhering to the body, the inside of the truck may be given a light coating of release agent satisfactory to the Engineer.

(4) Placing.

(a) The asphaltic mixture shall be dumped and spread on the approved prepared surface with the spreading and finishing machine. When properly compacted, the finished pavement shall be smooth, of uniform texture and density and shall meet the requirements of the typical cross sections and the surface tests. In addition, the placing of the asphaltic mixture shall be done without tearing, shoving, gouging or segregating the mixture and without producing streaks in the mat.

Unloading into the finishing machine shall be controlled so that bouncing or jarring the spreading and finishing machine shall not occur and the required lines and grades shall be obtained without resorting to hand finishing, except as shown under Section 340.6.(4)(d).

Unless otherwise shown on the plans, dumping of the asphaltic mixture in a windrow and then placing the mixture in the finishing machine with windrow pick-up equipment will be permitted. The windrow pick-up equipment shall be operated in such a manner that substantially all the mixture deposited on the roadbed is picked up and loaded into the finishing machine without contamination by foreign material. The windrow pick-up equipment will be so operated that the finishing machine will obtain the required line, grade and surface without resorting to hand finishing. Any operation of the windrow pick-up equipment resulting in the accumulation and subsequent shedding of accumulated material into the asphaltic mixture will not be permitted.

(b) When approved by the Engineer, level-up courses may be spread with a motor grader.

(c) The spreading and finishing machine shall be operated at a uniform forward speed consistent with the plant production rate, hauling capability, and roller train capacity to result in a continuous operation. The speed shall be slow enough that stopping between trucks is not ordinarily required. If, in the opinion of the Engineer, sporadic delivery of material is adversely affecting the mat, the Engineer may require paving operations to cease until acceptable methods are provided to minimize starting and stopping of the paver.

The hopper flow gates of the spreading and finishing machine shall be adjusted to provide an adequate and consistent flow of material. These shall result in enough material being delivered to the augers so that they are operating approximately 85 percent of the time or more. The augers shall provide means to supply adequate flow of material to the center of the paver. Augers shall supply an adequate flow of material for the full width of the mat, as approved by the Engineer. Augers should be kept approximately one-half to three-quarters full of mixture at all times during the paving operation.

(d) When the asphaltic mixture is placed in a narrow strip along the edge of an existing pavement, or used to level up small areas of an existing pavement, or placed in small irregular areas where the use of a finishing machine is not practical, the finishing machine may be eliminated when authorized by the Engineer.

(e) Adjacent to flush curbs, gutters and structures, the surface shall be finished uniformly high so that when compacted it will be slightly above the edge of the curb or structure.

(f) Construction joints of successive courses of asphaltic material shall be offset at least 150 millimeters. Construction joints on surface courses shall coincide with lane lines, or as directed by the Engineer.

(g) If a pattern of surface irregularities or segregation is detected, the Contractor shall make an investigation into the causes and immediately take the necessary corrective action. With the approval of the Engineer, placement may continue for no more than one full production day from the time the Contractor is first notified and while corrective actions are being taken. If the problem still exists after that time, paving shall cease until the Contractor further investigates the causes and the Engineer approves further corrective action to be taken.

(5) Compacting.

(a) The pavement shall be compacted thoroughly and uniformly with the necessary rollers to obtain the compaction and cross section of the finished paving mixture meeting the requirements of the plans and specifications.

(b) When rolling with the three-wheel, tandem or vibratory rollers, rolling shall start by first rolling the joint with the adjacent pavement and then continue by rolling longitudinally at the sides and proceed toward the center of the pavement, overlapping on successive trips by at least 300 millimeters, unless otherwise directed by the Engineer. Alternate trips of the roller shall be slightly different in length. On super-elevated curves, rolling shall begin at the low side and progress toward the high side, unless otherwise directed by the Engineer.

When rolling with vibratory steel-wheel rollers, equipment operation shall be in accordance with Item 217, "Rolling (Vibratory)", and the manufacturer's recommendations, unless otherwise directed by the Engineer. Vibratory rollers shall not be left vibrating while not rolling or when changing directions. Unless otherwise shown on the plans or approved by the Engineer, vibratory rollers shall not be allowed in the vibrating mode on mats with a plan depth of less than 40 millimeters.

The motion of the rollers shall be slow enough to avoid other than usual initial displacement of the mixture. If any displacement occurs, it shall be corrected to the satisfaction of the Engineer. The roller shall not be allowed to stand on pavement which has not been fully compacted. To prevent adhesion of the surface mixture to the steel-wheel rollers, the wheels shall be kept thoroughly moistened with water, but an excess of water will not be permitted. Necessary precautions shall be taken to prevent the dropping of diesel, gasoline, oil, grease or other foreign matter on the pavement, either when the rollers are in operation or when standing.

(c) The edges of the pavement along curbs, headers and similar structures, and all places not accessible to the roller, or in such positions as will not allow thorough compaction with the rollers, shall be thoroughly compacted with lightly oiled tamps.

(d) Rolling with a trench roller will be required on widened areas, in trenches and other limited areas where satisfactory compaction cannot be obtained with the approved rollers.

(6) In-Place Compaction Control. In-place compaction control is required for all mixtures. Unless otherwise shown on the plans, air void control shall be required.

(a) Air Void Control. The Contractor shall be responsible for determining the number and type of rollers to be used to obtain compaction to within the air void range required herein. The rollers shall be operated in accordance with the requirements of this specification and as approved by the Engineer.

Unless otherwise shown on the plans, rolling with a pneumatic-tire roller to seal the surface shall be provided. Rolling with a tandem or other steel-wheel roller shall be provided if required to iron out any roller marks.

Asphaltic concrete shall be placed and compacted to contain from five (5) to nine (9) percent air voids. The percent air voids will be calculated using the maximum theoretical specific gravity of the mixture determined according to Test Method Tex-227-F. Roadway specimens, which shall be either cores or sections of asphaltic pavement, will be tested according to Test Method Tex-207-F. The nuclear-density gauge or other methods which correlate satisfactorily with results obtained from project roadway specimens may be used when approved by the Engineer. Unless otherwise shown on the plans, the Contractor shall be responsible for obtaining the required roadway specimens at his expense and in a manner and at locations selected by the Engineer.

If the percent air voids in the compacted placement is greater than nine (9) percent but is 10 percent or less, production may proceed with subsequent changes in the construction operations and/or mixture. If the air void content is not reduced to between five (5) and nine (9) percent within one production day from the time the Contractor is notified, production shall cease. At that point, a test section as described below shall be required.

If the percent air voids is more than 10 percent, production shall cease immediately and a test section shall be required as described below.

In either case, the Contractor shall only be allowed to place a test section of one lane width, not to exceed 300 meters in length, to demonstrate that compaction to between five (5) and nine (9) percent air voids can be obtained. This procedure will continue until a test section with five (5) to nine (9) percent air voids can be produced. Only two (2) test sections per day will be allowed. When a test section producing satisfactory air void content is placed, full production may then resume.

Increasing the asphalt content of the mixture in order to reduce pavement air voids will not be allowed.

If the percent air voids is determined to be less than five (5) percent, immediate adjustments shall be made to the plant production by the Contractor, as approved by the Engineer, within the tolerances as outlined in Subarticle 340.3.(4), so that an adequate air void level results.

The Contractor is encouraged to perform supplemental compaction testing for his own information.

(b) Ordinary Compaction Control. When the requirement of air void control has been removed by plan note, one (1) three-wheel roller, one (1) pneumatic-tire roller, and one (1) tandem roller shall be furnished for each compaction operation except as provided below or approved by the Engineer. The use of a tandem roller may be waived by the Engineer when the surface is already adequately smooth and further steel-wheel rolling is shown to be ineffective. With approval of the Engineer, the Contractor may substitute a vibratory roller for the three-wheel roller and/or the tandem roller. Use of at least one (1) pneumatic-tire roller is required. Additional or heavier rollers shall be furnished if required by the Engineer.

Rolling patterns shall be established by the Contractor as outlined in Test Method Tex-207-F, Part IV, to achieve the maximum compaction, unless otherwise directed by the Engineer. The selected rolling pattern shall be followed unless changes in the mixture or placement conditions occur which affect compaction. When changes in the mixture or placement conditions occur, a new rolling pattern shall be established.

(c) Compaction Cessation Temperature. Regardless of the method required for in-place compaction control, all rolling for compaction shall be completed before the mixture temperature drops below 80°C.

(7) Ride Quality. Unless otherwise shown on the plans, Ride Quality will be required in accordance with Item 585, "Ride Quality for Pavement Surfaces".

(8) Opening to Traffic. The pavement shall be opened to traffic when directed by the Engineer. The Contractor's attention is directed to the fact that all construction traffic allowed on the pavement open to the public will be subject to the State laws governing traffic on highways.

If the surface ravels, flushes, ruts or deteriorates in any manner prior to final acceptance of the work, it will be the Contractor's responsibility to correct this condition at his expense, to the satisfaction of the Engineer and in conformance with the requirements of this specification.

340.7. Measurement. The quantity of asphaltic concrete will be measured by the composite mass or composite volumetric method.

(1) Composite Mass Method. Asphaltic concrete will be measured by the megagram of the composite "Asphaltic Concrete" of the type actually used in the completed and accepted work in accordance with the plans and specifications for the project. The composite asphaltic concrete mixture is hereby defined as the asphalt, aggregate, RAP and additives as noted in the plans and/or approved by the Engineer.

If mixing is done by a drum-mix plant or specialized recycling plant, measurement will be made on scales as specified herein.

If mixing is done by a weigh-batch plant or modified weigh-batch plant, measurement will be determined on the batch scales unless surge-storage is used. Records of the number of batches, batch design and the mass of the composite "Asphaltic Concrete" shall be kept. Where surge-storage is used, measurement of the material taken from the surge-storage bin will be made on truck scales or suspended hopper scales.

(2) Composite Volumetric Method. The asphaltic concrete will be measured by the cubic meter of compacted "Asphaltic Concrete" of the type actually used in the completed and accepted work in accordance with the plans and specifications for the project. The composite asphaltic concrete mixture is hereby defined as the asphalt, aggregate, RAP and additives as noted in the plans and/or approved by the Engineer. The volume of the composite asphaltic concrete mixture shall be calculated by the following formula:

$$V = \frac{W}{1000\ G_a}$$

V = Cubic meters of compacted "Asphaltic Concrete"
W = Total mass of asphaltic concrete in kilograms
G_a = Average actual specific gravity of three (3) molded specimens as prepared by Test Method Tex-206-F and determined in accordance with Test Method Tex-207-F.

If mixing is done by a drum-mix plant or specialized recycling plant, the mass "W" will be determined by scales as specified herein.

If mixing is done by a weigh-batch plant or modified weigh-batch plant and surge-storage is not used, mass will be determined by batch scales and records of the number of batches, batch designs and mass of asphalt and aggregate shall be kept. Where surge-storage is used, measurement of the material taken from the surge-storage bin will be made on truck scales or suspended hopper scales.

(3) **Ride Quality.** Ride quality will be measured as described in Item 585, "Ride Quality for Pavement Surfaces".

340.8. Payment.

(1) The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for the "Asphaltic Concrete" of the type specified.

Measurement Method	Bid Item	Unit of Measure
Composite Mass	Asphaltic Concrete	Megagram
Composite Volumetric	Asphaltic Concrete	Cubic Meter

The payment based on the unit bid price shall be full compensation for quarrying, furnishing all materials, additives, freight involved, for all heating, mixing, hauling, cleaning the existing base course or pavement, tack coat, placing, rolling and finishing asphaltic concrete mixture, transporting RAP from designated sources, transporting any excess RAP to locations shown on the plans, and for all manipulations, labor, tools, equipment and incidentals necessary to complete the work.

(2) When surface Test Type-B, as specified in Item 585, "Ride Quality for Pavement Surfaces", is used, a bonus or deduction for each 0.1609 kilometer section of each travel lane will be calculated in dollars and cents. A running total of this will be determined for each day's production. The bonus or deduction for ride quality will be paid for separately from the payment for the material placed.

(3) All templates, straightedges, core drilling equipment, scales and other weighing and measuring devices necessary for the proper construction, measuring and checking of the work shall be furnished, operated and maintained by the Contractor at his expense.

(4) State owned RAP from sources designated on the plans will be available at no cost to the Contractor.

ITEM 342

PLANT MIX SEAL

342.1. Description. This Item shall govern for the construction of a wearing surface composed of a compacted mixture of aggregate and asphalt cement mixed hot in a mixing plant, in accordance with the details shown on the plans and the requirements herein.

342.2. Materials. The Contractor shall furnish materials to the project meeting the following requirements prior to mixing. Additional test requirements affecting the quality of individual materials or the plant mix seal mixture shall be required when indicated on the plans.

(1) Aggregate.

(a) Description. Except for gradation limitations, aggregates shall conform to the material requirements of Item 302, "Aggregates for Surface Treatments", or Item 303, "Aggregate for Surface Treatments (Lightweight)". Gravel used as coarse aggregate shall be so crushed as to have a minimum of 85 percent of the particles retained on the 4.75 millimeter sieve having two (2) or more mechanically induced crushed faces, as determined by Test Method Tex-460-A, Part I.

When aggregate requiring polish value is supplied from a source that is rated by the Materials and Tests Division, the Rated Source Polish Value (RSPV) catalog will be used to determine polish value compliance.

When aggregate is supplied from a source that is not rated, the aggregate will be sampled and tested prior to use. The procedures will be in accordance with Test Methods Tex-400-A and Tex-438-A, Part I. The test value will not be less than the value shown on the plans.

Blending of aggregates to achieve polish value will not be permitted, unless otherwise shown on the plans. If blending is allowed, Test Method Tex-438-A, Part II, Method B will be used to determine the required blend percentages.

(b) **Grades.** The aggregate gradation shall conform to the master gradation limits for the grade shown on the plans:

		Percent by Mass or Volume
Grade 1:	Retained on 16.0 mm sieve	0
	Retained on 12.5 mm sieve	0-5
	Retained on 9.5 mm sieve	20-50
	Retained on 4.75 mm sieve	92-100
	Retained on 2.00 mm sieve	96-100
*Grade 2:	Retained on 16.0 mm sieve	0
	Retained on 12.5 mm sieve	0-5
	Retained on 9.5 mm sieve	20-50
	Retained on 4.75 mm sieve	80-95
	Retained on 2.00 mm sieve	85-95

Grade 3: As shown on plans

* Grade 2 aggregate may include fine aggregate meeting the requirements of Section 340.2.(1)(c). A maximum of 10.0 percent by mass or volume of fine aggregate may be required by the Engineer. The bulk specific gravity will be determined for each aggregate to be used in the mixture. If the determined values vary by 0.300 or more, the mixture proportions will be by the Volumetric Method, Test Method Tex-204-F, Part II.

Unless otherwise shown on the plans, the gradation of the aggregate determined in accordance with Test Method Tex-200-F (Dry Sieve Analysis) shall meet the above requirements prior to plant mixing with asphaltic material.

(2) Asphaltic Materials.

(a) The asphaltic material for plant mix seal shall be asphalt cement meeting the requirements of Item 300, "Asphalts, Oils and Emulsions". The grade of asphalt shall be designated by the Engineer after design tests have been made with the proposed aggregates. The Contractor shall notify the Engineer of the source of asphaltic material prior to design of the plant mix seal. This source shall not be changed during the course of the project, except on written permission by the Engineer.

(b) Tack Coat. Asphaltic materials shown on the plans or approved by the Engineer shall meet the requirements of Item 300, "Asphalts, Oils and Emulsions".

(3) Additives. Additives to facilitate mixing and/or improve the quality of the plant mix seal or tack coat shall be used when noted on the plans or may be used with the authorization of the Engineer.

Unless otherwise shown on the plans, the Contractor may choose to use either lime or a liquid antistripping agent to reduce the moisture susceptibility of the aggregate. The evaluation and addition of antistripping agents will be in accordance with Item 301, "Asphalt Antistripping Agents".

342.3. Plant Mix Seal Surfacing Mixture.

(1) General. The mixture shall be uniform and consist of aggregate and asphalt cement. The Engineer will select the asphalt content to be used in the mixture after tests have been made with the proposed aggregates.

Unless otherwise shown on the plans, the mixture of aggregate, asphalt and additives proposed for use will be evaluated in the design stage for moisture susceptibility in accordance with Item 301, "Asphalt Antistripping Agents". The Engineer may waive this test if a similar design, using the same ingredients, has proven satisfactory.

(2) Tolerances. The gradation of the aggregate shall not vary from the master gradation limits for the specified grade. The asphalt content of the mixture shall not vary from the asphalt content selected by the Engineer by more than 0.7 percent by mass or 1.7 percent by volume, when tested in accordance with Test Method Tex-210-F or Test Method Tex-228-F. If the plant mix seal produced varies from the asphalt content tolerance, adjustments shall be made by the Contractor until the plant mix seal meets this requirement.

342.4. Equipment.

(1) **General.** All equipment for the handling of all materials, mixing, placing and compacting of the plant mix seal shall be maintained in good repair and operating condition and subject to the approval of the Engineer. Any equipment found to be defective and potentially having a negative effect on the quality of the plant mix seal will not be allowed.

(2) **Mixing Plants.** Mixing plants may be the weigh-batch type, the modified weigh-batch type, or the drum-mix type. All plants shall be equipped with satisfactory conveyors, power units, mixing equipment, aggregate handling equipment, bins and dust collectors.

Automatic proportioning devices are required for all plants and shall be in accordance with Item 520, "Weighing and Measuring Equipment".

It shall be the Contractor's responsibility to provide safe and accurate means to enable inspection forces to take all required samples, to provide permanent means for checking the output of any specified metering device, and to perform calibration and mass checks as required by the Engineer.

When using fuel oil heavier than Grade No. 2, or waste oil, the Contractor shall insure that the fuel delivered to the burner is at a viscosity of 100 SSU or less, when tested in accordance with Test Method Tex-534-C, to insure complete burning of the fuel. Higher viscosities will be allowed if recommended by the burner manufacturer. If necessary, the Contractor shall preheat the oil to maintain the required viscosity.

The Contractor shall provide means for obtaining a sample of the fuel, just prior to entry into the burner, in order to perform the viscosity test. The Contractor shall perform this test or provide a laboratory test report that will establish the temperature of the fuel necessary to meet the viscosity requirements. There shall be an in-line thermometer to check the temperature of the fuel delivered to the burner.

Regardless of the burner fuel used, the burner or combination of burners and types of fuel used shall provide a complete burn of the fuel and not leave any fuel residue that will adhere to the heated aggregate.

(a) **Weigh-Batch Type.**

Cold Aggregate Bin Unit and Proportioning Device. The cold aggregate bin unit shall have a separate bin for each aggregate which is of sufficient size to store the amount of aggregate required to keep the plant in continuous operation and of proper design to prevent overflow of material from one bin to another. There shall be vertical partitions between each bin and on each end of the bins of sufficient height so that any overflow will be to the front and back, and not allow overflow to the sides or between bins. Overflow that might occur shall not fall onto any feeder belt. The proportioning device shall provide a uniform and continuous flow of aggregate in the desired proportion to the dryer. Each aggregate shall be proportioned from a separate bin.

Dryer. The dryer shall continually agitate the aggregate during heating. The temperature shall be controlled so that the aggregate will not be damaged in the drying and heating operations. The dryer shall be of sufficient size to keep the plant in continuous operation.

Screening and Proportioning. The screening capacity and size of the hot aggregate bins shall be sufficient to screen and store the amount of aggregate required to properly operate the plant and keep the plant in continuous operation at full capacity. The hot bins shall be constructed so that oversize and overloaded material will be discarded through overflow chutes. Provisions shall be made to enable inspection forces to have easy and safe access to the proper location on the mixing plant where representative samples may be taken from the hot bins for testing.

Aggregate Weigh Box and Batching Scale. The aggregate weigh box and batching scales shall be of sufficient capacity to hold and weigh a complete batch of aggregate. The weigh box and scales shall conform to the requirements of Item 520, "Weighing and Measuring Equipment".

Asphaltic Material Measuring System. If an asphaltic material bucket and scales are used, they shall be of sufficient capacity to hold and weigh the necessary asphaltic material for one batch. The bucket and scales shall conform to the requirements of Item 520, "Weighing and Measuring Equipment".

If a pressure type flow meter is used to measure the asphaltic material, the requirements of Item 520, "Weighing and Measuring Equipment", shall apply. This system shall include an automatic temperature compensation device to insure a constant percent by mass of asphaltic material in the plant mix seal.

Provisions of a permanent nature shall be made for checking the accuracy of the asphaltic material measuring device. The asphalt line to the measuring device shall be protected with a jacket of hot oil or other approved means to maintain the temperature of the line near the temperature specified for the asphaltic material.

Mixer. The mixer shall be of the pugmill type and shall have a capacity of not less than 1350 kilograms (of natural-aggregate mixture) in a single batch, unless otherwise shown on the plans. Any mixer that has a tendency to segregate the aggregate or fails to secure a thorough and uniform mixture with the asphaltic material shall not be used. All mixers shall be provided with an automatic timer that will lock the discharge doors of the mixer for the required mixing period. The dump door or doors and the shaft seals of the mixer shall be tight enough to prevent spilling of aggregate or mixture from the pugmill.

Surge-Storage System and Scales. A surge-storage system may be used to minimize the production interruptions during the normal day's operations. A device such as a gob hopper or other device approved by the Engineer to prevent segregation in the surge-storage bin shall be used. The plant mix seal shall be weighed upon discharge from the surge-storage system.

When a surge-storage system is used, scales shall be standard platform truck scales or other equipment such as weigh hopper (suspended) scales and shall conform to Item 520, "Weighing and Measuring Equipment". If truck scales are used, they shall be placed at a location approved by the Engineer. If other weighing equipment is used, the Engineer may require mass checks by truck scales for the basis of approval of the equipment.

Recording Device and Record Printer. The plant mix seal shall be weighed for payment. If a surge-storage system is used, an automatic recording device and a digital record printer shall be provided to indicate the date, project identification number, vehicle identification, total mass of the load, tare mass of the vehicle, the mass of plant mix seal in each load and the number of loads for the day, unless otherwise indicated on the plans. When surge-storage is not used, batch mass shall be used as the basis for payment and automatic recording devices and automatic digital record printers in accordance with Item 520, "Weighing and Measuring Equipment", shall be required.

(b) Modified Weigh-Batch Type.

General. This plant is similar to the weigh-batch type plant. The hot bin screens shall be removed and the aggregate control is placed at the cold feeds. The cold feed bins will be the same as those required for the drum-mix type plant.

Cold-Aggregate Bin Unit and Feed System. The number of bins in the cold-aggregate bin unit shall be equal to or greater than the number of stockpiles of individual materials to be used.

The bins shall be of sufficient size to store the amount of aggregate required to keep the plant in continuous operation and of proper design to prevent overflow of material from one bin to another. There shall be vertical partitions between each bin and on each end of the bins of sufficient height so that any overflow will be to the front and back and not allow overflow to the sides or between bins. Overflow that might occur shall not fall onto any feeder belt. The feed system shall provide a uniform and continuous flow of aggregate in the desired proportion to the dryer. The Contractor shall furnish a chart indicating the calibration of each cold bin in accordance with the manufacturer's recommendation, or other methods of cold bin calibration acceptable to the Engineer, when more than one bin is to be used.

Scalping Screen. A scalping screen shall be required after the cold feeds and ahead of the hot aggregate surge bins.

Dryer. The dryer shall continually agitate the aggregate during heating. The temperature shall be controlled so that the aggregate will not be damaged in the drying and heating operations. The dryer shall be of sufficient size to keep the plant in continuous operation.

Screening and Proportioning. The hot aggregate shall not be separated into sizes after being dried. There shall be one or more surge bins provided between the dryer and the weigh hopper. Surge bins shall be of sufficient size to hold enough combined aggregate for one complete batch of plant mix seal.

Aggregate Weigh Box and Batching Scale. The aggregate weigh box and batching scales shall be of sufficient capacity to hold and weigh a complete batch of aggregate. The weigh box and scales shall conform to the requirements of Item 520, "Weighing and Measuring Equipment".

Asphaltic Material Measuring System. If an asphaltic material bucket and scales are used, they shall be of sufficient capacity to hold and weigh the necessary asphaltic material for one batch. The bucket and scales shall conform to the requirements of Item 520, "Weighing and Measuring Equipment".

If a pressure type flow meter is used to measure the asphaltic material, the requirements of Item 520, "Weighing and Measuring Equipment", shall apply. This system shall include an automatic temperature compensation device to insure a constant percent by mass of asphaltic material in the mixture.

Provisions of a permanent nature shall be made for checking the accuracy of the asphaltic material measuring device. The asphalt line to the measuring device shall be protected with a jacket of hot oil or other approved means to maintain the temperature of the line near the temperature specified for the asphaltic material.

Mixer. The mixer shall be of the pugmill type and shall have a capacity of not less than 1350 kilograms (of natural-aggregate mixture) in a single batch, unless otherwise shown on the plans. Any mixer that has a tendency to segregate the aggregate or fails to secure a thorough and uniform mixture with the asphaltic material shall not be used. All mixers shall be provided with an automatic timer that will lock the discharge doors of the mixer for the required mixing period. The dump door or doors and the shaft seals of the mixer shall be tight enough to prevent spilling of aggregate or mixture from the pugmill.

Surge-Storage System and Scales. A surge-storage system may be used to minimize the production interruptions during the normal day's operations. A device such as a gob hopper or other device approved by the Engineer to prevent segregation in the surge-storage bin shall be used. The plant mix seal shall be weighed upon discharge from the surge-storage system.

When a surge-storage system is used, scales shall be standard platform truck scales or other equipment such as weigh hopper (suspended) scales and shall conform to Item 520, "Weighing and Measuring Equipment". If truck scales are used, they shall be placed at a location approved by the Engineer. If other weighing equipment is used, the Engineer may require mass checks by truck scales for the basis of approval of the equipment.

Recording Device and Record Printer. The plant mix seal shall be weighed for payment. If a surge-storage system is used, an automatic recording device and a digital record printer shall be provided to indicate the date, project identification number, vehicle identification, total mass of the load, tare mass of the vehicle, the mass of plant mix seal in each load and the number of loads for the day, unless otherwise indicated on the plans. When surge-storage is not used, batch mass shall be used as the basis for payment and automatic recording devices and automatic digital record printers in accordance with Item 520, "Weighing and Measuring Equipment", shall be required.

(c) Drum-Mix Type.

General. The plant shall be adequately designed and constructed for the process of mixing aggregates and asphalt. The plant shall be equipped with satisfactory conveyors, power units, aggregate-handling equipment and feed controls.

Cold-Aggregate Bin Unit and Feed System. The number of bins in the cold-aggregate bin unit shall be equal to or greater than the number of stockpiles of individual materials to be used.

The bins shall be of sufficient size to store the amount of aggregate required to keep the plant in continuous operation and of proper design to prevent overflow of material from one bin to another. There shall be vertical partitions between each bin and on each end of the bins of sufficient height so that any overflow will be to the front and back and not allow overflow to the sides or between bins. Overflow that might occur shall not fall onto any feeder belt. The feed system shall provide a uniform and continuous flow of aggregate in the desired proportion to the mixer. The Contractor shall furnish a chart indicating the calibration of each cold bin in accordance with the manufacturer's recommendation, or other methods of cold bin calibration acceptable to the Engineer, when more than one bin is used.

The system shall provide positive mass measurement of the combined cold-aggregate feed by use of belt scales or other approved devices. Provisions of a permanent nature shall be made for checking the accuracy of the measuring device as required by Item 520, "Weighing and Measuring Equipment". When a belt scale is used, plant mix seal production shall be maintained so that the scale normally operates between 50 percent and 100 percent of its rated capacity. Belt scale operation below 50 percent of the rated capacity may be allowed by the Engineer if accuracy checks show the scale to meet the requirements of Item 520, "Weighing and Measuring Equipment", at the selected rate. It shall be satisfactorily demonstrated to the Engineer that plant mix seal uniformity and quality have not been adversely affected.

Scalping Screen. A scalping screen shall be required after the cold feeds and ahead of the combined aggregate belt scales.

Asphaltic Material Measuring System. An asphaltic material measuring device meeting the requirements of Item 520, "Weighing and Measuring Equipment", shall be placed in the asphalt line leading to the mixer so that the cumulative amount of asphalt used can be accurately determined. Provisions of a permanent nature shall be made for checking the accuracy of the measuring device output. The asphalt line to the measuring device shall be protected with a jacket of hot oil or other approved means to maintain the temperature of the line near the temperature specified for the asphaltic material. The measuring system shall include an automatic temperature compensation device to maintain a constant percent by mass of asphaltic material in the plant mix seal.

Synchronization Equipment for Feed-Control Systems. The asphaltic material feed-control shall be coupled with the total aggregate mass measuring device to automatically vary the asphalt-feed rate in order to maintain the required proportion.

Mixing System. The mixing system shall control the temperature so that the aggregate and asphalt will not be damaged in the drying, heating and mixing operations. A continuously recording thermometer shall be provided which will indicate the temperature of the plant mix seal as it leaves the mixer.

Surge-Storage System and Scales. A surge-storage system shall be used to minimize the production interruptions during the normal day's operations. A device such as a gob hopper or other device approved by the Engineer to prevent segregation in the surge-storage bin shall be used. The plant mix seal shall be weighed upon discharge from the surge-storage system.

Scales shall be standard platform truck scales or other equipment such as weigh hopper (suspended) scales and shall conform to Item 520, "Weighing and Measuring Equipment". If truck scales are used, they shall be placed at a location approved by the Engineer. If other weighing equipment is used, the Engineer may require mass checks by truck scales for the basis of approval of the equipment.

Recording Device and Record Printer. Automatic recording devices and automatic digital record printers shall be provided to indicate the date, project identification number, vehicle identification, total mass of the load, tare mass of the vehicle, the mass of plant mix seal in each load and the number of loads for the day in accordance with Item 520, "Weighing and Measuring Equipment", unless otherwise shown on the plans.

(3) Asphaltic Material Heating Equipment. Asphaltic material heating equipment shall be adequate to heat the required amount of asphaltic material to the desired temperature. The heating apparatus shall be equipped with a continuously recording thermometer with a 24-hour chart that will record the temperature of the asphaltic material at the location of highest temperature.

(4) Spreading and Finishing Machine. The spreading and finishing machine shall be approved by the Engineer and shall meet the requirements indicated below.

(a) Screed Unit. The spreading and finishing machine shall be equipped with a heated compacting screed. It shall produce a finished surface meeting the requirements of the typical cross sections.

Extensions added to the screed shall be provided with the same compacting action and heating capability as the main screed unit, except for use on variable depth tapered areas and/or as approved by the Engineer.

The spreading and finishing machine shall be equipped with an approved automatic dual longitudinal screed control system and automatic transverse screed control system. The longitudinal controls shall be capable of operating from any longitudinal grade reference including a stringline, ski, mobile stringline, or matching shoe.

The Contractor shall furnish all equipment required for grade reference. It shall be maintained in good operating condition by personnel trained in the use of this type of equipment.

The grade reference used by the Contractor may be of any type approved by the Engineer. Control points, if required by the plans, shall be established for the finished profile in accordance with Item 5, "Control of the Work". These points shall be set at intervals not to exceed 15 meters. The Contractor shall set the grade reference from the control points. The grade reference shall have sufficient support so that the maximum deflection shall not exceed two (2) millimeters between supports.

(b) **Tractor Unit.** The tractor unit shall be equipped with a hydraulic hitch sufficient in design and capacity to maintain contact between the rear wheels of the hauling equipment and the pusher rollers of the finishing machine while the plant mix seal is being unloaded.

No portion of the mass of hauling equipment, other than the connection, shall be supported by the asphalt paver. No vibrations or other motions of the loading equipment, which could have a detrimental effect on the riding quality of the completed pavement, shall be transmitted to the paver.

The use of any vehicle which requires dumping directly into the finishing machine and which the finishing machine cannot push or propel to obtain the desired lines and grades without resorting to hand finishing will not be allowed.

(5) **Rollers.** Rollers provided shall meet the requirements for their type as follows:

(a) **Two-Axle Tandem Roller.** This roller shall be an acceptable self-propelled tandem roller.

(b) **Three-Wheel Roller.** This roller shall be an acceptable self-propelled three wheel roller.

(c) **Three-Axle Tandem Roller.** This roller shall be an acceptable self-propelled three axle roller.

(6) Straightedges and Templates. When directed by the Engineer, the Contractor shall provide acceptable 3-meter straightedges for surface testing. Satisfactory templates shall be provided as required by the Engineer.

(7) Alternate Equipment. When permitted by the Engineer, equipment other than that specified herein which will consistently produce satisfactory results may be used.

342.5. Stockpiling, Storage and Mixing.

(1) Stockpiling of Aggregates. Prior to stockpiling of aggregates, the area shall be cleaned of trash, weeds, grass and shall be relatively smooth and well drained. The stockpiling shall be done in a manner that will minimize aggregate degradation, segregation, mixing of one stockpile with another, and will not allow contamination with foreign material.

The plant shall have at least a two-day supply of aggregates on hand before production can begin and at least a two-day supply shall be maintained through the course of the project, unless otherwise directed by the Engineer.

No stockpile shall contain aggregate from more than one source.

When required by the Engineer, additional material shall not be added to stockpiles that have previously been sampled for approval.

Equipment of an acceptable size and type shall be furnished to work the stockpiles and prevent segregation and degradation of the aggregates.

(2) Storage and Heating of Asphaltic Materials. The asphaltic material storage capacity shall be ample to meet the requirements of the plant. Asphalt shall not be heated to a temperature in excess of that specified in Item 300, "Asphalts, Oils and Emulsions". All equipment used in the storage and handling of asphaltic material shall be kept in a clean condition at all times and shall be operated in such a manner that there will be no contamination with foreign matter.

(3) Feeding and Drying of Aggregate. The feeding of various sizes of aggregate to the dryer shall be done through the cold aggregate bins and the proportioning device in such a manner that a uniform and constant flow of materials in the required proportions will be maintained. The aggregate shall be dried and heated to the temperature necessary to produce a plant mix seal having the specified temperature.

(4) Mixing and Storage.

(a) Weigh-Batch Plant. In introducing the batch into the mixer, all aggregate shall be introduced first and shall be mixed thoroughly for a minimum period of five (5) seconds to uniformly distribute the various sizes throughout the batch before the asphaltic material is added. The asphaltic material shall then be added and the mixing continued for a wet mixing period of not less than 15 seconds. The mixing period shall be increased if, in the opinion of the Engineer, the plant mix seal is not uniform or the aggregates are not properly coated.

Temporary storing or holding of the plant mix seal by the surge-storage system will be permitted during the normal day's operation. The plant mix seal coming out of the surge-storage bin shall be of equal quality to that coming out of the mixer.

(b) Modified Weigh-Batch Plant. The mixing and storage requirements shall be the same as is required for a standard weigh-batch plant.

(c) Drum-Mix Plant. The amount of aggregate and asphaltic material entering the mixer and the rate of travel through the mixing unit shall be so coordinated that a uniform mixture of the specified grading and asphalt content will be produced.

Temporary storing or holding of the plant mix seal by the surge-storage system will be required during the normal day's operation. The plant mix seal coming out of the surge-storage bin shall be of equal quality to that coming out of the mixer.

(d) Discharge Temperature. The plant mix seal shall be at a temperature between 80°C and 130°C when discharged from the mixer. The Engineer will designate the temperature within the above limitations, and the mixture when discharged from the mixer shall not vary from this selected temperature more than 5°C. The temperature of the plant mix seal shall not be less than 80°C when placed on the road.

(e) **Moisture Content.** The plant mix seal shall have a moisture content not greater than three (3) percent by mass when discharged from the mixer, unless otherwise shown on the plans and/or approved by the Engineer. The moisture content shall be determined in accordance with Test Method Tex-212-F.

342.6. Construction Methods. Tack coat and/or plant mix seal may be placed only when the temperature of the surface to be overlaid is 15°C or more, and the air temperature is above 10°C and rising, but shall not be placed when the air temperature is below 15°C and falling. The air temperature will be taken in the shade away from artificial heat. It is further provided that the tack coat or plant mix seal shall be placed only when the humidity, general weather conditions and moisture condition of the pavement surface, in the opinion of the Engineer, are suitable.

(1) **Tack Coat.** Before the plant mix seal is laid, the surface upon which the tack coat is to be placed shall be cleaned thoroughly to the satisfaction of the Engineer. The surface shall be given a uniform application of tack coat using asphaltic materials of this specification. This tack coat shall be applied, as directed by the Engineer, with an approved sprayer at a rate not to exceed 0.3 liter per square meter of surface area. Where the plant mix seal will adhere to the surface on which it is to be placed without the use of a tack coat, the tack coat may be eliminated by the Engineer. The tack coat shall be rolled with a pneumatic tire roller when directed by the Engineer.

(2) **Transporting Plant Mix Seal Surfacing Mixture.** The plant mix seal, prepared as specified above, shall be hauled to the work site in tight vehicles previously cleaned of all foreign material. The dispatching of vehicles shall be arranged so that all material delivered may be placed and all rolling shall be completed during daylight hours. Covers and insulated truck beds shall be required, unless otherwise shown on the plans. If necessary to prevent the plant mix seal from adhering to the bed, the inside of the truck bed shall be given a light coating of release agent satisfactory to the Engineer.

(3) **Placing.** The plant mix seal shall be dumped directly into the specified spreading and finishing machine and spread on the approved prepared surface in such a manner that, when properly compacted, the finished surface will be smooth and of uniform texture and density. The spreading and finishing machine shall be operated at a speed satisfactory to the Engineer. If, in the opinion of the Engineer, sporadic delivery of plant mix seal adversely affects the quality of the work or unduly lengthens the

time the traffic is restricted from full use of the through lanes, laying operations shall cease and traffic shall be fully restored to the through lanes until consistent delivery of the plant mix seal is provided by the Contractor. During application of tack coat and plant mix seal, care shall be taken to prevent splattering of adjacent pavement, curb and gutter and structures.

(4) Compacting. Immediately following placement of the plant mix seal, the surface shall be rolled with a tandem or three wheel roller of such mass as to accomplish a good seating without excessive breakage of the aggregate. The speed and motion of the rollers shall be such as to avoid displacement of the plant mix seal. If any displacement occurs, it shall be corrected to the satisfaction of the Engineer. To prevent adhesion of the plant mix seal to the roller, the wheels shall be kept thoroughly moistened with a soap-water solution. Necessary precautions shall be taken to prevent the dropping of gasoline, oil, grease or other foreign matter on the pavement, either when the rollers are in operation or when standing. Sprinkling of the fresh mat shall be required when directed by the Engineer, to expedite opening the roadway to traffic. Sprinkling shall be with water or lime-water solution, as directed by the Engineer.

342.7. Measurement. The plant mix seal will be measured separately by the megagram of "Asphalt" and by the cubic meter or by the megagram, shown on the plans, of dry, loose "Aggregate" of the types and/or grades used in the completed and accepted work in accordance with the plans and specifications for the project.

Asphalt. The mass of asphalt cement will be calculated from the measured mass of plant mix seal surfacing mixture using the selected percentages of asphalt.

Aggregate by Volume. The volume of aggregate will be calculated from the measured mass of the plant mix seal surfacing mixture by use of the following formula:

$$V = \frac{(W - A)}{K}$$

Where:

V = Volume of dry, loose aggregate in cubic meters.

W = Total mass of plant mix seal surfacing mixture in kilograms, less any moisture contained in the mixture as determined by Test Method Tex-212-F, Part II.

A = Mass of asphalt cement in kilograms.

K = Oven dry unit weight of aggregate in kilograms per cubic meter.

The value "K" will be determined by Method A, unless otherwise shown on the plans.

Method A

The oven dry unit weight will be determined in accordance with Test Method Tex-404-A, "Determination for Unit Weight of Aggregate". The moisture content of the aggregate will be determined by Test Method Tex-212-F, Part II.

Method B

The oven dry unit weight will be determined by obtaining the mass and volume of a three (3) cubic meter or larger size sample of aggregate. This may be accomplished by placing the aggregate in the bed of a haul truck, or other acceptable container, and uniformly leveling the material across the top of the container. The moisture content of the aggregate will be determined by Test Method Tex-212-F, Part II.

The value "K" shall be checked at the following intervals:

Method A. Each 800 cubic meters of aggregate, minimum of one per day.

Method B. Each 2300 cubic meters of aggregate.

This value will be used for the day in which the sample is taken and will be used until the next sample is tested. If more than one test is run per day, the results will be averaged for computations.

The mass, "W", if mixing is done by a drum mixer, will be determined by truck scales or suspended hopper scales. The mass, if batched, will be determined on batch scales, and records of the number of batches, batch designs and mass of "Asphalt" and "Aggregate" shall be kept.

Aggregate by Mass. Aggregate will be measured by the megagram of the type used in the completed and accepted work. The aggregate mass will be determined from the total mass of plant mix seal surfacing mixture, in kilograms, less the selected percentage of asphalt and less the percentage of moisture as determined by Test Method Tex-212-F, Part II.

342.8. Payment.

(1) The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement", will be paid for at the unit price bid for "Asphalt" and for "Aggregate", of the types and/or grades specified, which prices shall be full compensation for quarrying, furnishing all materials and freight involved; for all heating, mixing, hauling, cleaning the existing pavement, placing tack coat and plant mix seal surfacing mixture, rolling, finishing, and sprinkling the finished surface; and for all manipulations, labor, tools, equipment and incidentals necessary to complete the work.

(2) All templates, straightedges, scales and other weighing and measuring devices necessary for the proper construction, measuring and checking of the work shall be furnished, operated and maintained by the Contractor at his expense.

ITEM 345

ASPHALT STABILIZED BASE
(Plant Mix)

345.1. Description. This Item shall govern for the construction of a base course, subbase course or foundation course, each course being composed of a compacted mixture of aggregate and asphalt cement mixed hot in a mixing plant, in accordance with the details shown on the plans and the requirements herein.

1994

METRIC STANDARD SPECIFICATIONS

FOR ROAD AND BRIDGE CONSTRUCTION

The Utah Department of Transportation

Utah A-126

Attachment C

UTAH DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION

COVER MATERIAL
(Expanded Shale)
ESCS

Section 405M, Seal Coat Section of the Standard Specifications for Road and Bridge Construction, Edition of 1992, of the State of Utah, shall control with the following modifications:

405.1 DESCRIPTION, delete this subsection in its entirety and substitute the following:

405.1.1 Construct and stockpile Type "C" Cover Material of crushed rock.

405.2 MATERIALS, Delete subsections 405.2.1, 405.2.2, 405.2.3, and 405.2.5.

Modify subsection 405.2.4 and 405.2.6 as follows:

Subsection 405.2.4.2 Replace 0-2 percent passing No. 200 with 0-1 in Table 405.1.

ASTM D-3319 and ASTM E-303 Delete subsection 405.2.4.8 and substitute Polishing - a polish value of at least 35. Aggregates consisting of carbonate type rocks (limestone, dolmite, etc.) shall not be allowed unless test reports proving function values satisfactory to UDOT can be supplied.

Subsection 405.2.6.1 Replace the word "Tons" with "Cubic Yards" in Table 405-2 and in the first sentence of the next two paragraphs.

405.3 CONSTRUCTION REQUIREMENTS Delete this subsection in its entirety and substitute the following:

405.3.2 Limitations

405.3.2.1 Complete all work prior to July 15.

405.4 METHOD OF MEASUREMENT Delete this subsection in its entirety and substitute the following:

Note: This special provision allows ESCS to be bid on a equal volumn bases,

405.4.1 Cover Material, by the Cubic Yard.

405.4.1.1 Payments may be made on individual completed stockpiles and not further partial payments will be made.

405.4.1.2 Payments shall be made at the unit bid price per cubic yard as computed from weigh tickets which shall be provided by the supplier.

405.4.1.3 Unless otherwise approved by the engineer, the conversion from pounds to cubic yards shall be as follows:

405.4.1.4 Number of cubic yards being delivered shall be determined by:

$$\frac{\text{Net pounds on weigh tickets}}{\text{Pounds per cubic foot x 27}}$$

Example: $\frac{40{,}000}{77.5 \times 27}$ = 19.12 cubic yards pay quantity.

(27 is the number of cubic feet in a cubic yard.)

405.4.1.5 Net Pounds on Weight Ticket shall be the material including moisture at the time the material is weighed in the delivery truck and recorded on approved weigh tickets.

405.4.1.6 Pounds per Cubic Foot shall be the loose weight (shoveling procedure) of the material being loaded and weighed and shall contain as near as possible, the same percent of moisture as that being weighed in the delivery truck.

405.4.1.6.1 The UDOT Materials Lab closest to the source will determine the weight per cubic foot to be used for all district.

405.5 BASIS OF PAYMENT Delete this subsection in its entirety and substitute the following:

405.5.1 The accepted quantities will be paid for at the contract unit price.

405.1 DESCRIPTION

405.1.1 Apply a coat of liquid or emulsified asphalt on a cleaned surface.

405.1.2 When required, follow with an application of cover material.

405.2 MATERIALS

405.2.1 Asphaltic Cement

AASHTO M-226 Table 2

405.2.1.1 As specified and as modified below:

- **Delete "Thin-Film Oven Test" requirement.**
- Change ductility requirements for AC-10 and AC-20 to: Ductility 4.0 °C 15+ cm.

AASHTO M-140

405.2.2 Anionic Emulsions—As specified and as modified: **Viscosity, Saybolt Fural at 50 °C** 140-400.

AASHTO M-208

405.2.3 Cationic Emulsions—As specified and as modified: **Viscosity, Saybolt Fural at 50 °C** 140-400.

405.2.4 Cover Material

AASHTO T-19

405.2.4.1 **Provide crushed slag or crushed natural aggregates** with a maximum dry unit weight of 1600 kg/m^3.

AASHTO T-27

405.2.4.2 **Grade within the following limits** to meet the specified test standard.

AASHTO T-11

	Table 405-1			
		Percent Passing		
	Sieve Size	Type A	Type B	Type C
1/2	12.5 mm	100		100
3/8	9.5 mm	85 - 100		70 - 90
No. 4	4.75 mm	0 - 20	100	0 - 5
No. 8	2.36 mm	0 - 5	85 - 100	0 - 3
No 16	1.18 mm		10 - 25	
No. 50	300 μm		0 - 5	
No. 200	75 μm	0 - 1	0 - 2	0 - 2

AASHTO T-96

405.2.4.3 Maintain wear at less than 30 percent.

AASHTO T-104

405.2.4.4 Maintain weight loss at less than 10 percent.

AASHTO T-19

405.2.4.5 Unit Weight—Use a maximum dry-unit weight of 1600 kg/m^3.

UDOT Test Procedure 8-929

405.2.4.6 Round Aggregate—Do not use material that contains more than 20 percent by weight with all round faces.

UDOT Test Procedure 8-945

405.2.4.7 Stripping—Ensure more than 90 percent retention.

405.2.4.8 Polishing—Do not use polished aggregates unless the Department is supplied with test reports proving satisfactory friction values.

405.2.5 Temporary Road Markers—Furnished and placed by the Contractor.

405.2.6 Acceptance Testing—By the Department

405.2.6.1 Cover Material

- **Stockpiles** will be sampled and tested using Table 405-2.

Table 405-2 Stockpiles—Samples and Tests	
Lot Quantity (Metric Ton)	Number of Samples
Lot ≥ 2300	5
1400 < Lot < 2300	4
Lot ≤ 1400	3

- **Stockpiles between 0 and 2300 t will be accepted** when the average gradation of the samples falls within the gradation band, and not more than one sample is outside the gradation band by more than 2 percentage points on any one sieve.

- **Stockpiles 2301 t or greater will be accepted** when the average gradation falls within the band, and not more that two samples are outside the gradation band by more than 2 percentage points on one sieve.

AASHTO T-11

- **No tolerance** will be allowed for the minus 75 μm portion of cover material.

405.3 CONSTRUCTION REQUIREMENTS

405.3.1 Cover Material Stockpile—Construct either individual stockpiles containing approximate metric tonnage for a single day of application or elongated stockpiles (maximum 7.5 m in height, 9.0 m top width) with approximate daily metric tonnage identified.

405.3.2 Surface Preparation

405.3.2.1 Clean the surface of all dirt, sand, dust, or other objectionable material.

405.3.2.2 Protect all structures from being spattered or marred including guardrail, guide posts, etc.

405.3.3 Temporary Road Marker Placement

405.3.3.1 Place Type "B" markers on center lines and Type "W" markers on lane lines at 12 m intervals before applying asphalt.

405.3.3.2 Place the reflective tape facing traffic when using Type "W" markers.

405.3.3.3 Remove covers immediately after the rolling is complete.

405.3.4 Asphalt Material Application

405.3.4.1 Use a distributor equipped with a hydrostatic system and full circulating spray bar to spray the emulsion.

405.3.4.2 Spray the emulsion at the specified rate. Maintain a tolerance of ± 0.14 L/m^2.

405.3.4.3 Maintain a distance of not more than 30 m between the distributor and the chip spreader.

405.3.5 Cover Material Application

405.3.5.1 Use a Flaherty Spread Master or Etayre Spreader to spread the cover material. Equipment of equal quality may be used.

405.3.5.2 Spread aggregate at the specified rate. Maintain a tolerance of +0.5 to a -1.0 kg/m^2.

405.3.6 Surface Rolling

405.3.6.1 Use pneumatic-tire rollers in a longitudinal direction to roll surface after the cover material has been satisfactorily spread.

405.3.6.2 Use **equipment** with at least two rollers up front and one roller behind. This last roller serves as a finish roller.

405.3.6.3 **Seat the aggregate adequately.**

405.3.7 Traffic Control

405.3.7.1 **Prepare a traffic control plan** in accordance with MUTCD.

405.3.7.2 After spreading aggregate, **provide a minimum of four hours** of traffic control using pilot vehicles.

405.3.7.3 **Sweep** the surface before allowing uncontrolled traffic on the sealant.

405.3.8 Limitations

405.3.8.1 **Complete** all work between May 15 and August 31.

405.3.8.2 **The Department will determine** if it is feasible to place the seal coat after August 31. **Written approval** must be obtained from the Engineer.

405.3.8.3 **Do not lay seal coat** unless the temperature in the shade is 21 °C and rising. Pavement surface may not be above 49 °C.

405.4 METHOD OF MEASUREMENT

405.4.1 General

405.4.1.1 Asphalt emulsion, by the metric ton.

405.4.1.2 Cover material, by the metric ton.

405.4.1.3 Asphalt additive, by the kilogram.

405.5 BASIS OF PAYMENT

405.5.1 General

405.5.1.1 The accepted quantities will be paid for at the contract unit price.

PAY ITEM	UNIT
Liquid Asphalt	Metric Ton
Emulsified Asphalt	Metric Ton
Cover Material	Metric Ton
Asphalt Additive	Kilogram

VIRGINIA
DEPARTMENT OF TRANSPORTATION

Road and Bridge Specifications

January 1994

Richmond

a series of crushers to the maximum size specified. It shall be essentially free from deleterious substances in accordance with the requirements of Section 203.

(a) **Crushed hydraulic cement concrete** will be permitted for use as crusher run aggregate provided it conforms to the physical requirements of Section 203 and shows no adverse chemical reaction. It shall not be used in a subsurface drainage application in combination with perforated pipe or as a base material where geotextile fabric is to be used.

(b) **Crushed gravel** shall consist of particles of which at least 90 percent by weight of material retained on the No. 10 sieve shall have at least one face fractured by artificial crushing. Tests will be performed in accordance with the requirements of VTM-15.

205.03—Detail Requirements.

(a) **Grading:** Grading shall conform to the following when tested in accordance with the requirements of AASHTO T27:

% by Weight of Materials Passing Sieve

Size No.	2 1/2 in	2 in	1 1/2 in	1 in	3/4 in	No. 4
24	Min. 100	95±5				32±18
25			Min. 100	95±5		32±18
26				Min. 100	95±5	38±22

(b) **Atterberg Limits:** The liquid limit shall be not more than 25. The plasticity index shall be not more than 3. Tests will be performed in accordance with the requirements of VTM-7.

(c) **Soundness Loss:** Soundness loss shall conform to the requirements of Table II-4 for aggregate bases. Tests will be performed in accordance with the requirements of AASHTO T103 or T104.

(d) **Abrasion Loss:** Abrasion loss shall be not more than 45 percent. Tests will be performed in accordance with the requirements of AASHTO T96.

SECTION 206—LIGHTWEIGHT AGGREGATE

206.01—Description.

These specifications cover lightweight aggregate used in hydraulic cement concrete and asphalt surface treatment.

206.02—Detail Requirements.

Lightweight aggregate shall consist of clay, shale, or slate expanded through a sintering or rotary kiln.

(a) **Lightweight aggregate used in hydraulic cement concrete** shall conform to the requirements of AASHTO M195.

(b) **Lightweight aggregate used for asphalt surface treatment** shall conform to the requirements of AASHTO M195 except that Sections 3, 6, and 8 will not apply. Grading shall conform to the requirements of Table II-3 ~~except that the maximum percentage by weight of material passing the No. 8 sieve shall be 16 percent and passing the No. 16 sieve shall be 9 percent.~~ Size No 8P with maximum of 1.7% passing the 200 sieve. This change is effective 1-1-97

SECTION 207—SELECT MATERIAL

207.01—Description.

These specifications cover nonplastic material obtained from roadway cuts, borrow areas, or commercial sources used as foundation for subbase, shoulder surfacing, fill, backfill, or other specific purposes.

207.02—Detail Requirements.

Select material shall consist of approved local or commercial materials free from roots, muck, and debris.

(a) **Grading:**

1. **Type I:** Grading for Type I shall conform to the job-mix formula selected from within the design range specified in Table II-6, subject to the applicable tolerances specified in Table II-7 when tested in accordance with the requirements of VTM- 25.

TABLE II-6
Design Range: Select Material, Type I

% by Weight of Material Passing

3 in Sieve	2 in Sieve	No. 10 Sieve	No. 40 Sieve	No. 200 Sieve
100	95-100	25-55	16-30	4-14

NO.8-P LIGHTWEIGHT AGGREGATE GRADATION

Sieve Size	Percent Passing
1/2	100
3/8	75-100
#4	5-30
#8	Max.5

Deleterious Material: The amount of deleterious material passing the N0.200 sieve by washed gradation shall not exceed 1.70 percent.

TABLE II-3
Sizes of Open Graded Coarse Aggregates

Va. Size No.	Amounts Finer Than Each Laboratory Sieve (Square Openings) (% by Weight)														
	4 in	3½ in	3 in	2½ in	2 in	1½ in	1 in	¾ in	½ in	⅜ in	No. 4	No. 8	No. 16	No. 50	No. 100
1	Min. 100	95 ± 5		43 ± 17		Max. 15		Max 5							
2			Min. 100	95 ± 5		43 ± 17		Max 15	Max. 5						
3				Min. 100	90-100	35-70	0-15		Max. 5						
357					Min. 100		60 ± 20		20 ± 10		Max. 5				
5						Min. 100	95 ± 5	58 ± 17	Max. 15	Max. 5					
56						Min. 100	95 ± 5	58 ± 17	25 ± 10	Max. 15	Max. 5				
57						Min. 100	95 ± 5		43 ± 17		Max. 7	Max. 3			
68							Min. 100	95 ± 5		48 ± 17	Max. 20	Max. 8	Max. 5		
7								Min. 100	95 ± 5	57 ± 17	Max. 15	Max. 5			
78								Min. 100	95 ± 5	60 ± 20	Max. 20	Max. 8	Max. 5		
8									Min. 100	92 ± 8	25 ± 15	Max. 8	Max. 5		
8P									Min. 100	75 - 100	5-30	Max. 5			
9										Min. 100	92 ± 8	25 ± 15	Max. 10	Max. 5	
10										Min. 100	92 ± 8				20 ± 10

No. 200
MAX
1.7 washed Test

and in reasonably close conformity with the lines shown on the plans or as established by the Engineer.

310.02—Materials.

Asphalt for tack coat shall be CRS-1, CRS-2, CRS-1h or CSS-1h and conform to the requirements of Section 210. CMS-2, conforming to the requirements of Section 210, may be used during the winter months. With the exception of CMS-2, asphalt for tack coat may be diluted with 50 percent water provided that resulting material produces a uniform application of the tack.

310.03—Procedures.

Equipment for heating and applying asphalt shall conform to the requirements of Section 314.04(b). The maximum application temperature of liquid asphalt shall conform to the requirements of Table III-1.

TABLE III-1
Liquid Asphalt Application Temperature

Grade	Max. Temperature (°F)
RC-70	180
RC-250	220
RC-800	225
RC-3000	290
MC-70	180
MC-250	220
MC-800	255
MC-3000	290
AC-5	300
AC-10	300
AC-20	300
AC-40	300
RS-2	175
SS-1h	180
AE-4	150
CRS-2	175
CSS-1h	180
CMS-2	200
CRS-1h	175
CRS-1	175

The existing surface shall be patched, cleaned, and rendered free from irregularities to the extent necessary to provide a reasonably smooth and uniform surface. Unstable corrugated areas shall be removed and replaced with suitable patching materials. The edges of existing pavements that are to be adjacent to new pavement shall be cleaned to permit adhesion of asphalt.

Tack material shall be uniformly applied with a pressure distributor conforming to the requirements of Section 314.04(b). Hand spray equipment shall not be used except in areas inaccessible by a pressure distributor. Undiluted asphalt shall be applied at the rate of 0.05 to 0.10 gallons per square yard. Diluted asphalt shall be applied at the rate of 0.10 to 0.15 gallons per square yard.

The tack coat shall be applied in a manner to offer the least inconvenience to traffic and permit one-way traffic without pickup or tracking of the asphalt.

The tack coat shall not be applied immediately prior to the course being placed. The tack coat shall be applied in accordance with the same weather limitations that apply to the course being placed. The quantity, rate of application, temperature, and areas to be treated shall be approved prior to application.

During the application of asphalt, care shall be taken to prevent spattering adjacent items. The distributor shall not be cleaned or discharged into ditches or borrow pits, onto shoulders, or along the right of way. When not in use, equipment shall be parked so that the spray bar or mechanism will not drip asphalt on the surface of the traveled way.

310.04—Measurement and Payment.

Tack coat, when a pay item, will be measured in gallons and will be paid for at the contract unit price per gallon. When not a pay item, the cost thereof shall be included in the price for other appropriate pay items.

Patching will be paid for at the contract unit price for the various items used unless a reconditioning item is included in the Contract.

Payment will be made under:

Pay Item	Pay Unit
Tack coat	Gallon

SECTION 311—PRIME COAT

311.01—Description.

This work shall consist of preparing and treating an existing surface with asphalt, and cover material if required, in accordance with the requirements of these specifications and in reasonably close conformity with the lines shown on the plans or as established by the Engineer.

311.02—Materials.

(a) **Asphalt** may be changed one viscosity grade by the Engineer during construction at no change in the contract unit price. Asphalt shall conform to the applicable requirements of Section 210.

(b) **Cover material** shall conform to the applicable requirements of Section 202 or 203. Lightweight aggregate shall conform to the requirements of Section 206. Cover material shall not be hauled directly from a washing plant for immediate use in the work.

311.03—Procedures.

The rates of application of materials shall be determined in accordance with the method described in Education Series No. 12 of the Asphalt Institute entitled *Asphalt Surface Treatments Construction Techniques.*

The weather limitations of Section 314.03 shall apply to asphalt prime coat work. When asphalt is to be used as a cover for cement stabilization or as a primer for asphalt concrete, the weather limitations specified for these particular operations shall apply.

Equipment for heating and applying asphalt and cover material shall conform to the requirements of Section 314.04. The maximum application temperature of the liquid asphalt shall conform to the requirements of Table III-1.

The surface to be primed shall be shaped to the required grade and section; rendered free from ruts, corrugations, segregated material, or other irregularities; and uniformly compacted.

Delays in priming may necessitate reprocessing or reshaping to provide a smooth compacted surface.

Asphalt shall be applied by means of a pressure distributor in a uniform continuous spread. When traffic is maintained, not more than 1/2 the width of the section shall be treated in one application. Care shall be taken that the application of asphalt at junctions of spreads is not in excess of the specified amount. Excess asphalt shall be removed from the surface by a squeegee. Skipped areas or deficiencies shall be corrected.

During the application of asphalt, care shall be taken to prevent spattering adjacent items. The distributor shall not be cleaned or discharged into ditches or borrow pits, onto shoulders, or along the right of way. When not in use,

equipment shall be parked so that the spray bar or mechanism will not drip asphalt on the surface of the traveled way.

When traffic is maintained, one-way traffic shall be permitted on the untreated portion of the roadbed. When the asphalt has been absorbed by the treated surface and will not pick up, traffic shall be transferred to the treated portion and the remaining width of the section primed.

The quantity, rate of application, temperature, and areas to be treated shall be approved before application of the prime coat.

If after application of the prime coat the asphalt fails to penetrate within the time specified and the roadway must be used by traffic, cover material shall be spread at the Contractor's expense in an amount that will prevent pickup of the asphalt.

311.04—Measurement and Payment.

Prime coat will be measured and paid for at the contract unit price per gallon for asphalt and per ton for cover material, in accordance with the requirements of Section 313.

SECTION 312—SEAL COAT

312.01—Description.

This work shall consist of applying asphalt followed by applying cover material in accordance with the requirements of these specifications and in reasonably close conformity with the lines shown on the plans or as established by the Engineer.

312.02—Materials.

(a) **Asphalt** may be changed one viscosity grade by the Engineer during construction at no change in the contract unit price. Asphalt shall conform to the applicable requirements of Section 210.

(b) **Cover material** shall conform to the applicable requirements of Section 203. Lightweight aggregate shall conform to the requirements of Section 206. Cover material shall not be hauled directly from a washing plant for immediate use in the work.

312.03—Equipment.

The following equipment or its equivalent is required:

1. equipment for heating and applying asphalt conforming to the requirements of Section 314.04(b)

2. a rotary power broom

3. at least one pneumatic tire roller. Additional rollers that may be required may be tandem steel wheel or three-wheel rollers weighing at least 8 tons. The pneumatic tire roller shall be self-propelled, and the gross load adjustable to apply 200 to 350 pounds per inch of rolling width as directed. Tires shall be designed for a tire pressure of at least 90 pounds per square inch. Steel wheel rollers shall be operated at a maximum speed of 3 miles per hour, and pneumatic tire rollers at a maximum speed of 5 miles per hour.

4. a mechanical roller-type hopper or a self-propelled aggregate spreader of an approved design

312.04—Procedures.

The rates of application of materials shall be determined in accordance with the method described in Education Series No. 12 of the Asphalt Institute entitled *Asphalt Surface Treatments Construction Techniques.*

The weather limitations specified in Section 314.03 shall apply to seal coat work.

Seal coating operations shall not be started until the surface is thoroughly compacted and cleaned of dust, mud, and foreign matter and the section to be sealed has been approved by the Engineer.

Asphalt shall be applied by means of a pressure distributor in a uniform continuous spread over the section to be treated and within the temperature range given in Table III-1. A strip of building paper at least 3 feet in width and having a length equal to that of the spray bar of the distributor plus 1 foot shall be used at the beginning of each spread. If the cutoff is not positive, the use of paper may be required at the end of each spread. The paper shall be removed and disposed of legally. The distributor shall be moving forward at the proper application speed at the time the spray bar is opened. Skipped areas and deficiencies shall be corrected. Junctions of spreads shall be carefully made to ensure a smooth riding surface.

The length of the spread of asphalt shall be regulated by the quantity of cover material in loaded trucks on the project.

The spread of asphalt shall be not more than 6 inches wider than the width covered by the cover material from the spreading device. Asphalt shall not be allowed to chill, set up, dry, or otherwise impair retention of the cover material.

During asphalt application, care shall be taken to prevent spattering adjacent items. The distributor shall not be cleaned or discharged into ditches or borrow pits, onto shoulders, or along the right of way. When not in use, equipment shall be parked so that the spray bar or mechanism will not drip asphalt material on the surface of the traveled way.

Immediately following asphalt application, cover material shall be applied in full-lane widths up to 12 feet. Laps shall be made only at lane dividers or at the crown of the roadway. Successive laps at lane dividers and the roadway crown shall be staggered from 3 to 6 inches. Spreading shall be accomplished in a manner so that the tires of the truck or aggregate spreader do not contact the uncovered and newly applied asphalt.

If directed, cover material shall be moistened with water to eliminate or reduce dust coating of aggregate. Moistening shall be done the day before the use of aggregate.

Immediately after cover material is spread, deficient areas shall be covered by additional material. Rolling shall begin immediately behind the spreader and shall consist of at least three complete coverages.

After application of cover material, the wearing surface shall be lightly broomed or otherwise maintained until cured as directed. Maintenance of the surface shall include distributing cover material over the surface to absorb free asphalt and cover any area deficient in cover aggregate. Maintenance shall be conducted so as not to displace embedded material. Excess material shall be swept from the surface by means of rotary brooms as required or as directed by the Engineer.

312.05—Measurement and Payment.

Seal coat will be measured and paid for at the contract unit price per gallon for asphalt and per ton for cover material, in accordance with the requirements of Section 313.

SECTION 313—ASPHALT SURFACE TREATMENT

313.01—Description.

This work shall consist of constructing a single or multiple course asphalt surface treatment in accordance with the requirements of these specifications and in reasonably close conformity with the lines shown on the plans or as established by the Engineer.

313.02—Materials.

(a) **Asphalt** may be changed one viscosity grade by the Engineer during construction at no change in the contract unit price. Asphalt shall conform to the applicable requirements of Section 210.

(b) **Cover material** shall conform to the applicable requirements of Sections 202 and 203. Coarse aggregate shall be a minimum Grade B. Lightweight aggregate shall conform to the requirements of Section 206. Cover material shall not be hauled directly from a washing plant for immediate use in the work.

313.03—Procedures.

Asphalt surface treatment may consist of applying one or more seal coats or a prime coat followed by one or more seal coats as specified. The weather limitations of Section 314.03 shall apply to asphalt surface treatment work. The Contractor shall have a certified Asphalt Paving Technician present during the paving operation.

(a) **Prime Coat:** When specified, a prime coat shall be applied in accordance with the requirements of Section 311. When cover material is specified, rolling shall be performed in accordance with the requirements of Section 312.

The prime coat shall be permitted to cure prior to the next application of asphalt.

During the period between application of the prime coat and the seal coat, the primed surface shall be kept in repair. Holes, ravels, and areas deficient in primer shall be patched and repaired with asphalt-treated materials by penetration methods or other approved procedures.

(b) **Seal Coat:** Each seal coat shall be applied in accordance with the requirements of Section 312. Successive applications of asphalt using emulsion or asphalt cements may be applied without any delay for curing. When cutback asphalt is used, the first seal coat shall be maintained and permitted to cure for at least 48 hours.

(c) **Opening to Traffic:** The roadway shall be kept open to traffic at all times. As soon as the final layer is placed, controlled traffic may be permitted thereon.

(d) **Rates of Application:** The application rates of asphalt surface treatment materials will be furnished to the Contractor by the Department.

313.04—Measurement and Payment.

Liquid asphalt will be measured in gallons and cover material will be measured in tons, complete-in-place, in accordance with the requirements of Section 109.01. Asphalt surface treatment will be paid for at the contract unit price per gallon for liquid asphalt and per ton for cover material. These prices shall include furnishing and applying materials and maintaining the treatment.

Payment will be made under:

Pay Item	Pay Unit
Liquid asphalt	Gallon
Cover material (Type)	Ton

SECTION 314—PENETRATION SURFACE COURSES

314.01—Description.

This work shall consist of constructing a wearing surface of crushed stone, slag, or crushed gravel penetrated with asphalt in accordance with the requirements of these specifications and in reasonably close conformity with the lines shown on the plans or as established by the Engineer.

314.02—Materials.

(a) **Asphalt** may be changed one viscosity grade by the Engineer during construction at no change in the contract unit price. Asphalt shall conform to the applicable requirements of Section 211.

(b) **Aggregate** shall be crushed stone, slag, or crushed gravel that conforms to the applicable requirements of Section 203. Aggregate shall not be hauled directly from a washing plant and used in the work.

(c) **Fine aggregate** shall be Grading B sand conforming to the requirements of Section 202.

MAR 10

BUILDEX
Haydite *Expanded Shale*
Lightweight Aggregate

Re: ESCS Chip Seal in Kansas and Missouri

Buildex placed its first Expanded Shale Chip Seal project in Kansas in 1973. The market has grown to the point that Buildex currently supplies between 35,000 - 50,000 cubic yards of ESCS Chip Seal annually, to markets in Kansas and Missouri. This equates to approximately 600 - 800 lane miles per year.

The product is used on city streets, county roads, and state highways.

The most common gradations used are:

Sieve Size	Buildex #1 Percent Retained	Buildex #2 Percent Retained
3/4	0	0
1/2	0-5	0
3/8	0-15	0-8
#4	70-100	80-100
#8	90-100	96-100
Material passing #200	2% Maximum	2% Maximum

Please contact Buildex for more information and specific project references.

Buildex, Inc. P.O. Box 15 Ottawa, Kansas 66067 (913) [illegible]-2177 Fax (913) 242-1281

Appendix 14B

Sections fro SHRP publication SHRP-H-322 (SHRP-M/FR-92-102) "*Standard Practice for Designs and Construction of Bituminous Surface Treatments*"

- Section 407 Chip seal
- Section 408 Slurry seal
- Section 702 Bituminous material
- Section 703 Aggregates

SHRP-M/FR-92-102

SHRP- H - 322

Development of a Procedure to Rate the Application of Pavement Maintenance Treatments

David J. Bullard
Roger E. Smith
Thomas J. Freeman

Texas Transportation Institute
Texas A&M University
College Station, Texas

Strategic Highway Research Program
National Research Council
Washington, DC 1992

Section 407.--CHIP SEAL

Description

407.01 This work consists of furnishing all materials, equipment, and labor for constructing the asphalt chip seal surface treatment areas. The treatment areas shall be constructed on the existing pavement in accordance with these specifications and in conformance with details and at the locations shown in the site descriptions. There is one treatment area for chip sealing at each project site and the demonstration site.

Equipment

407.02 The equipment used by the Contractor shall include but not be limited to the following:

(a) Power broom. A motorized power broom, center mount only, shall be used for removing loose material from the surface to be treated and for removing loose aggregate after work is completed.

(b) Rollers. A sufficient number of self-propelled, pneumatic-tired rollers shall be used for rolling aggregates after spreading such that the entire lane width of the treatment area is covered in one pass of the rollers. Each pneumatic-tired roller shall have a compacting width of not less than 60 inches and a minimum ground contact pressure of 80 pounds per square inch. If 60 inch wide rollers were used, then the contractor would be required to have 3 rollers to roll the 13 foot wide test sections.

(c) Asphalt distributer. A pressure distributor shall be used for applying the asphalt material. It shall be designed and operated to distribute the asphalt material in a uniform spray at the specified rate without atomization. It shall be equipped with a bitumeter having a dial registering feet of travel per minute. The dial shall be visible to the operator in order to maintain the constant speed required for the application at the specified rate. The pump shall be equipped with a tachometer having a dial registering gallons (or liters) per minute passing through the nozzles. The dial shall be readily visible to the operator. The distributor shall be provided with a full circulatory system that includes the spray bar. The distributor shall be provided with heaters that can be used to bring the asphalt material to spray application temperature. Means shall be provided for accurately indicating the temperature of the asphalt material at all times. The thermometer well shall not be in contact with the heating tube. The normal width of application of the spray bar shall be 13 feet with provision for greater or lesser width when necessary. A hose and spray nozzle attachment shall be provided for applying asphalt material to patches and areas inaccessible to the spray bar. The spray bar height, nozzle angle, and pump pressure will be calibrated weekly or as required by the Engineer.

The calibration shall be performed in accordance with TAI Manual Series No. 19(MS-19), 2nd Edition. The allowable deviation shall be not more than 10 percent in the longitudinal and transverse directions. The longitudinal and transverse spread rates shall be checked using ASTM D2995.

(d) Aggregate spreader. The aggregate spreader shall be a self-propelled mechanical spreader with and operational scalper screen capable of uniformly distributing aggregate at the prescribed rate. The aggregate spreader will be checked weekly or as required by the Engineer. The calibration shall be performed in accordance with TAI Manual Series No. 19(MS-19), 2nd Edition. The allowable deviation in the amount of aggregate spread shall not be more than 10 percent (by weight) in the longitudinal or transverse directions.

(e) Hauling Equipment. Trucks used for hauling aggregate shall have a cover of canvas or other suitable material of such size as to protect the aggregate from weather. Truck bed shall be covered and securely fastened when delivering aggregate to the project sites.

(f) Auxiliary Equipment. Shovels and other equipment shall be used as necessary to perform the work. Cleaning equipment including but not limited to power brooms, air compressors, water flushing equipment, and hand brooms shall be adequate for surface preparation.

Materials

407.03 Asphalt. The base asphalt to be emulsified shall be an AC-10, meeting the requirements of AASHTO M226, Table 2. The emulsified asphalt shall conform to Subsection 702.03 for emulsified asphalt grade CRS-2.

Acceptance sampling, point of acceptance, and test methods are specified in Subsection 106.06.

407.04 Mineral Aggregates. Aggregates shall meet the requirements of Subsection 703.13(a).

Acceptance sampling, point of acceptance, and test methods are specified in Subsection 106.06.

407.05 Water. All water shall be potable and compatible with the chip seal. Compatibility must be ensured by the Contractor.

407.06 Mix Design. The chip seal surface treatment shall be designed in accordance with TAI design method found in Manual Series No. 19 (MS-19), 2nd Edition. The contractor shall have the design of the chip seal prepared by qualified personnel, approved by the Engineer, experienced in asphalt surface treatment design.

The chip seal surface treatment design shall be based on traffic of over 2,000 vehicles per day and assume a slightly pocked, porous oxidized surface.

Application rate for the emulsified asphalt binder shall be from 0.25 and 0.40 gallon per square yard. The final application rate shall be determined after the source of materials is known.

Spread rate for the aggregate, based on weight of dry aggregate, shall be from 18 to 25 pounds per square yard. The final application rate shall be determined after the source of materials is known.

The design of the surface treatment shall be submitted to the Engineer for approval 15 working days prior to any work being accomplished. The design will include the following information:

(a) Aggregate gradation
(b) Bulk specific gravity of aggregate
(c) Loose unit weight of aggregate
(d) Emulsified asphalt rate of application and type
(e) Aggregate rate of application

In addition to the above data, the contractor is to submit with the design of the surface treatment a sample of the aggregate and the emulsion for use to the Engineer for verifying test results. The design may be verified by the government.

Construction Requirements

407.07 Weather Limitations. The chip seal surface treatment shall be placed only when the surface to be treated is dry or slightly damp, when the temperature of the road surface and the air temperature are 60 degrees F and rising, and when the weather is not foggy or rainy.

407.08 Preparation of Surface, General. All roadway surfaces to be treated shall be cleaned by the Contractor. The Contractor shall sweep the pavement with a motorized power broom to remove all loose material. All depressions not reached by the power broom will be cleaned by the Contractor using hand brooming. The Contractor shall ensure that the outer edges of the pavement to be treated including the 1 foot of the shoulder width, if a paved shoulder exists, are thoroughly cleaned. Work will not continue until the surface is approved by the Engineer.

407.09 Temporary Centerline Markings. Prior to the placement of the chip seal surface treatment, temporary centerline markings meeting the requirements of Section 635 shall be installed by the contractor.

407.10 Application of Emulsified Asphalt Binder. The rate of application for the emulsified asphalt binder shall be at the rate determined by the surface treatment design. See Subsection 407.06. The Engineer will make adjustments to the rate of application if necessary. Application of the emulsified asphalt binder shall be made uniformly at this rate with the pressure distributor, one full lane width at a time (including shoulder).

Further adjustments in the rate of application shall be made by the Engineer, if needed, during the course of the work. The emulsified asphalt binder shall be applied at a temperature between 125 and 185 degrees F. The final spray temperature will be specified by the Engineer.

Before beginning application, building paper shall be spread over the surface, from the beginning point back and from the endpoint forward, for a sufficient distance for the spray bar to be at full force when the surface to be treated is reached. The spray bar shall be shut off instantaneously at the endpoint to ensure a straight line and the full application of binder up to the endpoint. After the asphalt is applied, the building paper shall be removed and disposed of properly. A hand sprayer shall be used to apply asphalt binder necessary to touch up all spots missed by the distributor.

407.11 Application of Mineral Aggregates. After the asphalt binder has been spread evenly over the roadway surface, aggregates of the type specified shall be evenly applied to the roadway surface by self propelled spreader equipment. The aggregate shall be distributed uniformly by a spreader within 1 minute of the emulsified asphalt application.

All aggregate shall be watered down before placement, but not immediately before, to provide aggregates that are uniformly damp as approved by the Engineer at the time of placement on the roadway.

The aggregate shall be spread in one operation in such a manner that an 8 inch strip of the emulsified asphalt is left exposed along the longitudinal joint to form a lap for succeeding applications of the emulsified asphalt. If necessary, thin or bare spots in the spread of aggregates shall be corrected by hand spreading or other methods subject to the approval of the Engineer.

The aggregate shall be spread at the rate determined by the surface treatment design. See Subsection 407.06. The Engineer will make adjustments to the rate of application if necessary.

The aggregate shall be rolled following spreading. A maximum time of 3 minutes will be allowed between the spreading of the aggregate and completion of the initial rolling of that aggregate. The rollers shall proceed in a longitudinal direction at a speed less than or equal to 5 miles per hour. The rollers shall make three complete coverages of the aggregate with the final pass in the direction of traffic.

Immediately prior to opening to traffic, the surface of the roadway shall be swept, at the direction of the Engineer, with a power broom at adequate pressure to remove loose aggregate.

Trucks hauling aggregate shall be operated in a manner that shall not damage the roadway or the freshly applied surface.

Method of Measurement and Basis of Payment

407.12 All materials and work required by this Section will be measured and paid for in accordance with Section 410.

Section 408.--SLURRY SEAL

Description

408.01 This work consists of furnishing all materials, equipment, and labor for constructing the asphalt slurry seal treatment areas. The treatment areas shall be constructed on existing pavement in accordance with these specifications and in conformance with details and at the locations shown on the plans. There is one treatment area for slurry sealing at each project site and the demonstration site.

Equipment

408.02 The equipment used by the Contractor shall include but not be limited to the following:

(a) Slurry Seal Mixer. The slurry seal mixing machine shall be a continuous flow mixing unit with calibrated controls capable of delivering accurately predetermined proportions of aggregate, water, and asphalt emulsion to the mixing chamber and of discharging the thoroughly mixed product on a continuous basis. Each machine shall be equipped with metering devices, easily readable, that will accurately measure all raw materials prior to entering the pugmill. Each machine shall have an automated system capable of automatically sequencing in all raw materials to insure constant slurry mixture. The mixing chamber shall be capable of thoroughly blending all ingredients together. No violent mixing will be permitted. The aggregate shall be pre-wetted in the pugmill immediately prior to mixing with the emulsion.

The mixer shall be equipped with an approved fines feeder having an accurate metering device or other approved means to introduce a predetermined quantity of mineral filler into the mixer at the time and location that the aggregate is introduced into the mixing machine. The fines feeder shall be used whenever mineral filler is a part of the aggregate blend.

The mixing machine shall be equipped with a water pressure system and a fog-type spray bar adequate for complete fogging of the surface immediately ahead of the spreading equipment. Rate of fog application shall be 0.03 to 0.06 gallon of water per square yard.

The mixer shall be capable of mixing all materials at preset proportions regardless of the engine speed without changing the mixing machine settings.

The machine shall be capable of a minimum speed of 60 feet per minute and shall not exceed 130 feet per minute while in operation. The mixing machine shall have sufficient storage capacity to properly mix and apply a minimum of 7 tons of slurry seal.

Approved means of measuring all materials used in each slurry seal batch shall be provided, properly calibrated, and made accessible to the Engineer by the Contractor. The slurry seal mixer shall be checked weekly or as required by the Engineer. The calibration of the slurry seal mixer shall be performed in accordance with TAI Manual Series No. 19 (MS-19), 2nd Edition. The Engineer may use the recorders and measuring facilities of the slurry seal unit to determine application rates, asphalt emulsion content, and mineral filler content of individual loads.

(b) Spreading Equipment. Attached to the mixing machine shall be a mechanical type single squeegee distributor equipped with flexible material in contact with the surface to prevent loss of slurry and adjustable to assure a uniform spread of varying grades and crowns. It shall be steerable and adjustable in width with a flexible strike-off.

The box shall not cause grooving of the slurry by any of its parts. It shall be kept clean, and build-up of material on the spreader will not be permitted. The type drag, burlap, or other textile will be approved by the Engineer and it shall be cleaned or changed as frequently as needed or as designated by the Engineer. The drag shall be wetted at the beginning of each application.

(c) Hauling Equipment. Trucks used for hauling aggregate shall have a cover of canvas or other suitable material of such size as to protect the aggregate from weather. Truck beds shall be covered and securely fastened when delivering aggregate to the project sites.

(d) Auxiliary Equipment. Hand squeegees, shovels, and other equipment shall be used as necessary to perform the work. Cleaning equipment including but not limited to power brooms, air compressors, water flushing equipment, and hand brooms shall be adequate for surface preparation.

Materials

408.03 Asphalt. The emulsified asphalt shall be quick-set emulsified asphalt conforming to Subsection 702.03, Table 702-1.

Acceptance sampling and point of acceptance are specified in Subsection 106.06.

408.04 Mineral Aggregates. Aggregate shall meet the requirements of Section 703.13(b).

Point of acceptance is specified in Subsection 106.06.

408.05 Mineral Filler. Mineral filler shall meet the requirements of Subsection 703.11.

Acceptance of mineral filler is specified in Subsection 106.06.

408.06 Water. All water shall be potable and compatible with the slurry seal. Compatibility must be ensured by the Contractor.

408.07 Mix Design. The slurry mixture shall be designed in accordance with requirements of ASTM D 3910, as applicable. The Contractor shall have a mix design prepared by one of the following laboratories:

Alpha Labs
P.O. Box 74
Alpha, OH 45301
(513) 298-6647
Contact: Ben Benedict

ScanRoad, Inc.
P.O. Box 7677
Waco, TX 76714
(817) 772-7677
Contact: Tony Ng

Asphalt Technologies, Inc.
9890 B Elder Creek Road
Sacramento, CA 95829
(916) 381-8033
Contact: Jim Stevens

Valley Slurry Seal Lab
P.O. Box 1620
W. Sacramento, CA 95691
(916) 373-1500
Contact: Jim Harriman

Koch Materials
1194 Zinns Quarry Road
Reading, PA 17404
(717) 843-0975
Contact: Ron Kohlar

Sahuaro Labs
P.O. Box 6536
Phoenix, AZ 85005
(602) 252-3061
Contact: Mike Doyle

The mix design shall be based upon the requirement that the treated area will be opened to traffic within 2 hours after placement of the slurry seal mixture.

Residual asphalt content, percent weight of dry aggregate, shall be from 7.5 to 13.5 percent as determined by AASHTO T 59.

Application rate of slurry mixture, based on weight of dry aggregate, shall be from 15 to 25 pounds per square yard.

The mix design will be submitted to the Engineer for approval 15 working days before work begins. The mix design will include the following information:

(a) Aggregate gradation.

(b) Mineral filler to be used if needed, percentage by weight of aggregate.

(c) Emulsified asphalt percentage and type.

(d) Sand equivalent of aggregate.

(e) Setting time (40 minutes maximum).

(f) Water resistance test results; pass or fail.

(g) Results of Wet Track Abrasion Test (max. loss of 75 grams per sq ft).

In addition to the above data, the Contractor is to submit with the mix design a sample of the aggregate, the emulsified asphalt, and the mineral filler, for use to the Engineer for verifying test results.

After the design mix has been established, the mixture supplied to the project shall conform thereto within the following tolerances:

Passing U.S. No. 4 and larger sieves	± 7%
Passing U.S. No. 8 to U.S. No. 100 sieve	± 4%
Passing U.S. No. 200 sieve	± 2%
Residual Asphalt (by extraction)	± 0.4%
Mineral filler (portland cement)	± 0.5%

The Engineer may adjust the emulsified asphalt content during construction to account for the amount of asphalt absorbed by the pavement.

Construction Requirements

408.08 Weather Limitations. Slurry seal shall be applied only when the surface to be treated is dry or slightly damp, when the temperature of the road surface and the air temperature are 60°F and rising, and when the weather is not foggy or rainy.

408.09 Preparation of Surface, General. All roadway surfaces to be treated shall be cleaned by the Contractor. The Contractor shall sweep the pavement with a motorized power broom to remove all loose material. All depressions not reached by the power broom will be cleaned by the Contractor using hand brooming. The Contractor shall ensure that the outer edges of the pavement to be treated, including the 1 foot of the shoulder width if a paved shoulder exists, are thoroughly cleaned.

408.10 Temporary Centerline Markings. Following placement of the slurry seal surface treatment, temporary centerline marking meeting the requirements of Section 635 shall be installed by the contractor.

408.09 Application of Slurry Seal. The surface shall be fogged with water immediately preceding the spreader. The slurry seal mixture shall be of the desired consistency as it leaves the mixer. The mixture furnished shall conform to the established design mix. The total mixing time shall not exceed 4 minutes. A sufficient amount of slurry seal mixture shall be carried in all parts of the spreader such that complete coverage of the base surface is effected.

In areas not accessible to the slurry mixer, the slurry seal mixture shall be hand worked with approved squeegees.

Treated areas will be allowed to cure until such time as the Engineer permits these treated areas to be opened to traffic.

The following will not be permitted:

(a) Lumping, balling, or unmixed aggregate.

(b) Segregation of the emulsified asphalt and aggregate fines from the coarse aggregate. If the coarse aggregate settles to the bottom of the slurry seal mix, the slurry seal mix shall be removed from the base surface.

(c) Excessive breaking of the emulsified asphalt in the spreader box.

(d) Streaks or other unsightly appearances. The shoulder line shall be uniform and straight.

(e) Excessive build-up of slurry seal mix on longitudinal or transverse joints.

(f) If oversize materials are encountered, final screening prior to placement will be required.

Method of Measurement and Basis of Payment

408.10 All materials and work required by this Section will be measured and paid for in accordance with Section 410.

PART 700 MATERIALS

Section 702. -- BITUMINOUS MATERIALS

702.01 and 702.02 Reserved.

702.03 Emulsified Asphalts.

(a) The emulsified asphalts for chip sealing shall be cationic, grade CRS-2, and conform to the AASHTO M 208 Table 1. The base asphalt to be emulsified shall conform to AASHTO M 226, Table 2 for an AC-10.

The sieve test specified under AASHTO M 208 is not required.

(b) Emulsified asphalts for slurry sealing shall conform to the requirement of Table 702-1 below:

Table 702-1
Quick-Set Emulsified Asphalts

Property	Specification	AASHTO Test Method
Viscosity, 77° F, Saybolt Furol, sec	20 - 100	T 59
Residue by Distillation, %	57 min.	T 59
Sieve Test	0.10 max.	T 59
Tests on Residue from Distillation		
Penetration, 77° F, 100g, 5 sec	40 - 110	T 49
Solubility in Trichloroethylene, %	97.5 min.	T 44
Ductility, 77° F, cm	40 min.	T 51

702.04 Acceptance Procedures for Asphalts.

(a) General Acceptance Procedures. Acceptance of asphalt is subject to the following:

(1) Laboratory Tests. The supplier shall test all material intended for shipment to the Government.

(2) Examination of Shipping Container. Before loading, the supplier shall examine the shipping container and shall remove all remnants of previous cargos that might contaminate the material to be loaded.

(3) Delivery Ticket. The Contractor shall furnish with each shipment two copies of the delivery ticket. The delivery ticket shall contain the following information:

Consignees
Project No.
Grade
Net gallons
Net weight
Type and amount of antistripping agent
Identification No. (truck, car, tank, etc.)
Destination
Date
Loading temperature
Specific gravity at 60° F

(4) Test Results and Certification. The Contractor, or authorized supplier, shall deliver to the Engineer the applicable test results obtained from (1) above and a certification signed by an authorized supplier to cover the quality and quantity of material and the condition of container for each shipment. The certification shall be essentially in the following form and may be stamped, written, or printed on the delivery ticket:

"This is to certify that this shipment of _____ tons/gallons of _____ asphalt meets all contract specifications and the shipping container was clean and free from contaminating material when loaded."

Supplier:
Signed:

Failure to sign the certification will be cause to withhold use of the material until it can be sampled and tested for compliance.

(5) Acceptance Sampling Procedures. Samples of asphalt materials shall be taken by the Engineer in accordance AASHTO T 40, from the shipping containers at the point of delivery. Samples shall be taken of each separate tank at the time of discharge into distributors or other conveyances on the project.

(b) Alternate Acceptance Procedures. Asphalt will be accepted by certification under (a)(1) through (a)(4). Quality control reviews may be conducted by the Government or an authorized representative at the point of production to determine the reliability of the supplier's certifications.

If the certifications are not reliable, acceptance by certification will be discontinued and the contents of each shipping container will be sampled at the point of delivery in accordance with (a)(5), and tested for compliance prior to incorporation in the work. This procedure will be followed until the supplier's quality control and testing procedures are such that material meeting contract specifications is being consistently produced.

(c) Requirements for Asphalt Containing Antistripping Additives. In addition to either (a) or (b), the Contractor or authorized supplier shall furnish the Engineer on delivery of the initial shipment of fortified asphalt to the project and with subsequent shipments when ordered by the Engineer, a one quart sealed sample of the asphalt taken at time of loading at the refinery and prior to introduction of the additive, along with a separate 1 pint sample of the antistripping additive.

(d) Nonspecification Asphalt. Asphalt not conforming to the specifications will either be rejected or accepted in accordance with the following:

* The Engineer will evaluate the qualities of the nonconforming material and determine whether the deficiencies are such as to require complete removal of the material, or if in the interest of the Government, the nonconforming material may be accepted at a reduced price and permitted to be used or to remain in the completed work.

* All rejected asphalt shall be immediately removed from the work, including all portions of the work in which such rejected asphalt has been incorporated, and shall be replaced with specification material at no additional cost to the Government.

* When the nonconforming asphalt is permitted to remain in the work, the Engineer will determine the quantity of material represented and an appropriate adjustment in contract price based on engineering judgment.

Section 703. -- AGGREGATES

703.01 through 703.10 Reserved

703.11 Filler. Filler material for asphaltic mixtures shall meet the requirements of AASHTO M 17.

703.12 Reserved

703.13 Aggregate for Chip Seals and Slurry Seals. Aggregates shall meet the following requirements for grading and quality:

(a) Aggregates for Chip Seal. Aggregate shall be hard, durable particles or fragments of crushed stone or crushed gravel. Aggregates shall conform to the grading requirements in Table 703-1 below.

Table 703-1
Grading Requirements for Chip Seal Aggregate
(Percentage by Weight Passing U.S. Standard Sieves, AASHTO T 27 and T 11)

Sieve Designation	Percent Passing
1/2" square	100
3/8" square	40 - 70
1/4" square	0 - 15
U.S. No. 10	0 - 5
U.S. No. 200	0 - 1.0

Not less than 75 percent by weight of the aggregate shall be particles having at least one fractured face. The fracture requirement shall apply to material retained on each sieve size No. 10 and above if that sieve retains more than 5 percent of the total sample.

The portion of aggregate retained on the 3/8 inch sieve shall not contain more than 15 percent of particles by weight that are flat or elongated or both, when tested in accordance with ASTM D 4791 using a dimensional ratio of 1 : 5.

The aggregate shall have a minimum polish value of 32 as determined by AASHTO T 279.

The aggregate shall pass the static stripping test as determined by AASHTO T 182.

The aggregate shall show a durability factor not less than 35 (coarse and fine aggregate) as determined by AASHTO T 210.

Coarse aggregate shall have a percent of wear of not more than 30 at 500 revolutions as determined by AASHTO T 96.

The finished product shall be clean, uniform in quality, and free from wood, bark, roots, and other deleterious materials.

(b) Aggregates for Slurry Seal. Aggregate shall consist of manufactured sand or crusher fines, or other approved mineral aggregate or combination thereof. Aggregates shall conform to the grading requirements in Table 703-2 below.

Table 703-2
Grading Requirements for Slurry Seal Aggregate
(Percentage by Weight Passing U.S. Standard Sieves, AASHTO T 27 and T 11)

Sieve Designation	Percent Passing
5/16" square	99 - 100
U.S. No. 4	70 - 90
U.S. No. 8	45 - 70
U.S. No. 16	28 - 50
U.S. No. 30	19 - 34
U.S. No. 50	12 - 25
U.S. No. 100	7 - 18
U.S. No. 200	5 - 15

Smooth, textured sand of less than 1.25 percent water absorption shall not exceed 50 percent of the total combined aggregate as determined by the AASHTO T 84.

The aggregate shall have a minimum sand equivalent of 55 as determined by AASHTO T 176, Alternate Method No. 2.

The finished product shall be clean, uniform in quality, and free from wood, bark, roots, and other deleterious materials.

The aggregate shall show a durability factor not less than 35 as determined by AASHTO T 210.

Material used in the production of the aggregate shall have a percent of wear of not more than 35 at 500 revolutions as determined by AASHTO T 96.

Appendix 14C

Several states and SHRP's gradations for asphalt-aggregate surface treatment (chip seal) cover material using ESCS aggregates

Appendix C

ESCS GRADATIONS FOR ASPHALT SURFACE TREATMENT (CHIP SEAL) COVER MATERIAL

AMOUNT FINER THAN EACH LABORATORY SIEVE (SQUARE OPENING) MASS PERCENT

3/4" AND FINER

STATE:		Texas	Louisiana	Oklahoma	Colorado			SHRP
SIEVE SIZE		GRADE 3	SIZE 2	GRADE 3	TYPE IV			Normal Weight
3/4"	19mm	100	100		100			
5/8"	15.75mm	98 to 100		100				
1/2"	12.5mm	75 to 90	90 to 100	90 to 100	95 to 100			100
3/8"	9.5mm	20 to 40	40 to 70	40 to 75	60 to 80			40 to 70
#4	4.75mm	0 to 5	0 to 15	0 to 15	0 to 10			0 to 15
#8	2.36mm	#10 0-2	0 to 5	0 to 5				#10 0-5
#200	75μm		0 to 1	0 to 2	0 to 1			0 to 1
Dust				0 to 1				

5/8" OR 1/2" AND FINER

STATE:		Texas		Missouri	Colorado	Kansas	Utah	Virginia
SIEVE SIZE		GRADE 4		Buildex Pg. A142	TYPE II	TYPE CM-L	TYPE C	
5/8"	15.75mm	100		100		100		
1/2"	12.5mm	95 to 100		95 to 100	100	95 to 100	100	
3/8"	9.5mm	60 to 80		85 to 100	70 to 100	85 to 100	70 to 90	
#4	4.75mm	0 to 5		0 to 30	0 to 4	0 to 30	0 to 5	
#8	2.36mm			0 to 10		0 to 10	0 to 3	
#10	2.06mm	0 to 2						
#200	75μm			0 to 2	0 to 1	0 to 2	0 to 1	

3/8" AND FINER

STATE:		Texas	Louisiana	Missouri	Colorado	Wyoming	Utah	Virginia
SIEVE SIZE		GRADE 5	SIZE 3	Buildex Pg. A142	TYPE I	TYPE C	TYPE A	TYPE 8P
1/2"	12.5mm	100	100	100	100	100	100	100
3/8"	9.5mm	98 to 100	85 to 100	92 to 100	100	90 to 100	85 to 100	75 to 100
#4	4.75mm	20 to 40	10 to 40	0 to 20	0 to 15		0 to 20	5 to 30
#8	2.36mm		0 to 10	0 to 4		0 to 10	0 to 5	0 to 5
#10	2.06mm	0 to 2						
#16	1.18mm		0 to 5					
#200	75μm		0 to 1	0 to 2	0 to 1	0 to 2	0 to 1	*0 to 1.7 *Washed

Appendix 14D

Design Methods: asphalt-aggregate surface treatment (chip seal, seal coat) design method and guidelines

Appendix D

Appendix "D" was taken from the *Field Manual on Design and Construction of Seal Coats* by Bob M. Gallaway, July 1981.

Design Method:

The Design method recommended and described below is based on a modification of the original Kearby method which has been utilized extensively by Texas-Department of Transportation. Laboratory tests and calculations required in the design method are given below.

ASPHALT-AGGREGATE SURFACE TREATMENT (CHIP SEAL, SEAL COAT) DESIGN METHOD AND GUIDELINES

Laboratory Tests:

Dry Loose Unit Weight. The dry loose unit weight determination shall be made in accordance with Tex-404-A (ASTM C29 shoveling method) except that the aggregate shall be tested in an oven-dry condition.

Bulk Specific Gravity. The bulk specific gravity shall be made in accordance with Tex-403-A (ASTM C127) for all natural aggregate and by the test method Tex-433-A for synthetic aggregates.

Board Test. Place a sufficient quantity of aggregate on a board of known area such that full coverage one (1) stone depth is obtained. A one-half (1/2) square yard area is a convenient laboratory size. The weight of the aggregates applied in this area is obtained and converted to units of pounds per square yard. Good lighting is recommended and care should be taken to place the aggregate only one stone deep.

Calculations

The quantity of aggregate expressed in terms of square yards of road surface that can be covered with a cubic yard of aggregate and the quantity of asphalt in gallons per square yard can be found as described below:

Aggregate Quantity $S = \frac{27W}{Q}$ $A = 5.61E\left(1 - \frac{W}{62.4G}\right)(T) + V$

where:

S = Quantity of aggregate required, sq. yds. per cu. yd.
W = Dry loose unit weight, lbs. per cu. ft.
Q = Aggregate quantity determined from board test, lbs. per sq. yd.
A = Asphalt quantity, gallons per sq. yd. @ 60°F.
E = Embedment depth obtained from Figure D-1 as follows:

$$E = ed$$

where:

e = Aggregate embedment, percent (Figure D-1)
d = Average mat depth, inches = $\frac{1.33Q}{W}$
G = Dry bulk specific gravity of aggregate
T = Traffic correction factor obtained from Table D-1.
V = Correction of surface condition obtained from Table D-2
5.61 = (7.48) (9/12), or conversion factor

Note: Asphalt quantities calculated by these methods are for asphalt cement. Appropriate corrections must be made where a cutback or an emulsion is used as illustrated in the examples given below.

Sample Calculations

Given:

(W) Dry loose unit weight of aggregate = 52.4 lbs./cu. ft.
(G) Dry bulk specific gravity of aggregate = 1.57
(Q) Quantity of aggregate (board test) = 9.7 lbs./sq. yd.
Traffic = 700 vehicles per day, per lane
Roadway Surface Condition + slightly pocked, porous, oxidized

Quantity of Aggregate

$$A = 5.61E\left(1 - \frac{W}{62.4G}\right)(T) + V$$

$$d = \frac{1.33Q}{W} = \frac{1.33\,(9.7)}{52.4} = .246 \text{ inches}$$

e = 40 percent from Figure D-1
E = ed = .40 (.246) = 0.0985 inches
T = 1.05 from Table D-1
V = +0.03 from Table D-2

$$A = 5.61\,(0.0985)\left(1 - \frac{52.4}{62.4\,(1.57)}\right)(1.05) + 0.03$$

A = 0.30 gallons of asphalt per square yard of roadway surface

If an emulsion or cutback is to be used, the quantity to be utilized must be corrected for the amount of volatiles present in the asphalt material. The approximate amount of volatiles present in those cutbacks recommended for use in seal coats is shown on Table D-3. For example, the seal coat design method suggests that 0.30 gallons per square yard of residual asphalt cement is required.

Theoretically, the amount of RC-250 to be placed on the pavement is:

$$\frac{0.30}{.75} = 0.40 \text{ gallons per square yard}$$

However, field experience indicates that bleeding is likely if the theoretical amount is utilized. Thus, it is recommended that the calculated theoretical value be reduced and the method described below be utilized to calculate the amount of cutback to be used.

$$A_{\text{recommended}} = A + K\,(A_{\text{theoretical}} - A)$$

where:

$A_{\text{recommended}}$ = recommended quantity of cutback or emulsified asphalt to be used in field.

A = residual quantity of asphalt obtained from the design method given above.

$A_{\text{theoretical}}$ = theoretical quantity of cutback or emulsified asphalt obtained by dividing 'A' by the quantity of residual asphalt in the cutback (Table D-3) or emulsion and as described above.

K = correction factor based on field experience

It should be noted that correction factors (K) have not been verified for cutbacks by carefully controlled field experiments and therefore should be used as guidelines only: Suggested 'K' factors for cutbacks are as follows:

K = 0.70 for spring construction
K = 0.60 for summer construction
K = 0.80 for fall construction
K = 0.90 for winter construction

If the RC-250 is to be placed in the fall, the quantity to be used is:

$$A_{\text{recommended}} = 0.30 + 0.80\left(\frac{0.80}{0.75} - 0.30\right)$$

$A_{\text{recommended}}$ = 0.38 gallons of RC-250 per square yard of roadway surface

Field trail sections placed in Texas and reported in reference 4 suggest that reduced quantities of emulsion (as compared to the theoretical value calculated) can be utilized successfully. Thus, it is recommended that the calculated theoretical value be reduced and the method outlined above be utilized.

It should be noted that corrective factors (K) have not been verified by extensive controlled field experiments and therefore should be used as guidelines only. Suggested K factors for emulsions are as follows:

$K = 0.60$ for spring construction
$K = 0.40$ for summer construction
$K = 0.70$ for fall construction
$K = 0.90$ for winter construction

Assuming that the design method suggests that 0.30 gallons per square yard is required, the amount of an RS-2H emulsion that contains seventy percent (70%) residual asphalt that should be used in the summer is:

$$A_{\text{recommended}} = 0.30 + 0.40\left(\frac{0.30}{0.70} - 0.30\right)$$

$A_{\text{recommended}} = 0.35$ gallons of EA-CRS-2h emulsion per square yard of roadway surface.

It should be noted that the quantity of asphalt to be sprayed from the asphalt distributor must be corrected for temperature in order that the proper quantity will be retained on the roadway as measured at 60°F. If the design quantity of asphalt cement was 0.30 and the spray temperature were 340°F, the temperature correction factor would be 0.9057 (D-4).

Thus, $\frac{0.30}{0.9057}$ or 0.33 gallons of asphalt cement per square yard would be sprayed at 340°F in order to have 0.30 gallons per square yard on a 60°F surface. Temperature correction factors for asphalt cement are shown in Table D-4, for cutbacks in Table D-5 and for emulsions in Table D-5. Table D-4 and D-5 are from Asphalt Institute book "*The Asphalt Handbook*" MS-4. Table D-4 is also published in ASTM D 4311 "*Standard Practice for Determining Asphalt Volume Correction to a Base Temperature*".

Environmental Considerations

Experience shows that the ideal environment for the construction of seal coats is hot, dry weather with no rain for the next several days. Thus, the two most important environmental factors are temperature and moisture. Wind velocity is also a factor to be considered.

Both road surface and atmospheric temperatures are important because they influence how well the cover aggregate can be embedded in the binder and then how soon the roadway can be reopened to traffic. Soon after the asphalt is shot, its temperature will approach that of the roadway surface temperature. At this temperature the asphalt will be much more viscous (thicker) than at the spraying temperature. If the road surface is cool, the binder may become so viscous (depending on the type and grade of asphalt) that it will become nearly impossible to obtain adequate adhesion between the aggregate and asphalt and proper aggregate embedment during the rolling operation. The net result will be aggregate loss when the roadway is opened to traffic. Aggregate loss may also cause windshield damage and even result in loss of friction. On the other hand, if the road surface temperature is too high and the asphalt is low in viscosity, a longer time will be required to cool the mat to the point where traffic will no longer dislodge the aggregate particles. During hot, sunny weather, the most critical time of day to reopen a new seal coat job to traffic is between mid-day and late afternoon when the pavement surface temperature is highest. This problem will be most serious when dark colored aggregates are used and the area is one of high solar flux.

Asphalt emulsions have relatively low viscosities at low temperature as compared to asphalt cement. This physical feature of emulsions allows this asphalt material to satisfactorily adhere to the aggregate and to obtain adequate embedment at lower road surface temperatures.

Wet aggregates will not adhere to asphalt cements. However, wet aggregates can be used with asphalt cements provided the water evaporated from the aggregate surface and adequate adhesion is obtained prior to finish rolling and opening to traffic. If wet aggregates and asphalt cements are to be used successfully, they should be used on hot, low humidity days. Wind will speed aggregate drying and thus promote adhesion. Similar reasons dictate that asphalt cement should not be sprayed on top of a wet pavement surface.

The problems with moisture are reduced considerably if cationic asphalt emulsions are used. If properly compounded and used, such emulsions tend to displace aggregate surface water and allow the binder to make direct contact with the aggregate surface. However, an excess of moisture may slow the emulsion break and the evaporation of the separated water which may still present problems.

Wind speed is also a consideration. A light breeze may help evaporate moisture (or the solvent from cutbacks). High winds may distort the distributor spray pattern making it impossible to obtain uniform asphalt coverage. Also, in some areas the dust carried by high winds will have detrimental effects.

Specific limits for the environmental conditions prevailing during construction are given in Table D-6. If these limits are carefully observed, the chance of successfully placing a seal coat is greatly improved.

Aggregate Embedment

The seal coat design method, the construction operations and considerations for climatic conditions should be aimed at providing adhesion between the asphalt binder and the aggregate and proper embedment of the aggregate into the asphalt film. Improper adhesion and/or inadequate embedment depth will result in loss of coverstone aggregate. Suggested percent embedment depths during the life of seal coats are listed below:

immediately after construction	30 ± 10%
start of cool weather (first year)	35 ± 10%
start of cold weather (first year)	45 ± 10%
after two (2) years of service	70 ± 10%

For low traffic facilities, aggregate embedment immediately after construction should be in the range of 30 to 40 percent while 20 to 30 percent embedment is the preferred range for high traffic volume facilities.

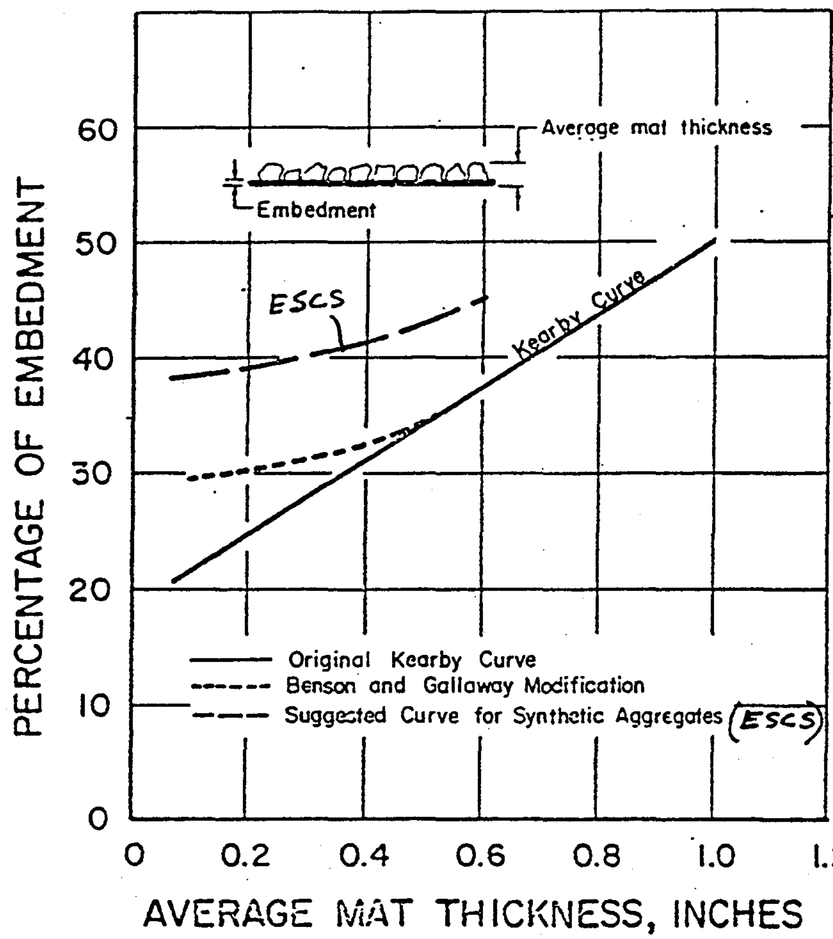


Figure D-1 Relation of Percent Embedment to Average Mat Thickness for Determining Quantity Of Asphalt for ESCS Lightweight Aggregate Chip Seals (Seals Coat).

Table D-1. Asphalt Application Rate - Correction Due to Traffic

Traffic - Vehicles Per Day Per Lane

	Over 1,000	500 to 1,000	250 to 500	100 to 250	Under 100
Traffic Factor (T)	1.00	1.05	1.10	1.15	1.20

Table D-2. Asphalt Application Rate Correction Due to Existing Pavement Surface Condition.

Description of Existing Surface	Asphalt Quantity Correction gal/sq. yd.
Flushed asphalt surface	- 0.06
Smooth, nonporous surface	- 0.03
Slightly porous, slightly oxidized surface	0.00
Slightly pocked, porous, oxidized surface	+ 0.03
Badly pocked, porous, oxidized surface	+ 0.06

Table D-3. Approximate Quantity of Cutter Stock in Cutbacks Commonly Used for Chip Seal (Seal Coat) Operations.

Type of Grade Of Cutback *	Approximate Quantity of Cutter Stock - Percent By Volume
RC-70	< 45
RC-250	< 35
RC-800	< 25
RC-3000	< 20
MC-800	< 25
MC-3000	< 20

* Ref. ASTM D-2027 Standard Specification for Cutback Asphalt (Medium-Curing Type) and ASTM D-2028 Standard Specification for Cutback Asphalt (Rapid-Curing Type).

Table D-4. Temperature-Volume Corrections for Asphalt Materials (Degrees Celsius)

Observed Temperature, °C	Volume Correction[C,D] Factor to 15°C		Observed Temperature, °C	Volume Correction[C,D] Factor to 15°C		Observed Temperature, °C	Volume Correction[C,D] Factor to 15°C		Observed Temperature, °C	Volume Correction[C,D] Factor to 15°C	
	A	B		A	B		A	B		A	B
−25,0	1,0254	1,0290	12,5	1,0016	1,0018	50,0	0,9782	0,9752	87,5	0,9552	0,9492
−24,5	1,0251	1,0286	13,0	1,0012	1,0014	50,5	0,9779	0,9749	88,0	0,9548	0,9489
−24,0	1,0248	1,0283	13,5	1,0009	1,0014	51,0	0,9776	0,9745	88,5	0,9545	0,9485
−23,5	1,0244	1,0279	14,0	1,0006	1,0007	51,5	0,9773	0,9742	89,0	0,9542	0,9482
−23,0	1,0241	1,0276	14,5	1,0003	1,0004	52,0	0,9770	0,9738	89,5	0,9539	0,9478
−22,5	1,0238	1,0272	15,0	1,0000	1,0000	52,5	0,9767	0,9735	90,0	0,9536	0,9475
−22,6	1,0235	1,0268	15,5	0,9997	0,9998	53,0	0,9763	0,9731	90,5	0,9533	0,9472
−21,5	1,0232	1,0265	16,0	0,9994	0,9993	53,5	0,9760	0,9728	91,0	0,9530	0,9468
−21,0	1,0228	1,0261	16,5	0,9991	0,9989	54,0	0,9757	0,9724	91,5	0,9527	0,9465
−20,5	1,0225	1,0258	17,0	0,9988	0,9986	54,5	0,9754	0,9721	92,0	0,9524	0,9461
−20,0	1,0222	1,0254	17,5	0,9985	0,9982	55,0	0,9751	0,9717	92,5	0,9521	0,9458
−19,5	1,0219	1,0250	18,0	0,9981	0,9978	55,5	0,9748	0,9714	93,0	0,9518	0,9455
−19,0	1,0216	1,0247	18,5	0,9978	0,9975	56,0	0,9745	0,9710	93,5	0,9515	0,9451
−18,5	1,0212	1,0243	19,0	0,9975	0,9971	56,5	0,9742	0,9707	94,0	0,9512	0,9448
−18,0	1,0209	1,0239	19,5	0,9972	0,9968	57,0	0,9739	0,9703	94,5	0,9509	0,9444
−17,5	1,0206	1,0236	20,0	0,9969	0,9964	57,5	0,9736	0,9700	95,0	0,9506	0,9441
−17,0	1,0203	1,0232	20,5	0,9966	0,9961	58,0	0,9732	0,9696	95,5	0,9503	0,9438
−16,5	1,0200	1,0228	21,0	0,9963	0,9957	58,5	0,9729	0,9693	96,0	0,9500	0,9434
−16,0	1,0196	1,0224	21,5	0,9959	0,9954	59,0	0,9726	0,9689	96,5	0,9497	0,9431
−15,5	1,0193	1,0221	22,0	0,9956	0,9950	59,5	0,9723	0,9686	97,0	0,9494	0,9427
−15,0	1,0190	1,0217	22,5	0,9953	0,9947	60,0	0,9720	0,9682	97,5	0,9491	0,9424
−14,5	1,0187	1,0213	23,0	0,9950	0,9943	60,5	0,9717	0,9679	98,0	0,9488	0,9421
−14,0	1,0184	1,0210	23,5	0,9947	0,9940	61,0	0,9714	0,9675	98,5	0,9485	0,9417
−13,5	1,0180	1,0206	24,0	0,9943	0,9936	61,5	0,9711	0,9672	99,0	0,9482	0,9414
−13,0	1,0177	1,0203	24,5	0,9940	0,9933	62,0	0,9708	0,9668	99,5	0,9479	0,9410
−12,5	1,0174	1,0199	25,0	0,9937	0,9929	62,5	0,9705	0,9665	100,0	0,9476	0,9407
−12,0	1,0171	1,0195	25,5	0,9937	0,9925	63,0	0,9701	0,9661	100,5	0,9473	0,9404
−11,5	1,0168	1,0192	26,0	0,9934	0,9922	63,5	0,9698	0,9658	101,0	0,9470	0,9400
−11,0	1,0164	1,0188	26,5	0,9928	0,9918	64,0	0,9695	0,9654	101,5	0,9467	0,9397
−10,5	1,0161	1,0185	27,0	0,9925	0,9915	64,5	0,9692	0,9651	102,0	0,9464	0,9393
−10,0	1,0158	1,0181	27,5	0,9922	0,9911	65,0	0,9689	0,9647	102,5	0,9461	0,9390
−9,5	1,0155	1,0177	28,0	0,9918	0,9907	65,5	0,9686	0,9644	103,0	0,9458	0,9387
−9,0	1,0152	1,0174	28,5	0,9915	0,9904	66,0	0,9683	0,9640	103,5	0,9455	0,9383
−8,5	1,0148	1,0170	29,0	0,9912	0,9900	66,5	0,9680	0,9637	104,0	0,9452	0,9380
−8,0	1,0145	1,0166	29,5	0,9909	0,9897	67,0	0,9677	0,9633	104,5	0,9449	0,9376
−7,5	1,0142	1,0163	30,0	0,9906	0,9893	67,5	0,9674	0,9630	105,0	0,9446	0,9373
−7,0	1,0139	1,0159	30,5	0,9903	0,9889	68,0	0,9670	0,9626	105,5	0,9443	0,9370
−6,5	1,0136	1,0155	31,0	0,9900	0,9886	68,5	0,9667	0,9623	106,0	0,9440	0,9366
−6,0	1,0132	1,0151	31,5	0,9897	0,9882	69,0	0,9664	0,9619	106,5	0,9437	0,9363
−5,5	1,0129	1,0148	32,0	0,9894	0,9879	69,5	0,9661	0,9616	107,0	0,9434	0,9359
−5,0	1,0126	1,0144	32,5	0,9891	0,9875	70,0	0,9568	0,9612	107,5	0,9431	0,9356
−4,5	1,0123	1,0140	33,0	0,9887	0,9871	70,5	0,9655	0,9609	108,0	0,9428	0,9353
−4,0	1,0120	1,0137	33,5	0,9984	0,9868	71,0	0,9652	0,9605	108,5	0,9425	0,9349
−3,5	1,0117	1,0133	34,0	0,9881	0,9864	71,5	0,9649	0,9602	109,0	0,9422	0,9346
−3,0	1,0114	1,0130	34,5	0,9878	0,9861	72,0	0,9646	0,9598	109,5	0,9419	0,9342
−2,5	1,0111	1,0126	35,0	0,9875	0,9857	72,5	0,9643	0,9595	110,0	0,9416	0,9339
−2,0	1,0107	1,0122	35,5	0,9872	0,9854	73,0	0,9640	0,9592	110,5	0,9413	0,9336
−1,5	1,0104	1,0119	36,0	0,9869	0,9850	73,5	0,9637	0,9588	111,0	0,9410	0,9932
−1,0	1,0101	1,0115	36,5	0,9866	0,9847	74,0	0,9634	0,9585	111,5	0,9407	0,9329
−0,5	1,0098	1,0112	37,0	0,9863	0,9843	74,5	0,9631	0,9581	112,0	0,9404	0,9325
0	1,0095	1,0108	37,5	0,9860	0,9840	75,0	0,9628	0,9578	112,5	0,9401	0,9322
0,5	1,0092	1,0104	38,0	0,9856	0,9836	75,5	0,9625	0,9575	113,0	0,9397	0,9319
1,0	1,0089	1,0101	38,5	0,9853	0,9833	76,0	0,9622	0,9571	113,5	0,9394	0,9315
1,5	1,0085	1,0097	39,0	0,9850	0,9829	76,5	0,9619	0,9568	114,0	0,9391	0,9312
2,0	1,0082	1,0094	39,5	0,9847	0,9826	77,0	0,9616	0,9564	114,5	0,9388	0,9308
2,5	1,0079	1,0090	40,0	0,9844	0,9822	77,5	0,9613	0,9561	115,0	0,9385	0,9305
3,0	1,0076	1,0086	40,5	0,9841	0,9819	78,0	0,9609	0,9557	115,5	0,9382	0,9302
3,5	1,0073	1,0083	41,0	0,9838	0,9815	78,5	0,9606	0,9554	116,0	0,9379	0,9298
4,0	1,0069	1,0079	41,5	0,9835	0,9812	79,0	0,9603	0,9550	116,5	0,9376	0,9295
4,5	1,0066	1,0076	42,0	0,9832	0,9808	79,5	0,9600	0,9547	117,0	0,9373	0,9292
5,0	1,0063	1,0072	42,5	0,9829	0,9805	80,0	0,9597	0,9543	117,5	0,9371	0,9289
5,5	1,0060	1,0068	43,0	0,9825	0,9801	80,5	0,9594	0,9540	118,0	0,9368	0,9285
6,0	1,0057	1,0065	43,5	0,9822	0,9798	81,0	0,9591	0,9536	118,5	0,9365	0,9282
6,5	1,0053	1,0061	44,0	0,9819	0,9794	81,5	0,9588	0,9533	119,0	0,9362	0,9279
7,0	1,0050	1,0058	44,5	0,9816	0,9791	82,0	0,9585	0,9529	119,5	0,9359	0,9275
7,5	1,0047	1,0054	45,0	0,9813	0,9787	82,5	0,9582	0,9526	120,0	0,9356	0,9272
8,0	1,0044	1,0050	45,5	0,9810	0,9784	83,0	0,9578	0,9523	120,5	0,9353	0,9269
8,5	1,0041	1,0047	46,0	0,9807	0,9780	83,5	0,9576	0,9519	121,0	0,9350	0,9265
9,0	1,0037	1,0043	46,5	0,9804	0,9777	84,0	0,9573	0,9516	121,5	0,9347	0,9262
9,5	1,0034	1,0040	47,0	0,9801	0,9773	84,5	0,9570	0,9512	122,0	0,9344	0,9258
10,0	1,0031	1,0036	47,5	0,9798	0,9770	85,0	0,9567	0,9509	122,5	0,9341	0,9255
10,5	1,0028	1,0032	48,0	0,9794	0,9766	85,5	0,9564	0,9506	123,0	0,9338	0,9252
11,0	1,0025	1,0029	48,5	0,9791	0,9763	86,0	0,9561	0,9502	123,5	0,9335	0,9248
11,5	1,0022	1,0025	49,0	0,9788	0,9759	86,5	0,9558	0,9499	124,0	0,9332	0,9245
12,0	1,0019	1,0022	49,5	0,9785	0,9756	87,0	0,9555	0,9495	124,5	0,9329	0,9241

[C] Use column A factors for asphalts with density at 15°C of 966 kg/m³ or higher.
[D] Use column B factors for asphalts with density at 15°C of 850 to 965 kg/m³.

Table D-4. (Continued) Temperature-Volume Corrections for Asphalt Materials (Degrees Celsius)

Observed Temperature, °C	Volume Correction[C,D] Factor to 15°C A	Volume Correction[C,D] Factor to 15°C B	Observed Temperature, °C	Volume Correction[C,D] Factor to 15°C A	Volume Correction[C,D] Factor to 15°C B	Observed Temperature, °C	Volume Correction[C,D] Factor to 15°C A	Volume Correction[C,D] Factor to 15°C B	Observed Temperature, °C	Volume Correction[C,D] Factor to 15°C A	Volume Correction[C,D] Factor to 15°C B
125.0	0.9326	0.9238	162.5	0.9104	0.8991	200.0	0.8886	0.8749	237.5	0.8673	0.8514
125.5	0.9323	0.9235	163.0	0.9101	0.8987	200.5	0.8883	0.8746	238.0	0.8670	0.8510
126.0	0.9320	0.9231	163.5	0.9098	0.8984	201.0	0.8880	0.8743	238.5	0.8667	0.8507
126.5	0.9317	0.9228	164.0	0.9095	0.8981	201.5	0.8877	0.8739	239.0	0.8664	0.8504
127.0	0.9314	0.9225	164.5	0.9092	0.8977	202.0	0.8874	0.8736	239.5	0.8661	0.8501
127.5	0.9311	0.9222	165.0	0.9089	0.8974	202.5	0.8872	0.8733	240.0	0.8658	0.8498
128.0	0.9308	0.9218	165.5	0.9086	0.8971	203.0	0.8869	0.8730	240.5	0.8655	0.8495
128.5	0.9305	0.9215	166.0	0.9083	0.8968	203.5	0.8866	0.8727	241.0	0.8652	0.8492
129.0	0.9302	0.9212	166.5	0.9080	0.8964	204.0	0.8863	0.8723	241.5	0.8650	0.8489
129.5	0.9299	0.9208	167.0	0.9077	0.8961	204.5	0.8860	0.8720	242.0	0.8647	0.8486
130.0	0.9296	0.9205	167.5	0.9075	0.8958	205.0	0.8857	0.8717	242.5	0.8644	0.8483
130.5	0.9293	0.9202	168.0	0.9072	0.8955	205.5	0.8854	0.8714	243.0	0.8641	0.8480
131.0	0.9290	0.9198	168.5	0.9069	0.8952	206.0	0.8851	0.8711	243.5	0.8638	0.8477
131.5	0.9287	0.9195	169.0	0.9066	0.8948	206.5	0.8849	0.8708	244.0	0.8636	0.8474
132.0	0.9284	0.9191	169.5	0.9063	0.8945	207.0	0.8846	0.8705	244.5	0.8633	0.8471
132.5	0.9281	0.9188	170.0	0.9060	0.8942	207.5	0.8843	0.8702	245.0	0.8630	0.8468
133.0	0.9278	0.9185	170.5	0.9057	0.8939	208.0	0.8840	0.8698	245.5	0.8627	0.8465
133.5	0.9275	0.9181	171.0	0.9054	0.8935	208.5	0.8837	0.8695	246.0	0.8624	0.8462
134.0	0.9272	0.9178	171.5	0.9051	0.8932	209.0	0.8835	0.8692	246.5	0.8622	0.8459
134.5	0.9269	0.9174	172.0	0.9048	0.8929	209.5	0.8832	0.8689	247.0	0.8619	0.8456
135.0	0.9266	0.9171	172.5	0.9046	0.8926	210.0	0.8829	0.8686	247.5	0.8616	0.8453
135.5	0.9263	0.9168	173.0	0.9043	0.8922	210.5	0.8826	0.8683	248.0	0.8613	0.8449
136.0	0.9260	0.9164	173.5	0.9040	0.8919	211.0	0.8823	0.8680	248.5	0.8610	0.8446
136.5	0.9257	0.9161	174.0	0.9037	0.8916	211.5	0.8820	0.8676	249.0	0.8608	0.8443
137.0	0.9254	0.9158	174.5	0.9034	0.8912	212.0	0.8817	0.8673	249.5	0.8605	0.8440
137.5	0.9251	0.9155	175.0	0.9031	0.8909	212.5	0.8815	0.8670	250.0	0.8602	0.8437
138.0	0.9248	0.9151	175.5	0.9028	0.8906	213.0	0.8812	0.8667	250.5	0.8599	0.8434
138.5	0.9246	0.9148	176.0	0.9025	0.8903	213.5	0.8809	0.8664	251.0	0.8596	0.8431
139.0	0.9242	0.9145	176.5	0.9022	0.8899	214.0	0.8806	0.8660	251.5	0.8594	0.8428
139.5	0.9239	0.9141	177.0	0.9019	0.8896	214.5	0.8803	0.8657	252.0	0.8591	0.8425
140.0	0.9236	0.9138	177.5	0.9017	0.8893	215.0	0.8800	0.8654	252.5	0.8588	0.8422
140.5	0.9233	0.9135	178.0	0.9014	0.8890	215.5	0.8797	0.8651	253.0	0.8585	0.8418
141.0	0.9230	0.9131	178.5	0.9011	0.8887	216.0	0.8794	0.8648	253.5	0.8582	0.8415
141.5	0.9227	0.9128	179.0	0.9008	0.8883	216.5	0.8792	0.8645	254.0	0.8580	0.8412
142.0	0.9224	0.9125	179.5	0.9005	0.8880	217.0	0.8789	0.8642	254.5	0.8577	0.8409
142.5	0.9222	0.9122	180.0	0.9002	0.8877	217.5	0.8786	0.8639	255.0	0.8574	0.8406
143.0	0.9219	0.9118	180.5	0.8999	0.8874	218.0	0.8783	0.8635	255.5	0.8571	0.8403
143.5	0.9216	0.9115	181.0	0.8996	0.8871	218.5	0.8780	0.8632	256.0	0.8568	0.8400
144.0	0.9213	0.9112	181.5	0.8993	0.8867	219.0	0.8778	0.8629	256.5	0.8566	0.8397
144.5	0.9210	0.9108	182.0	0.8990	0.8864	219.5	0.8775	0.8626	257.0	0.8563	0.8394
145.0	0.9207	0.9105	182.5	0.8988	0.8861	220.0	0.8772	0.8623	257.5	0.8560	0.8391
145.5	0.9204	0.9102	183.0	0.8985	0.8858	220.5	0.8769	0.8620	258.0	0.8557	0.8388
146.0	0.9201	0.9098	183.5	0.8982	0.8855	221.0	0.8766	0.8617	258.5	0.8554	0.8385
146.5	0.9198	0.9095	184.0	0.8979	0.8851	221.5	0.8763	0.8614	259.0	0.8552	0.8382
147.0	0.9195	0.9092	184.5	0.8976	0.8848	222.0	0.8760	0.8611	259.5	0.8549	0.8379
147.5	0.9192	0.9089	185.0	0.8973	0.8845	222.5	0.8758	0.8608	260.0	0.8546	0.8376
148.0	0.9189	0.9085	185.5	0.8970	0.8842	223.0	0.8755	0.8604	260.5	0.8543	0.8373
148.5	0.9186	0.9082	186.0	0.8967	0.8839	223.5	0.8752	0.8601	261.0	0.8540	0.8370
149.0	0.9183	0.9079	186.5	0.8964	0.8835	224.0	0.8749	0.8598	261.5	0.8538	0.8367
149.5	0.9180	0.9075	187.0	0.8961	0.8832	224.5	0.8746	0.8595	262.0	0.8535	0.8364
150.0	0.9177	0.9072	187.5	0.8959	0.8829	225.0	0.8743	0.8592	262.5	0.8532	0.8361
150.5	0.9174	0.9069	188.0	0.8956	0.8826	225.5	0.8740	0.8589	263.0	0.8529	0.8357
151.0	0.9171	0.9065	188.5	0.8953	0.8823	226.0	0.8737	0.8586	263.5	0.8526	0.8354
151.5	0.9168	0.9062	189.0	0.8950	0.8819	226.5	0.8735	0.8582	264.0	0.8524	0.8351
152.0	0.9165	0.9059	189.5	0.8947	0.8816	227.0	0.8732	0.8579	264.5	0.8521	0.8348
152.5	0.9163	0.9056	190.0	0.8944	0.8813	227.5	0.8729	0.8576	265.0	0.8518	0.8345
153.0	0.9160	0.9052	190.5	0.8941	0.8810	228.0	0.8726	0.8573	265.5	0.8515	0.8342
153.5	0.9157	0.9049	191.0	0.8938	0.8807	228.5	0.8723	0.8570	266.0	0.8512	0.8339
154.0	0.9154	0.9046	191.5	0.8935	0.8803	229.0	0.8721	0.8566	266.5	0.8510	0.8336
154.5	0.9151	0.9042	192.0	0.8932	0.8800	229.5	0.8718	0.8563	267.0	0.8507	0.8333
155.0	0.9148	0.9039	192.5	0.8930	0.8797	230.0	0.8715	0.8560	267.5	0.8504	0.8330
155.5	0.9145	0.9036	193.0	0.8927	0.8794	230.5	0.8712	0.8557	268.0	0.8501	0.8326
156.0	0.9142	0.9033	193.5	0.8924	0.8791	231.0	0.8709	0.8554	268.5	0.8498	0.8323
156.5	0.9139	0.9029	194.0	0.8921	0.8787	231.5	0.8707	0.8551	269.0	0.8496	0.8320
157.0	0.9136	0.9026	194.5	0.8918	0.8784	232.0	0.3704	0.8548	269.5	0.8493	0.8317
157.5	0.9133	0.9023	195.0	0.8915	0.8781	232.5	0.8701	0.8545	270.0	0.8490	0.8314
158.0	0.9130	0.9020	195.5	0.8912	0.8778	233.0	0.8698	0.8541	270.5	0.8487	0.8311
158.5	0.9127	0.9017	196.0	0.8909	0.8775	233.5	0.8695	0.8538	271.0	0.8484	0.8308
159.0	0.9124	0.9013	196.5	0.8906	0.8771	234.0	0.8693	0.8535	271.5	0.8482	0.8305
159.5	0.9121	0.9010	197.0	0.8903	0.8768	234.5	0.8690	0.8532	272.0	0.8479	0.8302
160.0	0.9118	0.9007	197.5	0.8901	0.8765	235.0	0.8687	0.8529	272.5	0.8476	0.8299
160.5	0.9115	0.9004	198.0	0.8898	0.8762	235.5	0.8684	0.8526	273.0	0.8473	0.8296
161.0	0.9112	0.9000	198.5	0.8895	0.8759	236.0	0.8681	0.8523	273.5	0.8470	0.8293
161.5	0.9109	0.8997	199.0	0.8892	0.8755	236.5	0.8678	0.8520	274.0	0.8468	0.8290
162.0	0.9106	0.8994	199.5	0.8889	0.8752	237.0	0.8675	0.8517	274.5	0.8465	0.8287

[C] Use column A factors for asphalts with density at 15°C of 966 kg/m³ or higher.
[D] Use column B factors for asphalts with density at 15°C of 850 to 965 kg/m³.

Table D-4. Temperature-Volume Corrections for Asphalt Materials (Degrees Fahrenheit)

Observed Temperature, °F	Volume Correction Factor to 60°F[a,b] A	B
0	1.0211	1.0241
1	1.0208	1.0237
2	1.0204	1.0233
3	1.0201	1.0229
4	1.0197	1.0225
5	1.0194	1.0221
6	1.0190	1.0217
7	1.0186	1.0213
8	1.0183	1.0209
9	1.0179	1.0205
10	1.0176	1.0201
11	1.0172	1.0197
12	1.0169	1.0193
13	1.0165	1.0189
14	1.0162	1.0185
15	1.0158	1.0181
16	1.0155	1.0177
17	1.0151	1.0173
18	1.0148	1.0168
19	1.0144	1.0164
20	1.0141	1.0160
21	1.0137	1.0156
22	1.0133	1.0152
23	1.0130	1.0148
24	1.0126	1.0144
25	1.0123	1.0140
26	1.0119	1.0136
27	1.0116	1.0132
28	1.0112	1.0128
29	1.0109	1.0124
30	1.0105	1.0120
31	1.0102	1.0116
32	1.0098	1.0112
33	1.0095	1.0108
34	1.0091	1.0104
35	1.0088	1.0100
36	1.0084	1.0096
37	1.0081	1.0092
38	1.0077	1.0088
39	1.0074	1.0084
40	1.0070	1.0080
41	1.0067	1.0076
42	1.0063	1.0072
43	1.0060	1.0068
44	1.0056	1.0064
45	1.0053	1.0060
46	1.0040	1.0056
47	1.0046	1.0052
48	1.0042	1.0048
49	1.0038	1.0044
50	1.0035	1.0040
51	1.0031	1.0036
52	1.0028	1.0032
53	1.0024	1.0028
54	1.0021	1.0024
55	1.0017	1.0020
56	1.0014	1.0016
57	1.0010	1.0012
58	1.0007	1.0008
59	1.0003	1.0004
60	1.0000	1.0000
61	0.9997	0.9996
62	0.9993	0.9992
63	0.9990	0.9988
64	0.9986	0.9984
65	0.9983	0.9980
66	0.9979	0.9976
67	0.9976	0.9972
68	0.9972	0.9968
69	0.9969	0.9964
70	0.9965	0.9960
71	0.9962	0.9956
72	0.9958	0.9952
73	0.9955	0.9948
74	0.9951	0.9944

Observed Temperature, °F	Volume Correction Factor to 60°F[a,b] A	B
75	0.9948	0.9940
76	0.9944	0.9936
77	0.9941	0.9932
78	0.9937	0.9929
79	0.9934	0.9925
80	0.9930	0.9921
81	0.9927	0.9917
82	0.9923	0.9913
83	0.9920	0.9909
84	0.9916	0.9905
85	0.9913	0.9901
86	0.9909	0.9897
87	0.9906	0.9893
88	0.9902	0.9889
89	0.9899	0.9885
90	0.9896	0.9881
91	0.9892	0.9877
92	0.9889	0.9873
93	0.9885	0.9869
94	0.9882	0.9865
95	0.9878	0.9861
96	0.9875	0.9857
97	0.9871	0.9854
98	0.9868	0.9850
99	0.9864	0.9846
100	0.9861	0.9842
101	0.9857	0.9838
102	0.9854	0.9834
103	0.9851	0.9830
104	0.9847	0.9826
105	0.9844	0.9822
106	0.9840	0.9818
107	0.9887	0.9814
108	0.9833	0.9810
109	0.9830	0.9806
110	0.9826	0.9803
111	0.9823	0.9799
112	0.9819	0.9795
113	0.9816	0.9791
114	0.9813	0.9787
115	0.9809	0.9783
116	0.9806	0.9779
117	0.9802	0.9775
118	0.9799	0.9771
119	0.9795	0.9767
120	0.9792	0.9763
121	0.9788	0.9760
122	0.9785	0.9756
123	0.9782	0.9752
124	0.9778	0.9748
125	0.9775	0.9744
126	0.9771	0.9740
127	0.9768	0.9736
128	0.9764	0.9732
129	0.9761	0.9728
130	0.9758	0.9725
131	0.9754	0.9721
132	0.9751	0.9717
133	0.9747	0.9713
134	0.9744	0.9709
135	0.9740	0.9705
136	0.9737	0.9701
137	0.9734	0.9697
138	0.9730	0.9693
139	0.9727	0.9690
140	0.9723	0.9686
141	0.9720	0.9682
142	0.9716	0.9678
143	0.9713	0.9674
144	0.9710	0.9670
145	0.9706	0.9666
146	0.9703	0.9662
147	0.9699	0.9659
148	0.9696	0.9655
149	0.9693	0.9651

Observed Temperature, °F	Volume Correction Factor to 60°F[a,b] A	B
150	0.9689	0.9647
151	0.9686	0.9643
152	0.9682	0.9639
153	0.9679	0.9635
154	0.9675	0.9632
155	0.9672	0.9628
156	0.9669	0.9624
157	0.9665	0.9620
158	0.9662	0.9616
159	0.9658	0.9612
160	0.9655	0.9609
161	0.9652	0.9605
162	0.9648	0.9601
163	0.9645	0.9597
164	0.9641	0.9593
165	0.9638	0.9589
166	0.9635	0.9585
167	0.9631	0.9582
168	0.9628	0.9578
169	0.9624	0.9574
170	0.9621	0.9570
171	0.9618	0.9566
172	0.9614	0.9562
173	0.9611	0.9559
174	0.9607	0.9555
175	0.9604	0.9551
176	0.9601	0.9547
177	0.9597	0.9543
178	0.9594	0.9539
179	0.9590	0.9536
180	0.9587	0.9532
181	0.9584	0.9528
182	0.9580	0.9524
183	0.9577	0.9520
184	0.9574	0.9517
185	0.9570	0.9513
186	0.9567	0.9509
187	0.9563	0.9505
188	0.9560	0.9501
189	0.9557	0.9498
190	0.9553	0.9494
191	0.9550	0.9490
192	0.9547	0.9486
193	0.9543	0.9482
194	0.9540	0.9478
195	0.9536	0.9475
196	0.9533	0.9471
197	0.9530	0.9467
198	0.9526	0.9463
199	0.9523	0.9460
200	0.9520	0.9456
201	0.9516	0.9452
202	0.9513	0.9448
203	0.9509	0.9444
204	0.9506	0.9441
205	0.9503	0.9437
206	0.9499	0.9433
207	0.9496	0.9429
208	0.9493	0.9425
209	0.9489	0.9422
210	0.9486	0.9418
211	0.9483	0.9414
212	0.9479	0.9410
213	0.9476	0.9407
214	0.9472	0.9403
215	0.9469	0.9399
216	0.9466	0.9395
217	0.9462	0.9391
218	0.9459	0.9388
219	0.9456	0.9384
220	0.9452	0.9380
221	0.9449	0.9376
222	0.9446	0.9373
223	0.9442	0.9369
224	0.9439	0.9365

Observed Temperature, °F	Volume Correction Factor to 60°F[a,b] A	B
225	0.9436	0.9361
226	0.9432	0.9358
227	0.9429	0.9354
228	0.9426	0.9350
229	0.9422	0.9346
230	0.9419	0.9343
231	0.9416	0.9339
232	0.9412	0.9335
233	0.9409	0.9331
234	0.9405	0.9328
235	0.9402	0.9324
236	0.9399	0.9320
237	0.9395	0.9316
238	0.9392	0.9313
239	0.9389	0.9309
240	0.9385	0.9305
241	0.9382	0.9301
242	0.9379	0.9298
243	0.9375	0.9294
244	0.9372	0.9290
245	0.9369	0.9286
246	0.9365	0.9283
247	0.9362	0.9279
248	0.9359	0.9275
249	0.9356	0.9272
250	0.9352	0.9268
251	0.9349	0.9264
252	0.9346	0.9260
253	0.9342	0.9257
254	0.9339	0.9253
255	0.9336	0.9249
256	0.9332	0.9245
257	0.9329	0.9242
258	0.9326	0.9238
259	0.9322	0.9234
260	0.9319	0.9231
261	0.9316	0.9227
262	0.9312	0.9223
263	0.9309	0.9219
264	0.9306	0.9216
265	0.9302	0.9212
266	0.9299	0.9208
267	0.9296	0.9205
268	0.9293	0.9201
269	0.9289	0.9197
270	0.9286	0.9194
271	0.9283	0.9190
272	0.9279	0.9186
273	0.9276	0.9182
274	0.9273	0.9179
275	0.9269	0.9175
276	0.9266	0.9171
277	0.9263	0.9168
278	0.9259	0.9164
279	0.9256	0.9160
280	0.9253	0.9157
281	0.9250	0.9153
282	0.9246	0.9149
283	0.9243	0.9146
284	0.9240	0.9142
285	0.9236	0.9138
286	0.9233	0.9135
287	0.9230	0.9131
288	0.9227	0.9127
289	0.9223	0.9124
290	0.9220	0.9120
291	0.9217	0.9116
292	0.9213	0.9113
293	0.9210	0.9109
294	0.9207	0.9105
295	0.9204	0.9102
296	0.9200	0.9098
297	0.9197	0.9094
298	0.9194	0.9091
299	0.9190	0.9087

[a] Use column A factors for asphalts with API gravity at 60°F of 14.9° or less or with specific gravity 60/60°F of 0.967 or higher.
[b] Use column B factors for asphalts with API gravity at 60°F from 15.0° to 34.9° or with specific gravity 60/60°F from 0.850 to 0.966.

Table D-4. (Continued) Temperature-Volume Corrections for Asphalt Materials (Degrees Fahrenheit)

Observed Temperature, °F	Volume Correction Factor to 60°F[a,b] A	B	Observed Temperature, °F	Volume Correction Factor to 60°F[a,b] A	B	Observed Temperature, °F	Volume Correction Factor to 60°F[a,b] A	B	Observed Temperature, °F	Volume Correction Factor to 60°F[a,b] A	B
300	0.9187	0.9083	350	0.9024	0.8902	400	0.8864	0.8724	450	0.8705	0.8550
301	0.9184	0.9080	351	0.9021	0.8899	401	0.8861	0.8721	451	0.8702	0.8547
302	0.9181	0.9076	352	0.9018	0.8895	402	0.8857	0.8717	452	0.8699	0.8543
303	0.9177	0.9072	353	0.9015	0.8891	403	0.8854	0.8714	453	0.8696	0.8540
304	0.9174	0.9069	354	0.9011	0.8888	404	0.8851	0.8710	454	0.8693	0.8536
305	0.9171	0.9065	355	0.9008	0.8884	405	0.8848	0.8707	455	0.8690	0.8533
306	0.9167	0.9061	356	0.9005	0.8881	406	0.8845	0.8703	456	0.8687	0.8529
307	0.9164	0.9058	357	0.9002	0.8877	407	0.8841	0.8700	457	0.8683	0.8526
308	0.9161	0.9054	358	0.8998	0.8873	408	0.8838	0.8696	458	0.8680	0.8522
309	0.9158	0.9050	359	0.8995	0.8870	409	0.8835	0.8693	459	0.8677	0.8519
310	0.9154	0.9047	360	0.8992	0.8866	410	0.8832	0.8689	460	0.8674	0.8516
311	0.9151	0.9043	361	0.8989	0.8863	411	0.8829	0.8686	461	0.8671	0.8512
312	0.9148	0.9039	362	0.8986	0.8859	412	0.8826	0.8682	462	0.8668	0.8509
313	0.9145	0.9036	363	0.8982	0.8856	413	0.8822	0.8679	463	0.8665	0.8505
314	0.9141	0.9032	364	0.8979	0.8852	414	0.8819	0.8675	464	0.8661	0.8502
315	0.9138	0.9029	365	0.8976	0.8848	415	0.8816	0.8672	465	0.8658	0.8498
316	0.9135	0.9025	366	0.8973	0.8845	416	0.8813	0.8668	466	0.8655	0.8495
317	0.9132	0.9021	367	0.8969	0.8841	417	0.8810	0.8665	467	0.8652	0.8492
318	0.9128	0.9018	368	0.8966	0.8838	418	0.8806	0.8661	468	0.8649	0.8488
319	0.9125	0.9014	369	0.8963	0.8834	419	0.8803	0.8658	469	0.8646	0.8485
320	0.9122	0.9010	370	0.8960	0.8831	420	0.8800	0.8654	470	0.8643	0.8481
321	0.9118	0.9007	371	0.8957	0.8827	421	0.8797	0.8651	471	0.8640	0.8478
322	0.9115	0.9003	372	0.8953	0.8823	422	0.8794	0.8647	472	0.8636	0.8474
323	0.9112	0.9000	373	0.8950	0.8820	423	0.8791	0.8644	473	0.8633	0.8471
324	0.9109	0.8996	374	0.8947	0.8816	424	0.8787	0.8640	474	0.8630	0.8468
325	0.9105	0.8992	375	0.8944	0.8813	425	0.8784	0.8637	475	0.8627	0.8464
326	0.9102	0.8989	376	0.8941	0.8809	426	0.8781	0.8633	476	0.8624	0.8461
327	0.9099	0.8985	377	0.8937	0.8806	427	0.8778	0.8630	477	0.8621	0.8457
328	0.9096	0.8981	378	0.8934	0.8802	428	0.8775	0.8626	478	0.8618	0.8454
329	0.9092	0.8978	379	0.8931	0.8799	429	0.8772	0.8623	479	0.8615	0.8451
330	0.9089	0.8974	380	0.8928	0.8795	430	0.8768	0.8619	480	0.8611	0.8447
331	0.9086	0.8971	381	0.8924	0.8792	431	0.8765	0.8616	481	0.8608	0.8444
332	0.9083	0.8967	382	0.8921	0.8788	432	0.8762	0.8612	482	0.8605	0.8440
333	0.9079	0.8963	383	0.8918	0.8784	433	0.8759	0.8609	483	0.8602	0.8437
334	0.9076	0.8960	384	0.8915	0.8781	434	0.8756	0.8605	484	0.8599	0.8433
335	0.9073	0.8956	385	0.8912	0.8777	435	0.8753	0.8602	485	0.8596	0.8430
336	0.9070	0.8952	386	0.8908	0.8774	436	0.8749	0.8599	486	0.8593	0.8427
337	0.9066	0.8949	387	0.8905	0.8770	437	0.8746	0.8595	487	0.8590	0.8423
338	0.9063	0.8945	388	0.8902	0.8767	438	0.8743	0.8592	488	0.8587	0.8420
339	0.9060	0.8942	389	0.8899	0.9763	439	0.8740	0.8588	489	0.8583	0.8416
340	0.9057	0.8938	390	0.8896	0.8760	440	0.8737	0.8585	490	0.8580	0.8413
341	0.9053	0.8934	391	0.8892	0.8756	441	0.8734	0.8581	491	0.8577	0.8410
342	0.9050	0.8931	392	0.8889	0.8753	442	0.8731	0.8578	492	0.8574	0.8406
343	0.9047	0.8927	393	0.8886	0.8749	443	0.8727	0.8574	493	0.8571	0.8403
344	0.9044	0.8924	394	0.8883	0.8746	444	0.8724	0.8571	494	0.8568	0.8399
345	0.9040	0.8920	395	0.8880	0.8742	445	0.8721	0.8567	495	0.8565	0.8396
346	0.9037	0.8916	396	0.8876	0.8738	446	0.8718	0.8564	496	0.8562	0.8393
347	0.9034	0.8913	397	0.8873	0.8735	447	0.8715	0.8560	497	0.8559	0.8389
348	0.9031	0.8909	398	0.8870	0.8731	448	0.8712	0.8557	498	0.8556	0.8386
349	0.9028	0.8906	399	0.8867	0.8728	449	0.8709	0.8554	499	0.8552	0.8383
									500	0.8549	0.8379

Specific Gravity Calculations

The basic formula for specific gravity of a substance is the mass in air of a unit volume of the substance at a stated temperature divided by the mass in air of an equal volume of gas-free distilled water at a stated temperature. Or:

$$G_x = \frac{W_x}{W_w} \quad (2a) \qquad or \qquad G_x = \frac{W_x}{V_x \gamma_w} \quad (2b)$$

where G_x = specific gravity of the substance
W_x = mass of a unit volume of the substance
W_w = mass of a unit volume of gas-free distilled water
V_x = volume of the substance
γ_w = density of water

The volume of asphalt, which changes with temperature, can be determined using Eq. 1. However, the volume of water (or density) also changes with temperature, as discussed in the following paragraphs.

[a] Use column A factors for asphalts with API gravity at 60°F of 14.9° or less or with specific gravity 60/60°F of 0.967 or higher.
[b] Use column B factors for asphalts with API gravity at 60°F from 15.0° to 34.9° or with specific gravity 60/60°F from 0.850 to 0.966.

Table D-5. Temperature-Volume Corrections for Emulsified Asphalts

Legend: t = observed temperature in degrees Fahrenheit (Celsius)
M = multiplier for correcting volumes to the basis of 15.6°C (60°F)

t °C	t °F	M*	t °C	t °F	M*	t °C	t °F	M*
10.0	50	1.00250	35.0	95	.99125	57.8	136	.98100
10.6	51	1.00225	35.6	96	.99100	58.3	137	.98075
11.1	52	1.00200	36.1	97	.99075	58.9	138	.98050
11.7	53	1.00175	36.7	98	.99050	59.4	139	.98025
12.2	54	1.00150	37.2	99	.99025	60.0	140	.98000
12.8	55	1.00125	37.8	100	.99000	60.6	141	.97975
13.3	56	1.00100	38.3	101	.98975	61.1	142	.97950
13.9	57	1.00075	38.9	102	.98950	61.7	143	.97925
14.4	58	1.00050	39.4	103	.98925	62.2	144	.97900
15.0	59	1.00025	40.0	104	.98900	62.8	145	.97875
15.6	60	1.00000	40.6	105	.98875	63.3	146	.97850
16.1	61	.99975	41.1	106	.98850	63.9	147	.97825
16.7	62	.99950	41.7	107	.98825	64.4	148	.97800
17.2	63	.99925	42.2	108	.98800	65.0	149	.97775
17.8	64	.99900	42.8	109	.98775	65.6	150	.97750
18.3	65	.99875	43.3	110	.98750	66.1	151	.97725
18.9	66	.99850	43.9	111	.98725	66.7	152	.97700
19.4	67	.99825	44.4	112	.98700	67.2	153	.97675
20.0	68	.99800	45.0	113	.98675	67.8	154	.97650
20.6	69	.99775	45.6	114	.98650	68.3	155	.97625
21.1	70	.99750	46.1	115	.98625	68.9	156	.97600
21.7	71	.99725	46.7	116	.98600	69.4	157	.97575
22.2	72	.99700	47.2	117	.98575	70.0	158	.97550
22.8	73	.99675	47.8	118	.98550	70.6	159	.97525
23.3	74	.99650	48.3	119	.98525	71.1	160	.97500
23.9	75	.99625	48.9	120	.98500	71.7	161	.97475
24.4	76	.99600	49.4	121	.98475	72.2	162	.97450
25.0	77	.99575	50.0	122	.98450	72.8	163	.97425
25.6	78	.99550	50.6	123	.98425	73.3	164	.97400
26.1	79	.99525	51.1	124	.98400	73.9	165	.97375
26.7	80	.99500	51.7	125	.98375	74.4	166	.97350
27.2	81	.99475	52.2	126	.98350	75.0	167	.97325
27.8	82	.99450	52.8	127	.98325	75.6	168	.97300
28.3	83	.99425	53.3	128	.98300	76.1	169	.97275
28.9	84	.99400	53.9	129	.98275	76.7	170	.97250
29.4	85	.99375	54.4	130	.98250	77.2	171	.97225
30.0	86	.99350	55.0	131	.98225	77.8	172	.97200
30.6	87	.99325	55.6	132	.98200	78.3	173	.97175
31.1	88	.99300	56.1	133	.98175	78.9	174	.97150
31.7	89	.99275	56.7	134	.98150	79.4	175	.97125
32.2	90	.99250	57.2	135	.98125			
32.8	91	.99225						
33.3	92	.99200						
33.9	93	.99175						
34.4	94	.99150						

After the specific gravity of asphalt is found at 25/25°C (77/77°F), its specific gravity at 15.6/15.6°C (60/60°F) can be calculated by expressing Eq. 2b for both temperatures, combining, appropriately substituting Eq. 1 and simplifying to become

$$G_{15.6/15.6} = \frac{G_{25/25}\ \gamma_{w25}}{M_{25}\ \gamma_{w15.6}} \quad \text{or} \quad \left(G_{60/60} = \frac{G_{77/77}\ \gamma_{w77}}{M_{77}\ \gamma_{w60}} \right) \tag{3}$$

where γ_{w25} (γ_{77}) = density of water at 25°C (77°F) = 0.9970g/ml,
$\gamma_{w15.6}$ (γ_{w60}) = density of water at 15.6°C (60°F) = 0.9988g/ml,
M_{25} (M_{77}) = multiplier from Table 2.8, 2.9, or 2.10

Assume the specific gravity of an asphalt cement at 77/77°F is 1.003. From Table 2.9, M for 77°F is 0.9941 (Column A). The specific gravity at 60/60°F is then

$$\frac{1.003\ (0.9970)}{0.9941\ (0.9988)} = 1.007$$

Table D-6. Temperature Limitations for Asphalt Selection at the Time of Construction

Temperature Limitations, °F	AC	Anionic	Cationic
Minimum Surface Temperature for 2 days prior	70	60	60
Minimum Ambient Temperature for 7 days after	70	60	60

(With moderate traffic after construction) No rainfall in 48 hours.

Appendix 14E

ASTM D 5360 “*Standard Practice for Design and Construction of Bituminous Surface Treatments*”

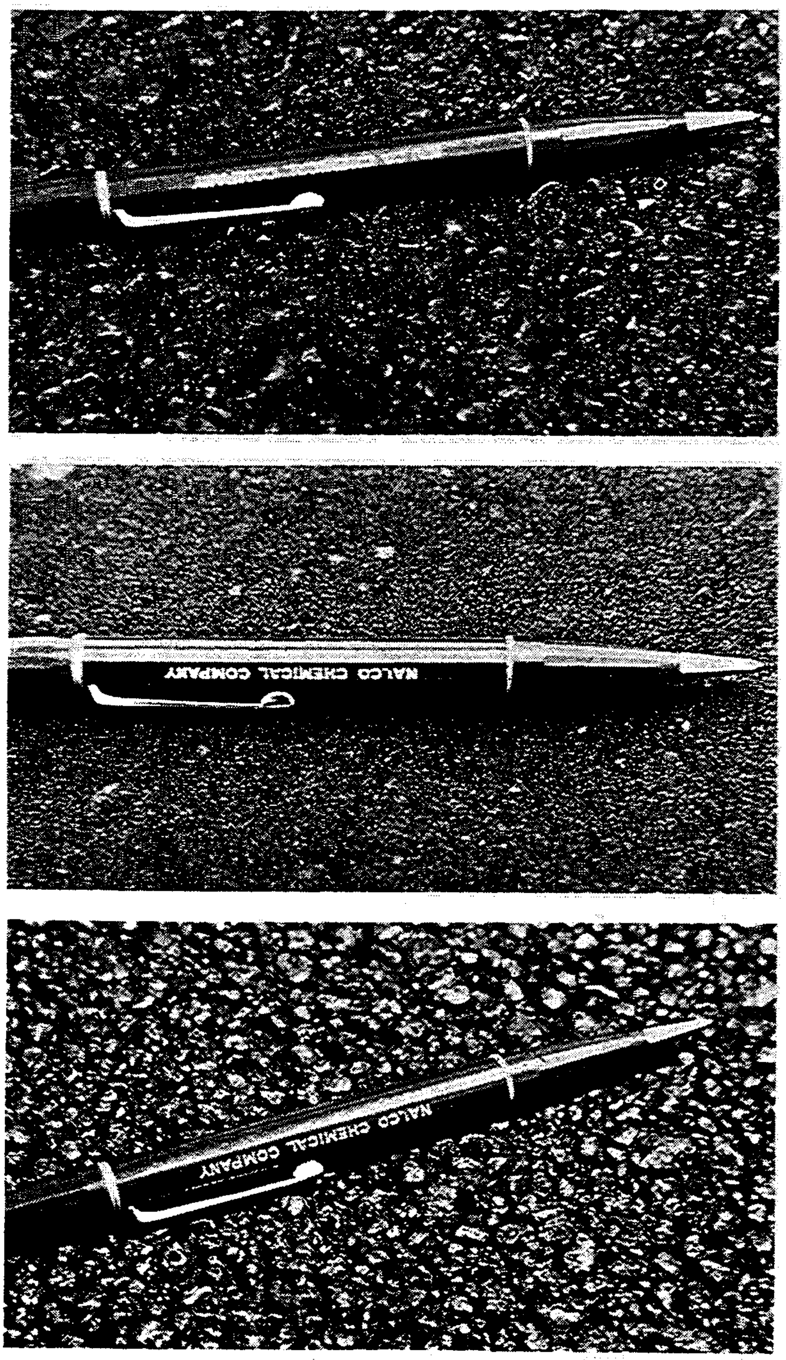
Visit www.ASTM.org for document

Appendix 14F

July 1971 Public Works Publication article titled "*A look at Open Mixes to Improve Skid Resistance*" by Verdi Adam, Materials and Research Engineer, Louisiana Department of Highways

A Look at Open Mixes to Improve Skid Resistance

VERDI ADAM
Materials and Research Engineer, Louisiana Department of Highways



■ **THREE of 11 bituminous surfaces tested are (from top) open graded crushed gravel mix, Kentucky sand asphalt, expanded clay plant mix seal.**

WHAT will undoubtedly prove to be a very useful study of the skid resistance of asphalt pavement surfaces was commenced in 1969 by the Louisiana Department of Highways, in cooperation with the Federal Highway Administration. Planned to extend over a three-year period, the study is a fairly comprehensive evaluation of various bituminous surfaces over the study period, or longer if necessary, involving continuing measurements of skid resistance as well as durability. Its ultimate objective is determination of the types of surfaces offering the highest coefficient of friction, or skid resistance, under wet conditions.

Since several of the mixes were of the type that would require thin applications, the study is generally oriented toward economical rehabilitation of surfaces. This article will address itself mainly to plant mix seals, their construction and performance.

Eleven different types of bituminous surfaces were constructed on US 190, Baton Rouge-Denham Springs Highway, a 4-lane facility. The project consisted of ten duplicate 1,000-foot test sections on one single 1,000-foot test section. These were constructed on the westbound roadway which has an average daily traffic volume of 11,000 vehicles.

The various types of mixtures used were as follows:

Hot Mixes

Dense graded hot mix surface consisting of crushed gravel, coarse sand, fine sand, mineral filler and asphalt cement. This control section was approximately one inch thick.

Open graded hot mix consisting of a minimum of 15 percent crushed gravel screenings, crushed gravel, coarse sand, mineral filler and asphalt cement. Approximate thickness was one inch.

Expanded clay hot mix consisting of expanded clay aggregate, coarse sand, fine sand, mineral filler and asphalt cement. A one inch thickness was placed.

Sand Asphalts

Louisiana sand asphalt hot mix surface consisting of local coarse sand, fine sand, mineral filler and asphalt cement. The thickness was approximately ¾ inch.

Kentucky sand asphalt hot mix surface consisting of asphalt impregnated sandstone rock and asphalt cement. The mix contains approximately 3.5 to 4.5 percent natural bitumen. Approximate thickness was ¾ inch.

Plant Mix Seals

Crushed gravel plant mix seal consisting of crushed gravel (95 percent crushed) and asphalt cement. Thickness was approximately ⅝ inch.

Expanded clay plant mix seal consisting of expanded clay aggregate and asphalt cement. Thickness approximately ⅝ inch.

Slag plant mix seal consisting of blast furnace slag and asphalt cement. Again a ⅝ inch thickness was placed.

Crushed gravel plant mix seal consisting of crushed gravel (75 percent crushed) and asphalt cement. Only one section was constructed. Thickness was approximately ⅝ inch.

Slurry Seals

Expanded clay slurry seal consisting of expanded clay aggregate, two percent cement and a cationic quickset emulsion. Approximate thickness was ⅜ inch.

Granite slurry seal consisting of granite, two percent cement and a cationic quickset emulsion. Thickness approximately ⅜ inch.

In all, 21 test sections were constructed using the same mix on both lanes of the westbound roadway. Sections were randomly located. All sections except the slurry seals were constructed under contract; the slurry seals were applied by Department maintenance forces.

Each section was constructed with normal effort while care was exercised to insure uniformity throughout the experiment. Usual control tests were conducted such as Marshall stability, specific gravity, gradation, asphalt content and roadway density. The plant mix seals were tested for gradation after extraction and asphalt content only, whereas the slurry seals were tested for gradation only.

Each section was constructed in one lift with the exception of the slurry seals which were applied in two lifts. All mixtures were spread using a spreader with automatic screed control to approximate the required thickness.

Rolling of the asphaltic concrete mixtures was done by a tandem, pneumatic and tandem roller respectively. The sand asphalt mixtures were rolled with only a tandem roller; the plant mix seals with a tandem and then a pneumatic roller; the slurry seals were rolled with a pneumatic roller after the emulsion cured.

The asphalt cement used in the hot mixes and plant mix seals was AC-3, 60/70 penetration.

Plant mix seals had never been used in Louisiana in the past and due to their high asphalt contents (from 7 to 16 percent) they did require special handling. Normally the aggregate and asphalt were mixed at temperatures below 260°F. This was to insure a thick film of asphalt around the aggregate for proper bond, since the mix is very open. Due to the texture it is necessary to require the addition of an antistripping additive (0.5 percent Redicote 80-S) to the asphalt cement.

In cases where the mixing or discharge temperatures exceeded 260°F there was a tendency for the asphalt to flow to the bottom of the truck bed and result in a sticky condition which required immediate cleaning. Otherwise a soap and water solution is adequate to prevent sticking.

In summary, the construction of plant mix seals did not pose any unusual construction problems when the temperature did not exceed 260°F. With the high ambient temperatures encountered, the compacted seals were subjected to traffic in the same manner as dense graded mixes and performed satisfactorily with no displacement.

The granite slurry seal sections were declared unsatisfactory—for the test—due to problems encountered during application and will not be discussed further.

Skid Resistance Testing

The skid testing was done with a system meeting ASTM E274-65T. This equipment consists of a two-wheel trailer and a tow vehicle, with very sophisticated instrumentation, capable of conducting tests at any speed up to 60 mph. The system is fully automatic and can take measurements on the left, right, or both wheels simultaneously. All testing was done on a wet surface. Experienced operators were used for the testing.

For the purposes of this study, testing speeds of 20, 40 and 60 mph were selected for tests to be made at the end of construction and after 4, 8, 12, 24 and 36 months. Additionally, tests were to be conducted at 18 and 30 months using a testing

SKID testing trailer has sophisticated instrumentation, is capable of testing with either or both wheels.

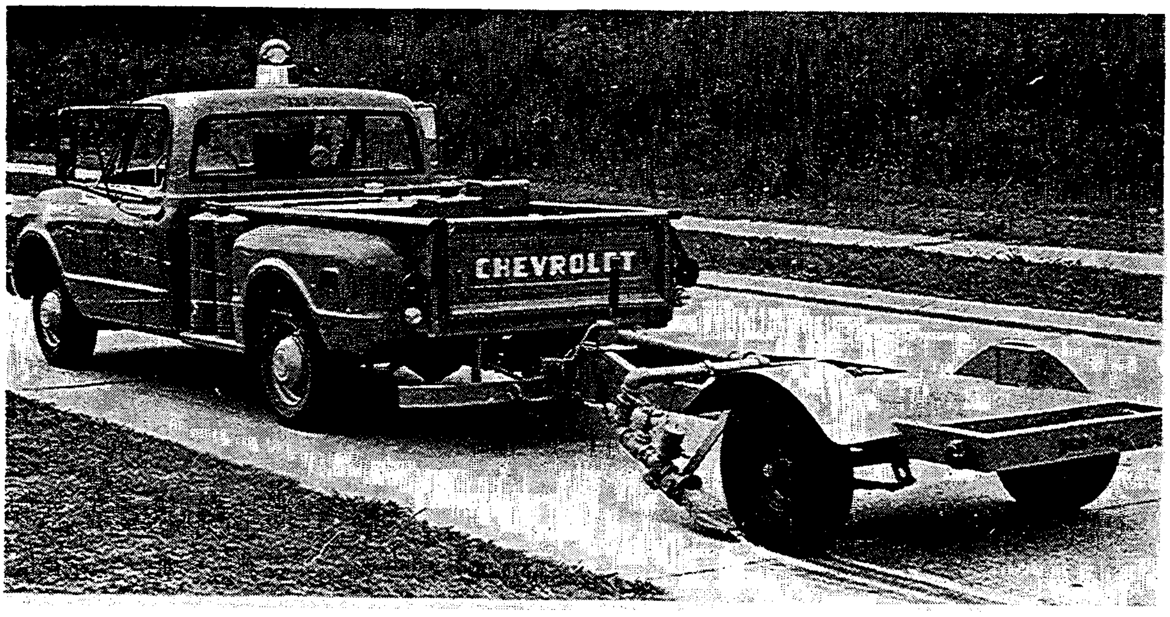


Table 1—Skid Test Results (Skid Numbers at 40 MPH)

	Outside Lane Only ADT 6500				Inside Lane Only ADT 4500			
Age in Months	0	4	12	18	0	4	12	18
HOT MIXTURES								
Dense Graded	36	37	42	39	44	50	51	52
Open Graded	44	43	44	44	48	48	52	53
Expanded Clay	31	36	45	46	42	47	55	61
PLANT MIX SEALS								
Gravel (95% crushed)	42	47	46	45	43	52	52	49
Gravel (75% crushed)	39	40	35	40	40	42	46	43
Expanded Clay	60	60	59	55	57	66	66	61
Slag	52	56	51	51	53	59	61	57
SAND ASPHALTS								
Louisiana	33	..	..	..	32	..	..	..
Kentucky	66	56	56	50	72	68	69	68
SLURRY SEAL								
Expanded Clay	67	61	42*		73	74	65*	

* Measurement made at 14 months.

speed of 40 mph, the nationally accepted speed. All data reported herein is Skid Numbers (SN) at 40 mph on a wet surface. A Skid Number is the coefficient of friction multiplied by 100 for convenience.

The measured SN, as well as the actual coefficient of friction of the surface of a roadway, will vary due to various reasons, the most pronounced of which seems to be the cleanliness of the surface from roadfilm or dust. Measurements show that the SN values increase by a maximum of five points from the worst to the best average condition, an example of which may be found after a prolonged dry spell as compared to immediately after a heavy rain to clean the surface. Therefore, values reported for various ages should be reviewed with this in mind. However, all results for a given age for all test sections are made the same day under similar conditions.

Presently—at the time of this writing—the study is 18 months old. Therefore, the data given here includes up to 18-month measurements and is not complete.

Test Results

The SN results available up to an age of 18 months are tabulated in Table 1. The roughness values of the test sections are shown in Table 2.

The traffic counts on the inside and outside lanes are 4,500 and 6,500 vehicles per day respectively. Therefore, for the purposes of this article it would be desirable to review the data separately for each lane—there is a different trend for the lighter traffic than for the heavier.

It will be noted in Table 1 that the outside lane, under heavier traffic, shows that the sand asphalt made using Louisiana sands is totally unacceptable with an initial SN of 33. Within a relatively short period of time several accidents were reported on these sections, consequently both were discontinued and resurfaced.

There is no universally accepted minimum SN value required for the driving task at this time. The National Cooperative Highway Research Program has undertaken a $300,000 study to develop this information for AASHO. The study will be completed in approximately 18 months. However, in the meantime the FHWA considers a pavement slippery when the SN is below 35. It is the writer's belief that a terminal SN of 40 is required for high speed-high traffic volume pavements. However, this has not been experimentally confirmed and is subject to discussion and readjustment in the future.

It is further indicated in Table 1 that the dense graded hot mix shows the lowest SN value, closely followed by plant mix seal with 75 percent crushed aggregate. This is a clear indication that there is a need for a very high percentage of angular faces when gravel is used The other two hot mix sections show continuing satisfactory performance with fairly high SN values.

Kentucky sand asphalt shows a rapid rate of reduction down to 50, with the slurry seal following the same trend. The expanded clay slurry seal, after 14 months of traffic, dropped to an SN of 42.

It is noteworthy that the values for the inside lane, after 18 months of exposure to traffic, are considerably higher than for the outer lane.

Figures 1 and 2 graphically illustrate the trends in SN for the two lanes.

The dense graded hot mix—at age 18 months—gives an SN of 39 under heavy traffic and 52 under light traffic. This is quite significant, we believe, and should be discussed. This type of mix is very densely graded, with an abundance of fine sand. The low SN values under heavy traffic probably indicate flushing of the asphalt and the fines resulting in a very smooth surface. When these values are compared with those for the open graded hot mix, it becomes quite obvious that under heavy traffic, when fairly small gravel is used, it is imperative

FIGURE 1. Skid numbers for outside (heavy traffic) lane during 18-month test.

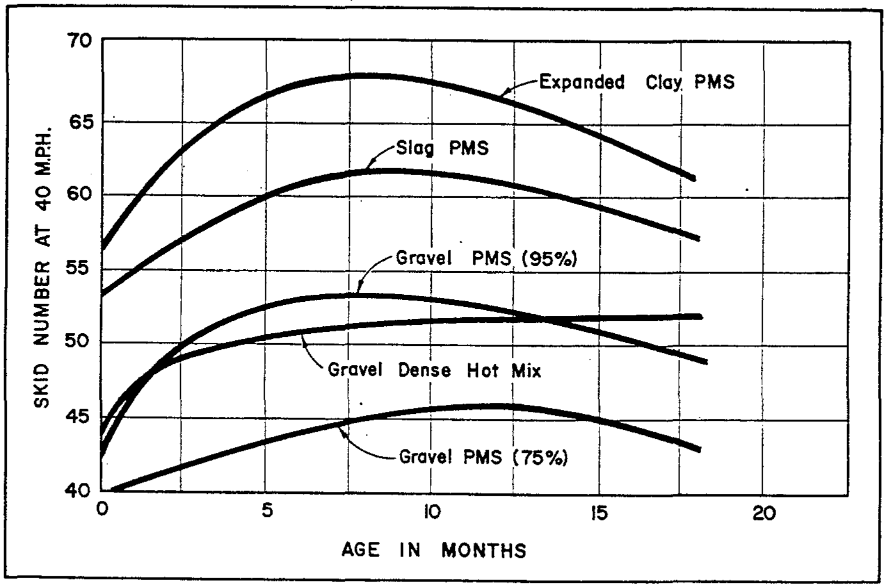


Table 2—Stopping Distances in Feet for Various Sections*

	Outside Lane	Inside Lane
HOT MIXTURES		
Dense Graded	330	225
Open Graded	280	220
Expanded Clay	265	185
PLANT MIX SEALS		
Gravel (95% crushed)	270	245
Gravel (75% crushed)	320	290
Expanded Clay	210	185
Slag	230	200
SAND ASPHALT		
Kentucky Sand Asphalt	240	165
SLURRY SEAL		
Expanded Clay	300	175

* Based on skid numbers at 60 mph for average car—tests at 18 months, except that expanded clay slurry seal was tested at 14 months.

Table 3—Average Roughness in Inches per Mile

Test Section	4 Months	12 Months
HOT MIXTURES		
Dense Graded Gravel	76	97
Open Graded Gravel	70	88
Expanded Clay	86	104
SAND ASPHALTS		
Louisiana Sand Asphalt	80	...
Kentucky Sand Asphalt	85	108
PLANT MIX SEALS		
Crushed Gravel (95%)	68	86
Crushed Gravel (75%)	58	81
Expanded Clay	62	81
Slag	54	76
SLURRY SEALS		
Expanded Clay	85	108
Granite	82	111

(Average roughness prior to overlaying was 75)

that open graded mixes with highly crushed gravel be utilized with a minimum of fines. The mix shows little change in skid resistance under heavy traffic, maintaining an SN of 44. Under the lighter traffic both mixes show satisfactory results.

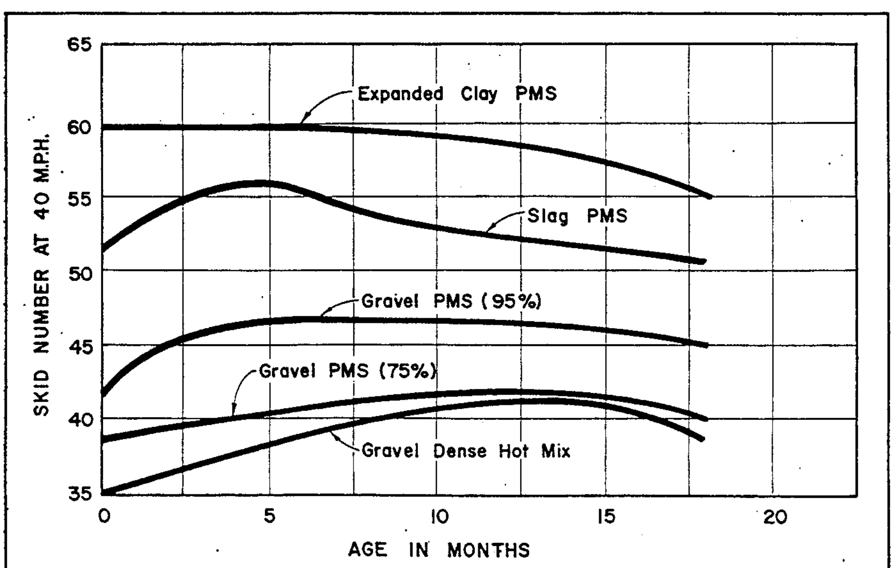
Another significant observation is of the performance of expanded clay aggregate in densely graded hot mix and plant mix seal. Both types fare well under light and heavy traffic. Of all the dense graded hot mixtures, the expanded clay section shows the best results. In plant mix seals expanded clay aggregate shows the highest SN values, regardless of traffic The slag plant mix seal is a close second, with good results also.

In order to translate the SN results to more familiar terms, Table 2 is included. It shows the distance it would take an average automobile to come to a stop, with all four wheels locked, from a velocity of 60 mph. It is interesting to note that under heavy traffic the stopping distance can be reduced by approximately 120 feet by going to an expanded clay plant mix seal from a densely graded hot mix, or by 100 feet by using a slag seal. Under lighter traffic the reductions would be much more conservative.

It should also be pointed out that all open mixes show very little difference in stopping distances under heavy and light traffic. All other mixes are affected more profoundly.

Table 3 lists the roughness results for each section as measured by a Bureau of Public Roads Roughometer. All plant mix seal sections give lower roughness values than all other types of surfaces, indicating much smoother riding qualities.

FIGURE 2. Comparable results for the inside lane, where the traffic is lighter.



Some Interim Conclusions

Under heavy traffic, open mixes are more desirable to insure proper skid resistance. When skid qualities, smoothness and appearance are considered, the plant mix seals show the most promise, with the exception of gravel with 75 percent crushed faces.

Under light traffic, all surfaces are performing satisfactorily except Louisiana sand asphalt.

In Louisiana, all contracts requiring plant mix seals have been found to be competitively priced as compared to regular hot mix or three-application surface treatment, with considerably better performance.

Extreme care should be exercised in controlling the temperature of the plant mix seals. A maximum of 260°F should be carefully maintained. This is most critical when haul distances are in excess of 20 miles. At higher temperatures the asphalt will flow to the bottom of the truck bed resulting in undesirable conditions.

Since the start of this study the Department of Highways has constructed several plant mix seal projects. Some of these are under traffic counts in excess of 78,000 vehicles per day on the Interstate system. To date, these projects have performed very well.

Our study may show later that the high SN values in these mixes are only temporary due to densification or clogging of the surface voids. Nevertheless, with the present emphasis on skid resistance, expenditures for experimentation of this type is justifiable and, in fact, very desirable. □□□

Appendix 14G

Design Methods for open-graded friction course, OGFC, (plant mix seal)

Design Methods for Open Graded Friction Course - OGFC (Plant Mix Seal)

The following design methods were developed by different districts of the Texas DOT.

Design Procedure "A"

1. Assume a ratio of 1:10 (asphalt to aggregate) by volume based on the unit weight of the aggregate.

2. Determine estimated percent asphalt by weight:

$$\text{Percent asphalt (wt)} = \frac{\text{wt. of 1 cu. ft. asphalt}}{\text{wt. of 1 cu. ft. asphalt} + \text{wt. 10 cu. ft. aggregate}} * 100$$

Example:

Unit weight of asphalt = sp. gravity * 62.4 = 1.025 *62.4 = 64 lb/cf

Unit weight of aggregate (loose vol.) = 54 lb/cf

1:10 ratio by volume:

Asphalt (1 cu. ft.) = 64 lb.

Aggregate (10 cu.ft.) = 540 lb.

Total = 604 lb.

$$\text{Estimated percent asphalt (wt)} = \frac{64}{604} \times 100 = 10.6\ \%$$

3. Determine design percent asphalt by weight:

   a. Using the above estimated starting point percent asphalt, mix a 1000 gram sample at 200°F, 210°F, and 230°F. Immediately after mixing, spread in 10 inch pyrex plates and place in 140°F ovens. Observe for excess drain down at 15 minutes, 1 hour, and 24 hour intervals.

   b. Vary the percent of asphalt by +0.5 percent and -0.5 percent. Mix and observe samples as noted above.

c. The design percent asphalt and plant discharge temperature is selected from the above samples yielding an approximate 20 to 30 percent drain down.

<u>Design Procedure "B"</u>

Procedure "B" uses a 4-part design to arrive at the proper amount of AC-20 to be used in the OGFC mixture.

1. Experience with OGFC has shown that 16.5 percent by volume is close to the optimum asphalt content.

2. The design is a rather subjective procedure. Strange as it may seem, there is a definite change in the ease of mixing and coating at the optimum asphalt content. Start at a low percentage and moved up in increments of ½ percentage points. This is based on the findings from "one" above, that is ½, 1, and 1½ percent above and below the presupposed optimum.

3. A modification of FHWA Surface Capacity test is used to determine oil retention.

4. Finally, a modification of the FHWA Drain Down test is used to estimate asphalt requirements. The weighted average is taken of these findings to determine the recommended asphalt content.

Appendix 14H

International Surfacing Inc., Guide Specification for Open, Dense and Gap-Graded Asphalt Concrete Pavements with Asphalt-Rubber Binder

INTERNATIONAL SURFACING, INC. GUIDE SPECIFICATION FOR

OPEN, DENSE, AND GAP-GRADED ASPHALT CONCRETE PAVEMENTS WITH ASPHALT-RUBBER BINDER

Note: Attached are "Notes to Engineer" which are referenced by an asterisk (*). It is important that these notes be referred to when developing a specification from this guide for highway, road, street, and airport asphalt-rubber paving projects.

1. SCOPE

This specification covers material, equipment, and construction procedures for *dense-graded, open-graded, gap-graded** asphalt concrete pavement using a reacted asphalt-rubber binder.

2. PREQUALIFICATION OF A NEW ASPHALT-RUBBER MATERIAL

Prequalification of a new asphalt-rubber material or applicator/supplier may be requested at any time. Prequalification will be based on three controlled field applications evaluated after three years' performance under traffic. The controlled field applications may be of other construction related uses utilizing asphalt-rubber materials. New asphalt-rubber material that has been evaluated and prequalified by an agency recognized nationally may be prequalified by that agency upon disclosure of suitable evidence of successful performance. Notwithstanding other agency prequalification, this agency reserves the right to withhold prequalification pending the performance evaluation of local controlled field applications.

3. ASPHALT-RUBBER BINDER

3.1 General

The asphalt-rubber binder shall be a uniform reacted blend of compatible paving grade asphalt cement, granulated reclaimed vulcanized rubber, extender oil, if required, and liquid anti-striping agent when indicated by standard moisture susceptibility tests. The asphalt-rubber binder shall be *Type I, Type II, or Type III** binder and shall meet the physical parameters listed in Table 1 for the type of binder specified when reacted at 350 degrees F ± 10 degrees F for 60 minutes.

Changes by Joe Cano 2-14-97

TABLE 1

SPECIFICATIONS FOR ASPHALT-RUBBER BINDER

		Type I (a)	Type II (b)	Type III (c)
Apparent Viscosity, 347° F, Spindle 3, 12 RPM, cps (ASTM 2669)	Min	1,000	1,000	1,000
	Max	4,000	4,000	4,000
Penetration, 77° F, 100g, 5 sec.: 1/10 mm. (ASTM D5)	Min	25	50	75
	Max	75	100	150
Penetration, 39.2° F, 200g, 60 sec.: 1/10 mm. (ASTM D5)	Min	~~15~~ 10	~~25~~ 15	~~40~~ 20
Softening Point: ° F (ASTM D36)	Min	~~150~~ 135	~~120~~ 135	~~110~~ 135
Resilience, 77° F: % (ASTM D3407)	Min	20	~~10~~ 20	~~0~~ 20
Ductility, 39.2° F, 1 cpm: cm. (ASTM D113)	Min	5	~~10~~ 5	~~15~~ 5
TFOT Residue, (ASTM D1754) Penetration Retention, 39.2° F: %	Min	75	75	75
Ductility Retention, 39.2° F: %	Min	50	50	50

a. Type I Hot Climate - Average July max 110° F
Average Jan. low 30° F or above

b. Type II Moderate Climate - Average July max 100°
Average Jan. low 15-30° F

c. Type III Cold Climate - Average July max 80° F
Average Jan. low 15° F or lower

3.2 Materials

3.2.1 Asphalt Cement: The asphalt cement for the asphalt-rubber binder shall comply with requirements of ASTM D 3381 and AASHTO M-226. The grade selected shall be determined by laboratory testing performed by the asphalt-rubber supplier to insure appropriate compatibility and reacting characteristics*.

3.2.2 Asphalt Extender Oil: An asphalt-extender oil may be added, if necessary, to meet the requirements of Table 1. Extender oil shall be a resinous, high flash point, aromatic hydrocarbon meeting the following test requirements:

Viscosity, SSU, at 100 degrees F (ASTM D88)	2500 min.
Flash Point, COC, degrees F (ASTM D92)	390 min.
Molecular Analysis (ASTM D 2007):	
Asphaltenes, Wt. %	0.1 max.
Aromatics, Wt. %	55.0 min.

3.2.3 Granulated Reclaimed Vulcanized Rubber

3.2.3.1 General: The ground tire rubber shall be produced from processing automobile and/or truck tires by ambient grinding methods. The rubber shall be substantially free from contaminants including fabric, metal, mineral, and other non-rubber substances. The rubber shall be sufficiently dry to be free flowing and not produce a foaming problem when added to hot asphalt cement. Up to 4% by weight of talc or other appropriate blocking agent can be added to reduce agglomeration of the rubber particles.

3.2.3.2 Physical Requirements

3.2.3.2.1 Gradation and Particle Length: When tested in accordance with ASTM C-136 using a 50 gram sample, the resulting rubber gradation shall meet the following gradation limits for the type of rubber specified.

	Percent Passing	
Sieve Size	Type II Open or Gap Graded	Type III Dense or Gap Graded
No. 8	—	—
No. 10	100	100
No. 16	75 - 100	98 - 100
No. 30	25 - 60	70 - 100
No. 50	0 - 20	10 - 40
No. 200	0 - 5	0 - 5
Max. Particle Length	3/16″	—

3.2.3.2.2 Fiber Content: The ground rubber shall be designated Grade A or Grade B. For grade A rubber, the fiber content shall be less than 0.1% by weight. For grade B rubber, the fiber content shall be less than 0.5% by weight. Fiber content shall be determined by weighing fiber agglomerations which are formed during the gradation test procedure. Rubber particles shall be removed from the fiber agglomerations before weighing*.

3.2.3.2.3 Moisture Content: For each rubber type and grade, the moisture content shall be less than 0.75% by weight.

3.2.3.2.4 Mineral Contaminants: For each rubber type and grade, the mineral contaminant amount shall not be greater than 0.25% by weight as determined after water separating a 50 gm. rubber sample in a 1 liter glass beaker filled with water.

3.2.3.2.5 Metal Contaminants: The rubber shall contain no visible metal particles as indicated by thorough stirring of a 50 gm. sample with a magnet.

3.2.3.3 Packaging: The ground rubber shall be supplied in moisture resistant disposable bags which weigh either 50 ± 2 Lbs. or 60 ± 2 Lbs. The bags shall be palletized into units each containing 50 bags to provide net pallet weights of either 2500 ± 100 lbs. or 3000 ± 100 lbs. Glue shall be placed between layers of bags to increase the unit stability during shipment. Palletized units shall be double wrapped with U. V. resistant stretch wrap.

3.2.3.4 Labeling: Each bag of rubber shall be labeled with the manufacturer designation for the rubber, the specific type, and grade of rubber in accordance with this specification (example - Type I, Grade A), the nominal bag weight designation (50 or 60 lb.), and manufacturer lot number designation. Palletized units shall contain a label which indicates the manufacturer designation, rubber grade and type, net pallet weight, and production lot number.

3.2.3.5 Certification: The manufacturer shall ship along with the rubber, certificates of compliance which certify that all requirements of this specification are complied with for each production lot number or shipment.

3.2.3.6 Anti-Stripping Agent: If required by the Job-Mix Formula to produce appropriate water resistance, an anti-stripping agent that is heat stable and approved for use by the specifying agency shall be incorporated into the asphalt-rubber material at the percentage required by the job mix formula. It shall be added to the asphalt cement prior to blending with the granulated rubber.

3.3 Asphalt-Rubber Binder Mixture Design

The mixture design shall be performed by the asphalt-rubber supplier. The proportion of granulated rubber shall be between 15 and 20 percent by weight of the total mixture.

The asphalt-rubber supplier shall supply to the engineer a blend formulation at least 10 days before pavement construction is scheduled to begin. The blend formulation shall consist of the following information:

Asphalt Cement
- Source of Asphalt Cement
- Grade of Asphalt Cement
- Source and Grade of Extender Oil
- Percentage of Asphalt Cement and Extender Oil by Total Weight of the Asphalt-Rubber Blend

Granulated Reclaimed Rubber
- Source of Granulated Rubber
- Grade of Granulated Rubber
- Percentage of Granulated Rubber by Total Weight of the Asphalt-Rubber Mixture

If granulated rubber from more than one source is utilized the above information will be required for each granulated rubber used.

Anti-Strip Agent
- Source of Anti-Strip
- Percentage of Anti-Strip by Weight of the Asphalt

Physical properties of the blend in accordance with Table 1.

3.4 Asphalt-Rubber Mixing and Production Equipment

All equipment utilized in production and proportioning of the asphalt-rubber binder shall be described as follows:

3.4.1 Asphalt Heating Tank: An asphalt heating tank with a hot oil heat transfer system or retort heating system capable of heating asphalt cement to the necessary temperature for blending with the granulated rubber. This unit shall be capable of heating a minimum of 3,000 gallons of asphalt cement.

3.4.2 Blender: The asphalt-rubber mechanical blender with a two stage continuous mixing process capable of producing a homogeneous mixture of asphalt cement and granulated rubber, at the mix design specified ratios, as directed by the engineer. This unit shall be equipped with a granulated rubber feed system capable of supplying the asphalt cement feed system, as not to interrupt the continuity of the blending process. A separate asphalt cement feed pump and finished product pump are required. This unit shall have both an asphalt cement totalizing meter in gallons and a flow rate meter in gallons per minute.

3.4.3 Storage Tank: An asphalt-rubber storage tank equipped with a heating system to maintain the proper temperature for pumping and adding of the binder to the aggregate and an internal mixing unit within the storage vessel capable of maintaining a proper mixture of asphalt cement and granulated rubber.

3.4.4 Supply System: An asphalt-rubber supply system equipped with a pump and metering device capable of adding the binder by volume to the aggregate at the percentage required by the job-mix formula.

3.4.5 Temperature Gage: An armored thermometer of adequate range in temperature reading shall be fixed in the asphalt-rubber feed line at a suitable location near the mixing unit.

3.5 Asphalt-Rubber Mixing and Reaction Procedure

3.5.1 Asphalt Cement Temperature: The temperature of the asphalt cement shall be between 375 and 425 degrees F at the addition of the granulated rubber.

3.5.2 Blending and Reacting: The asphalt and granulated rubber shall be combined and mixed together in a blender unit, pumped into the agitated storage tank, and then reacted for a minimum of 45 minutes from the time the granulated rubber is added to the asphalt cement. Temperature of the asphalt-rubber mixture shall be maintained between 325 degrees F and 375 degrees F during the reaction period.

3.5.3 Transfer: After the material has reacted for at least 45 minutes, the asphalt-rubber shall be metered into the mixing chamber of the asphalt concrete production plant at the percentage required by the job-mix formula.

3.5.4 Delays: When a delay occurs in binder use after its full reaction, the asphalt-rubber shall be allowed to cool. The asphalt-rubber shall be reheated slowly just prior to use to a temperature between 325 degrees and 375 degrees F, and shall also be thoroughly mixed before pumping and metering into the hot plant for combination with the aggregate. The viscosity of the asphalt-rubber shall be checked by the asphalt-rubber supplier. If the viscosity is out of the range specified in Section 3 of this specification, the asphalt-rubber shall be adjusted by the addition of the either asphalt cement or granulated rubber as required to produce a material with the appropriate viscosity.

4. ASPHALT-RUBBER CONCRETE

Shale or slate (ESCS)

4.1 Mineral Aggregate

4.1.1 General: The aggregate for the asphalt concrete mixture shall be composed of hard durable particles of crushed stone, crushed gravel, crushed slag, or expanded clay lightweight aggregate. The aggregate shall be free from organic or decomposed materials, clay balls or lumps, adhered dust and deleterious coatings. Angular natural sand or manufactured sand may be used as the fine aggregate portion. Rounded natural sands are not permitted. Mineral filler, if used, shall meet requirements of ASTM D242 or AASHTO M17.

4.1.2 Physical Requirements

4.1.2.1 Fractured Faces: The aggregate retained on the No. 4 screen shall consist of at least ____*____ particles which have at least one fractured or crushed face.

4.1.2.2 Abrasion Loss: The aggregate shall have an abrasion loss which does not exceed ____*____ when tested for 500 revolutions in accordance with ASTM C131 or AASHTO T96.

4.1.2.3 Sand Equivalent Value: The sand equivalent value of the aggregate shall be a minimum of ____*____ when tested in accordance with ASTM D2419 or AASHTO T176.

4.1.2.4 Gradation: The gradation of the aggregate shall meet the following limits when tested in accordance with ASTM C136 or AASHTO T27.

Sieve Size	% Passing*
1"	________
3/4"	________
1/2"	________
3/8"	________
No. 4	________
No. 8	________
No. 30	________
No. 50	________
No. 200	________

4.2 Blotter Requirements

Blotter material, if required, shall be composed of fine aggregate or sand meeting the following gradations requirements when tested in accordance with ASTM C136 or AASHTO T27.

Sieve Size	% Passing
3/8"	100
No. 4	75-100
No. 16	45-80
No. 50	10-30
No. 100	0-10

5. JOB-MIX FORMULA

5.1 Mixture Design

The mixture design shall be performed by the *asphalt-rubber supplier, the agency, or an approved laboratory**, and shall be used as the basis for determining the job-mix formula. The design method used shall be in accordance with _____*_____. The mixture design shall be submitted to the engineer at least 10 days prior to construction. Based on information contained in the mixture design, the engineer shall approve a job-mix formula with the following tolerances allowed for single tests on aggregate gradation and asphalt-rubber binder content.

JOB MIX TOLERANCE

Sieve Size	Percent Tolerance
1/2" and larger	± 8
3/8"	± 7
No. 4, No. 8	± 6
No. 30, No. 50	± 5
No. 200	± 3
Asphalt-Rubber Binder Content	± 0.5

The mixture design shall include sufficient test results and documentation to assure that all requirements for the aggregate (Section 4) and the asphalt-rubber binder (Section 3) are fulfilled.

5.2 Job-Mix Formula

The mixture design shall recommend the job-mix formula and shall list the following information:

1. Aggregate
   - source and identification (for each material used)
   - gradation (for each material used)
   - blend percentage
   - mixture gradation

2. Asphalt-Rubber
   - source and grade of asphalt cement
   - source and type of extender oil
   - source and identification of granulated rubber
   - granulated rubber percentage for the asphalt-rubber binder
   - type and amount of additive(s), if required
   - temperature when added to aggregate

3. Recommended asphalt-rubber binder content by both weight of total mix and weight of dry aggregate.

4. Recommended mixture production temperature.

5. Recommended lay down temperature.

6. Density guidelines.

6. CONSTRUCTION EQUIPMENT

6.1 Asphalt-Rubber/Aggregate Mixing Equipment

The addition and mixing of the asphalt-rubber with the aggregate shall be accomplished with one of the following types of hot-mix asphalt plants.

Batch Mixing - Batch mix plant consisting of cold aggregate storage and feed, drier, gradation control unit, hot aggregate storage bins, aggregate weigh-hopper, and a twin-shaft pugmill mixing unit. Also, the plant may be equipped with hot-mix surge or storage bins for short-term holding of the mixture until spreading.

Drier-Drum Mixing - Drier-drum mix plant consisting of cold aggregate storage and feed, automatic weighing system, drier-drum mixer and hot-mix surge or storage bins for short term holding of the mixture until spreading.

The asphalt-rubber/aggregate mixing equipment shall be capable of producing a paving mixture meeting all of the requirements contained in this specification. Specifically the plant shall provide proper aggregate gradation, asphalt-rubber binder content and mixing temperature.

6.2 Mixture Spreading Equipment:

Paving shall be accomplished with self-propelled, mechanical spreading and finishing equipment, pneumatic tire or tracked type, having a tamping bar or vibratory screed or strike-off assembly capable of distributing the material to not less than the full width of a traffic lane and to the depth needed to achieve the minimum compacted thickness or finished grade as required. The screed or strike-off assembly shall be equipped with a heating unit that maintains the temperature needed to prevent tearing of the paving mixture during spreading. Pavers that leave ridges, indentations or other marks in the surface that cannot be eliminated by rolling or prevented by adjustment in operation of the equipment shall not be used.

6.3 Hauling Equipment

Trucks for hauling the paving mixture shall be tailgate discharge, dump or moving bottom (horizontal discharge) type, and compatible with the spreading equipment. If a dump unit is utilized, the bed will not push down on the paver receiving hopper when fully raised or have too short a bed which results in mixture spillage in front of the paver.

The trucks shall be equipped, when ordered by the engineer, with a canvas or similar covering so as to prevent rapid mixture heat loss during cooler weather or as a result of long hauling distances.

6.4 Compaction Equipment

Rollers shall be self-propelled, 2-axle(tandem) steel-wheel type and shall have a minimum weight of 8 tons. For open-graded surface mixtures, maximum roller weight shall be 10 tons and for dense and gap-graded mixtures, maximum roller weight shall be 12 tons. All rollers shall be equipped with pads and a watering system to prevent sticking of the paving mixture to the steel-tired wheel (drums). Vibratory rollers should be used for breakdown passes on dense and gap-graded mixes only. Unless otherwise permitted by the engineer, the contractor shall furnish a minimum of two of the rollers as described above. Pneumatic-tired rollers will not be used, due to the increased adhesiveness of the asphalt-rubber binder.

6.5 Blotter Spreading Equipment

Blotter shall be spread using hopper or whirl type tailgate spreaders.

7. CONSTRUCTION PROCEDURES

7.1 General

Potholes and other areas of pavement failure and major depressions in the existing pavement surface shall be repaired by patching with asphalt concrete.

Cracks greater in width than 1/4 inch shall be repaired by *cleaning routing** and filling with an appropriate sealant.

Immediately prior to application of a tack coat, the surface shall be thoroughly cleaned by sweeping.

7.2 Tack Coat:*

7.3 Asphalt-Rubber Production Records

The asphalt-rubber supplier shall maintain records indicating for each batch of asphalt-rubber binder produced the quantity of asphalt cement in gallons, the temperature of the asphalt cement, the amount of anti-stripping or other additives, if used, in gallons, and the quantity of granulated rubber in pounds. This information shall be provided to the engineer on a daily basis.

7.4 Asphalt-Rubber/Aggregate Mixture Preparation

The asphalt-rubber binder shall be at a temperature of 325 degrees F to 375 degrees F when pumped and metered into the mixing plant.

The aggregate shall be dried and heated to provide a paving mixture immediately after mixing, having a temperature of ______*______ and a moisture content not exceeding 1.0 percent by weight of mixture.

The mixing operation shall be sufficient to achieve a satisfactory mixture with a minimum of 95% coated particles as determined by AASHTO T195 or ASTM D2489.

If the mixture is discharged from the mixer into a hot-mix surge or storage bind, the bin shall be operated so that segregation of the mixture will be minimized.

7.5 Hauling of Asphalt-Rubber/Aggregate Mixture

Truck beds shall be clean of materials such as dirt, mud and aggregates. Just prior to loading of the mixture, the truck bed shall be sprayed with a light application of a soapy solution or a silicone emulsion (oiling with kerosene or diesel fuel will not be permitted due to adverse effects on the binder) to reduce sticking of the mixture to the truck bed.

When directed by the engineer, the mixture shall be covered with a canvas or similar covering to prevent rapid cooling.

7.6 Spreading of Asphalt-Rubber/Aggregate Mixture

The mixture shall be placed and finished by means of paving equipment as required by Section 6.2 except under certain conditions or at certain locations where the engineer determines use of self-propelled pavers impractical. The temperature of the mixture immediately behind the paver shall be between ______*______ and ______*______ degrees F.

The paving equipment shall place the mixture without segregation or tearing within the specified tolerances and true to the line, grade and crown indicated on the plans. In order to achieve a continuous spreading operation, the speed of the paver shall be coordinated with the production of the mixing plant.

The width of each pass of the paver shall be limited to the maximum width of the heated screed or strike-off assembly and side augers. The screed may be extended, at the discretion of the engineer, beyond the end of the auger for short distances where irregularities in the pavement width occur.

The mixture shall not be placed on any wet surface or when weather conditions will otherwise prevent it from proper handling or finishing. The mixture shall be placed only when the atmospheric temperature is at least 60 degrees F for open-graded mixes and at least 50 degrees F for dense-grades mixes.

7.7 Compaction of Asphalt-Rubber/Aggregate Mixture

The mixture shall be rolled by means of the compaction equipment as required by Section 6.4. A minimum of two rollers shall be used for mixture compaction unless otherwise directed by the engineer. The steel-tired wheel (drums) shall be wetted with plain water or, if necessary, with soapy water to prevent mixture pick-up during rolling.

Initial or breakdown compaction shall commence immediately after mixture spreading and shall consist of ______*______ coverages unless otherwise directed by the engineer to prevent damage to the course being compacted. A coverage shall be as many passes as are necessary to cover the entire width being paved, with a pass being one movement of a roller in either direction. Each coverage shall be complete before subsequent coverages are started. Final rolling consisting of not less than one complete coverage, shall be used to smooth the surface of the mat. All rolling shall be accomplished without excessive aggregate fracturing or mixture shoving.

7.8 Application of Blotter Materials

The application of blotter material (usually 1 to 2 pounds per square yard) meeting the requirements of Section 4.2 may be required on a warm mat before opening to traffic. The use, rate and locations for blotter material shall be designated by the engineer. Any blotter material shall be uniformly applied using equipment specified in Section 6.5.

7.9 Traffic Control

Traffic shall be directed through the project with such signs, barricades, devices, flagmen, and pilot vehicles as may be necessary to provide the maximum safety for the public and the workmen with minimum interruption of the work and to protect the mat from damage until sufficiently cooled or covered with blotter to carry traffic.

8. METHOD OF MEASUREMENT AND BASIS OF PAYMENT

8.1 Asphalt-Rubber Binder

The asphalt-rubber shall be measured and paid for per ton of binder in the mixture under Asphalt-Rubber Binder which includes asphalt cement extender oil and granulated rubber.

8.2 Anti-Strip*

8.3 Asphalt-Rubber Concrete

The asphalt-rubber/aggregate mixture shall be measured and paid for per ton in-place under Asphalt-Rubber Concrete which includes the mineral aggregate as specified, the binder mixture preparation, hauling, spreading and compaction as specified.

8.4 Blotter Material

The blotter material will be measured and paid for per ton in-place under Blotter Material, as specified.

8.5 Tack Coat

The tack coat will be measured and paid for per ton in-place under Asphalt For Tack Coat, as specified.

8.6 Patching

Any pavement patching as specified will be measured and paid for per square yard under Pavement Repair (patching).

8.7 Crack Sealing

Any crack sealing as specified will be measured and paid for per linear foot under Pavement Repair (crack sealing).

8.8 Traffic Control

The traffic control will be a lump sum item and paid for under Traffic Control, as specified.

NOTES TO ENGINEER

Section 1

Specify that either an open-graded, dense-graded or gap-graded asphalt concrete is to be constructed.

Section 3.1

The asphalt-rubber binder is available in three types. Type I asphalt-rubber is a low stiffness material suited for use in cold climates, Type II is a moderately stiff material used in moderate climates, and Type III is a high stiffness material which is suitable for hot climates. The first blank in Section 3 should specify the type of asphalt-rubber to be used (Type I, II or III).

Section 3.2.1

It is not necessary, and is sometimes counterproductive, to select the grade of asphalt cement to be used in preparing the asphalt-rubber binder. The asphalt-rubber supplier should be allowed to select the grade of asphalt cement that when blended with the rubber will meet the properties specified in Table 1.

If the Engineer wishes to specify an asphalt cement grade the following table presents the grades that are generally used for Types I, II and III binders. If possible, it is recommended that AC or Penetration grade asphalts should be specified since the original and not the aged residue properties of the asphalt cement controls the low temperature properties of the asphalt-rubber.

Type I	Type II	Type III
AR-1000 w/ extender as required	AR-1000, AR-2000	AR-2000, AR-4000
AC 2.5 w/ extender if required	AC 2.5, AC 5	AC 10, AC 20
200-300 w/ extender if required	120-150, 200-300	60-70, 85-100

Section 3.2.3.2.2

For dense, open or gap graded mix either Grade A or Grade B is acceptable. For spray applications only Grade A rubber should be used since the fibers may clog the spray nozzles.

Section 4.1.2.4

Proper selection of mineral aggregate is very important for production of an asphalt concrete paving mixture containing an asphalt-rubber binder. In addition to the general descriptive requirements contained in Section 4.1 gradation, fractured faces, abrasion loss, and sand equivalent parameters are used in this specification for identifying aggregates which are appropriate for specific mixtures and traffic conditions. Limits for these parameters are contained in Table 2 for open-graded gap-graded or dense-graded mixtures.

Changes by Joe Cano 2-14-97

TABLE 2

SUGGESTED GRADATION SPECIFICATION FOR DENSE, OPEN AND GAP-GRADED ASPHALT-RUBBER CONCRETE

Sieve Size	Dense-Graded 3/8"	Dense-Graded 1/2"	Dense-Graded 3/4"	Open-Graded 3/8"	Open-Graded 1/2"	Gap-Graded 3/8"	Gap-Graded 1/2"	Gap-Graded 3/4"
1"	100	100	100	100	100	100	100	100
3/4"	100	100	90-100	100	100	100	100	90-100
1/2"	100	90-100	70-90	100	95-100	100	90-100	65-85
3/8"	90-100	75-95	60-80	85-100	75-95	~~90-100~~ 78-92	70-90	50-70
#4	60-80	50-70	40-60	25-55	20-~~45~~56	~~50-65~~ 28-42	~~35-50~~ 24-42	~~30-45~~ 22-42
#8	40-60	35-50	30-45	5-15	5-15	~~28-40~~ 15-25	~~20-32~~ 15-25	~~16-28~~ 15-25
#30	18-30	15-25	12-22	0-10	0-10	~~12-22~~ 5-15	~~8-18~~ 5-15	~~6-16~~ 5-15
#50	8-18	6-16	5-14	—	—	~~6-16~~ –	~~5-14~~ –	~~4-12~~ –
#200	2-8	2-8	2-6	0-5	0-5	3-7	~~2-8~~ 3-7	~~2-6~~ 3-7

(1) Fractured Faces (percent by weight of particles retained on the No. 8 sieve with at least 1 fractured surface) 90% Min.

(2) Abrasion Loss (ASTM C131 or AASHTO T96) 40% Max.

(3) Sand Equivalent (ASTM D2419 or AASHTO T176) 45 Min.

The limits contained in Table 2 are intended to be a guide for selection of appropriate aggregates. These limits may be modified for use in areas where aggregates meeting these requirements cannot be produced at a reasonable cost. The use of a standard gradation from a state highway department, city or county that generally follows these guidelines may be used. If such a standard gradation specification is used for dense-graded mixtures, it is important that the design gradation be selected on the coarse side of the band so that sufficient voids are present to accommodate the increased binder content and greater film thickness generally associated with asphalt-rubber paving mixtures.

If it is desired to use aggregates which greatly differ from stated requirements, please contact ISI to assure that appropriate materials are specified.

Section 5.1

Select who will perform the mix design. It is our recommendation that the asphalt-rubber supplier perform the mix design since they are familiar with the variations in the test procedures required when using asphalt-rubber instead of standard asphalt cement.

Section 5.1

Modified Marshall or Hveem mixture design procedures are applicable to asphalt-rubber hot mixes.

In general, asphalt-rubber hot mixes may contain substantially increased binder contents than normally expected with standard mixes. Because of the resilient nature of the binder and the shear susceptibility characteristics, the asphalt-rubber hot mix may exhibit significantly higher flows in the Marshall evaluation and reduced stability in the Hveem evaluation.

For detailed mix design procedures and background design rational refer to the report entitled "Design Methods for Hot-Mixed Asphalt-Rubber Concrete Paving Materials" authored by James G. Chehovits and published in the proceedings of the National Seminar on Asphalt-Rubber, Kansas City, Missouri, October, 1989. This report is available from the Asphalt-Rubber Producers Group or from International Surfacing, Inc. For open-graded mixtures, the recommended design procedure is as outlined in the FHWA Report No. FHWA-RD-74-2 entitled "Design of Open-Graded Asphalt Friction Courses".

Section 7.1

Selected whether cracks should be cleaned or routed. If there are a large number of cracks it may be more cost effective to seal the cracks with a slurry seal or tight blade.

Section 7.2

Tack coat may be either an asphalt cement or diluted emulsified asphalt which is typical of that used in the area. Consideration should be given to elimination of the tack coat if the pavement being overlaid has excess free surface asphalt or if the pavement is being constructed on a new asphalt concrete surface.

Section 7.4

Mixture temperature should be as follows:

Open-graded - 275 to 325 degrees F
Dense-graded - 290 to 325 degrees F
Gap-graded - 290 to 325 degrees F

Section 7.6

Mixture spread temperature shall be as follows:

Open-graded - 250 to 300 degrees F
Dense-graded - 275 to 300 degrees F
Gap-graded - 275 to 300 degrees F

Section 7.7

Breakdown compaction shall consist of at least 3 full coverages for dense-graded or gap-graded mixtures and at least 2 full coverages for open-graded mixtures.

With some asphalt-rubber mixtures, rolling may need to be delayed for several minutes after laydown to reduce shoving and displacement.

Use of vibratory rollers is recommended for at least the first breakdown coverage for dense and gap-graded mixtures of 1-inch or greater thickness, but shall not be used for open-graded mixtures. On many mixes, the use of vibratory mode for breakdown rolling will provide improved compaction without problems normally experienced with standard asphalt concrete.

Rolling should achieve at least 95% of the design density of dense-graded and gap-graded mixtures. Requirements for sampling and testing of density may be incorporated into this section.

Section 8.2

A contingent bid item for anti-strip should be allowed for and be paid for by the pound of anti-strip additive used.

Appendix 14I

International Surfacing Inc., Guide Specification for Asphalt-Rubber Stress Absorbing Treatments (SAM or SAMI) for Highways, Roads, Streets, and Airports

INTERNATIONAL SURFACING, INC.
GUIDE SPECIFICATION
FOR
ASPHALT-RUBBER STRESS ABSORBING TREATMENTS (SAM or SAMI) for HIGHWAYS, ROADS, STREETS and AIRPORTS

Note: Attached are "Notes to Engineer" which are referenced to by an asterisk (*). It is important that these notes be referred to when developing a specification from this guide for highway, road, street, and airport asphalt-rubber projects. It is recommended that International Surfacing be contacted to see if there are any changes to these specifications or to assist in preparation of the project specifications.

1. SCOPE

This specification covers the material, equipment, and construction procedures for a Stress Absorbing ____*____.

2. PREQUALIFICATION OF A NEW ASPHALT-RUBBER MATERIAL

Prequalification of a new asphalt-rubber material or applicator may be requested at any time. Prequalification will be based on three controlled field applications evaluated after three years performance under traffic. New asphalt-rubber material that has been evaluated and prequalified by an agency recognized nationally may be prequalified by this agency upon disclosure of suitable evidence of successful performance. Notwithstanding other agency prequalification, this agency reserves the right to withhold prequalification pending the performance evaluation of local controlled field applications.

3. MATERIALS

3.1 ASPHALT CEMENT

The grade of asphalt cement for the asphalt-rubber mixture shall be ____*____ or ____*____ which shall comply with the requirements of ____*____. The grade shall be based on laboratory testing by the asphalt-rubber supplier, to insure compatibility with the ground reclaimed rubber.

If indicated necessary by laboratory testing, an approved anti-stripping additive may be added to the asphalt cement at up to 1.0 percent by weight of the asphalt cement.

3.2 GROUND RECYCLED RUBBER

3.2.1 General: The ground recycled rubber shall be produced primarily from processing automobile and/or truck tires by ambient grinding methods. The rubber shall be substantially free from contaminants including fabric, metal, mineral, and other non-rubber substances. The rubber shall be sufficiently dry to be free flowing and not produce a foaming problem when added to hot asphalt cement. Up to 2 percent by weight of talc or other appropriate blocking agent may be added to reduce agglomeration of the rubber particles.

3.2.2 Physical Requirements

3.2.2.1 Gradation and Particle Length: When tested in accordance with ASTM C 136 using a 50 gram sample, the resulting rubber gradation shall meet the following gradation limits for the type of rubber specified.

Type I Rubber Gradation

Sieve Size	Percent Passing
# 8	100
#10	95 - 100
#16	40 - 60
#30	0 - 20
#50	0 - 10
Max. Particle Length	3/16"

The use of rubber from multiple sources is acceptable provided that the overall blend of rubber meets the gradation requirements.

3.2.3.2 Fiber Content: The ground rubber shall be Grade A with a fiber content less than 0.1% by weight. Fiber content shall be determined by weighing fiber agglomerations which are formed during the gradation test procedure. Rubber particles shall be removed from the fiber agglomerations before weighing.

3.2.3.3 Moisture Content: For each rubber type and grade, the moisture content shall be less than 0.75% by weight. (Ref. Section 3.2.4)

3.2.3.4 Mineral Contaminants: For each rubber type and grade, the mineral contaminant amount shall not be greater than 0.25% by weight as determined after water separating a 50 gm. rubber sample in a 1 liter glass beaker filled with water.

3.2.3.5 Metal Contaminants: The rubber shall contain no visible metal particles as indicated by thorough stirring of a 50 gm. sample with a magnet.

3.2.4 Packaging: The ground rubber shall be supplied in either: reusable bulk containers holding 2,000 pounds or more of ground rubber; or in moisture resistant disposable bags with 50 +/– 2 pounds or 60 +/– 2 pounds of ground rubber.

The weight of the ground rubber in the bulk containers shall be within 1.0 percent of the certified weight. The containers shall not be stacked on top of each other during storage or shipment.

The small bags (50 to 60 lbs.) shall be palletized into units each containing 50 bags to provide net pallet weights of either 2500 +/– 100 lbs. or 3000 +/– 100 lbs. Glue shall be placed between layers of bags to increase the unit stability during shipment. Palletized units shall be double wrapped with U.V. resistant stretch wrap.

3.2.5 Labeling: Each container load of rubber shall be labeled with the manufacturer designation for the rubber, the specific type, and grade of rubber in accordance with this specification (example - Type I, Grade A), the nominal bag weight, and manufacturer lot number designation. The bulk containers (2,000+ lb.) shall have the certified weight of rubber clearly marked on a side.

3.2.6 Certification: The manufacturer shall ship along with the rubber, certificates of compliance which certify that all requirements of this specification are complied with for each production lot number or shipment.

3.3 DILUENT

The diluent shall have the following properties:

Flash Point	130°F Minimum
Initial Boiling Point (ASTM D 86)	340°F Minimum
Dry Point (ASTM D 86)	390° - 415°F
Total Saturates	85% Minimum

3.4 ANTI-STRIPPING AGENT

If required, an anti-stripping agent that is heat stable and approved for use by the specifying agency shall be incorporated into the asphalt-rubber material to produce appropriate water resistance.

Changes by Joe Cano 2-14-97

3.5 ASPHALT-RUBBER BINDER MIXTURE DESIGN: The mixture design shall be performed by the asphalt-rubber supplier. The proportion of ground rubber shall be between ~~18~~ 17 and ~~25~~ 22 percent by weight of the total mixture.

See Insert #1 Page I-8

The asphalt-rubber supplier shall supply to the Engineer a blend formulation at least 10 days before pavement construction is scheduled to begin. The blend formulation shall consist of the following information:

Asphalt Cement
- Source of Asphalt Cement
- Grade of Asphalt Cement
- Percentage of Asphalt Cement by Total Weight of the Asphalt-Rubber Blend

Ground Recycled Rubber
- Source of Ground Rubber
- Grade of Ground Rubber
- Percentage of Ground Rubber by Total Weight of the Asphalt-Rubber Mixture

If ground rubber from more than one source is utilized the above information will be required for each ground rubber used.

Anti-Strip Agent
Source of Anti-Strip
Percentage of Anti-Strip by Weight of the Asphalt

Diluent
Source of Diluent
Grade of Diluent
Percentage of Diluent Allowable by Volume of Asphalt-Rubber Mixture

Minimum Viscosity based on laboratory testing by the Asphalt-Rubber Supplier

[ESCS]

3.6 COVER AGGREGATE

3.6.1 General: Aggregate shall be composed of a clean and durable crushed rock, crushed gravel or crushed slag. The aggregate shall be free from organic or decomposed materials, clay balls or lumps, adhered dust and deleterious coatings.

3.6.2 Physical Requirements

3.6.2.1 Fractured Faces: The aggregate retained on the No. 8 screen shall consist of at least ___*___ percent particles which have at least one fractured or crushed face.

3.6.2.2 Abrasion Loss: The aggregate shall have an abrasion loss which does not exceed ___*___ when tested for 500 revolutions in accordance with ASTM C 131 or AASHTO T 96.

3.6.2.3 Gradation: The gradation of the aggregate shall meet the following limits for the specified aggregate when tested in accordance with ASTM C 136 or AASHTO T 27.___*___

3.6.2.4 Asphalt Pre-Coating:___*___ If specified, the aggregate shall be hot pre-coated with 0.5 +/– 0.25 percent paving grade asphalt cement. The amount of precoating shall be determined by the Engineer. The precoated aggregate should have a "salt and pepper" appearance. The temperature of the hot pre-coated aggregate shall be ___*___ to ___*___ at the site.

3.6.2.5 Sample Submittal: Proposed aggregate samples shall be submitted to the asphalt-rubber supplier a minimum of 21 days prior to application to test for aggregate stripping characteristics. The results shall be submitted to the Engineer. Anti-strip will be included as a contingency bid item.

4. EQUIPMENT

4.1 BROOMS

The equipment used by the contractor shall include a self-propelled rotary power broom for cleaning joints and mobile pickup brooms* for pavement cleaning and excess cover material removal.

4.2 ASPHALT-RUBBER MIXING AND PRODUCTION EQUIPMENT:

All equipment utilized in production and proportioning of the asphalt-rubber binder shall be described as follows:

4.2.1 Asphalt Heating Tank: An asphalt heating tank with a hot oil heat transfer system or retort heating system capable of heating asphalt cement to the necessary temperature for blending with the ground rubber. This unit shall be capable of heating a minimum of 2,500 gallons of asphalt cement.

4.2.2 Blender: The asphalt-rubber mechanical blender with a two stage continuous mixing process capable of producing a homogeneous mixture of asphalt cement and ground rubber at the design specified ratios. This unit shall be equipped with a ground rubber feed system capable of supplying the asphalt cement feed system, as not to interrupt the continuity of the blending process. A separate asphalt cement feed pump and finished product pump are required. This unit shall have both an asphalt cement totalizing meter in gallons and a flow rate meter in gallons per minute.

4.2.3 Distributor Truck: A truck or trailer mounted self-powered distributor truck equipped with a retort heating unit, and an internal mixing device capable of maintaining a uniform mixture of asphalt cement and ground rubber. It shall be equipped with a full circulating spreader bar and a pumping system capable of applying asphalt-rubber material within +/– 0.05 gallons per square yard tolerance of the specified application rate and must give a uniform covering of the surface to be treated. The distributor shall have a boot board on the rear of the vehicle and a bootman shall accompany the distributor. The bootman shall ride in a position so that all spray bar tips are in full view and readily accessible for unplugging if a plugged tip should occur. The distributor shall also include a tachometer, pressure gauge, volume measuring device and thermometer.

4.3 COVER MATERIAL SPREADER

The cover material (chip) spreader shall be a self-propelled machine with an aggregate receiving hopper in the rear, belt conveyors to carry the aggregate to the front, and a spreading hopper equipped with a spread roll. The spreader shall be in good mechanical condition and be capable of applying the cover material uniformly across the spread at the specified rate.

4.4 ROLLING EQUIPMENT

A minimum of three operational self-propelled pneumatic-tired rollers shall be used for the required rolling of the cover material. The pneumatic tired rollers shall carry a minimum loading of 3,000 pounds on each wheel and a minimum air pressure of 100 pounds per square inch in each tire.

4.5 AGGREGATE HAULING EQUIPMENT

Trucks for hauling cover material shall be tailgate discharge and shall be equipped with a device to lock onto the hitch at the rear of the cover material spreader. Haul trucks shall also be compatible with the cover aggregate spreader so that the dump bed will not push down on the spreader when fully raised or have too short a bed which results in aggregate spillage while dumping into the receiving hopper.

5. CONSTRUCTION

5.1 ASPHALT-RUBBER MIXING AND REACTION PROCEDURE

5.1.1 Asphalt Cement Temperature: The temperature of the asphalt cement shall be between 375°F and 450°F at the addition of the ground rubber.

5.1.2 Mixing and Reacting: The asphalt and ground rubber shall be combined and mixed together in a blender unit and pumped into the agitated storage tank. The temperature of the asphalt-rubber mixture shall be maintained between 325°F and 400°F for a sufficient time to achieve the minimum viscosity specified in the blend formulation.

5.1.3 Diluent: After the reaction between asphalt cement and ground rubber has occurred, the viscosity of the hot asphalt-rubber mixture may be adjusted for spraying and/or better "wetting" of the cover material by the addition of a diluent. The diluent shall comply with the requirements of Section 3.3 of and shall not exceed 7.5 percent by volume of the hot asphalt-rubber mixture. Diluent shall not be used in SAMI binders.

5.1.4 Delays: When an extended delay occurs in binder use after achieving the required reaction, the asphalt-rubber shall be allowed to cool. The asphalt-rubber shall be reheated slowly just prior to use to a temperature between 325°F and 400°F, and shall also be thoroughly mixed before spraying. The viscosity of the asphalt-rubber may be adjusted by the addition of the either asphalt cement or ground rubber as required to produce a material with the appropriate viscosity.

5.2 APPLICATION OF ASPHALT-RUBBER MATERIAL

Placement of the asphalt-rubber membrane shall be made only under the following conditions:

1. The pavement surface temperature shall be 50°F and rising for use with hot precoated chips. The pavement surface temperature shall be 70°F and rising for use with cold, coated or uncoated, aggregate.

2. The pavement surface is clean and absolutely dry.

3. The wind conditions are not excessive.

4. All construction equipment such as the asphalt-rubber distributor, cover material spreader, haul trucks with cover material, and rollers are in position and ready to commence membrane placement operations.

5. Rain is not imminent.

The asphalt-rubber mixture shall be applied at a temperature of 325° to 400°F at a rate _____*_____ to _____*_____. Transverse joints shall be constructed by placing building paper the width of the membrane application at the beginning and end of each work area. Once the spraying has progressed beyond the paper, the paper shall be removed immediately and disposed of as directed by the Engineer. All longitudinal joints shall not exceed a four inch overlap.

5.3 APPLICATION OF COVER MATERIAL

Cover material shall be applied immediately to the asphalt-rubber membrane at a rate of ______*______ to ______*______. The cover material shall be surface dry at the time of application.

5.4 ROLLING

At least three operational pneumatic-tired rollers operating in a uniform pattern, covering the full width of the aggregate spread, complying with the requirement of Section 4.4, shall be provided to accomplish the required embedment of the cover material. At some project locations or where production rates dictate, fewer rollers may be utilized as directed by the Engineer. At no time shall there be less than an adequate number of pneumatic-tired rollers operating to cover the entire width of the application with one pass.

Sufficient rollers shall be used for the initial rolling to cover the width of the aggregate spread with one pass. The first pass shall be made immediately behind the cover material spreader, and if the spreading is stopped for any extended period, the cover material spreader shall be moved ahead or off the site so that all cover material may be immediately rolled. A minimum of three complete passes with rollers is required. Rolling shall continue uninterrupted so that the required number of passes is completed within the minimum amount of time possible.

5.6 TRAFFIC CONTROL

Except when it is necessary that hauling equipment must travel on the newly applied membrane, traffic of all types shall be kept off the membrane until it has had time to set properly. However, when it is absolutely necessary that hauling equipment or piloted traffic travel on the newly applied membrane, the speed shall not exceed 15 miles per hour.

5.7 REMOVING LOOSE COVER MATERIAL

All loose cover material shall be removed from the paved surface by brooming in not less than 1/2 hour nor more than 36 hours after application; however, if because of weather conditions, temperature or other reasons, the Engineer determines that conditions are not conducive to obtaining the best results, brooming shall be discontinued until the Engineer has considered all conditions and has determined the best time for the removal of the cover material. The cover material shall be removed by means of a power broom conforming to Section 4.1 which shall be in good condition and of a design suitable for the work. The action of the broom shall be such that particles adhering to the membrane will not be dislodged.

5.8 FLUSH COAT*

6. MEASUREMENT AND PAYMENT

6.1 Asphalt Rubber Binder: Asphalt-Rubber binder shall be measured and paid for per ______*______ in-place under Asphalt-Rubber ______*______ Binder which includes the asphalt cement, extender oil, diluent and ground rubber and application of the asphalt-rubber binder. For bidding purposes use ______*______ gallons per square yard.

6.2 Cover Aggregate: Cover Aggregate shall be measured and paid for by the square yard under Cover Aggregate which includes the cleaning of the existing surface, aggregate, asphalt cement pre-coating______*______, hauling, spreading, rolling and sweeping of excess aggregate. For bidding purposes use ______*______ pound per square yard.

6.3 Flush Coat: Flush Coat will be paid for by the gallon under Flush Coat which shall include asphalt emulsion and application. For bidding purposes use .12 gallons per square yard of SS-1h emulsion diluted with an equal volume of (50%) water.

6.5 Traffic Control: Traffic control will be a lump sum item and paid for under Traffic Control.

6.6 Anti-Strip: Anti-strip, if required, will be paid for by the gallon under Anti-strip as a contingency item.

NOTES TO ENGINEER

Section 1

For a *Stress Absorbing Membrane,* the blank should read "Membrane". For a *Stress Absorbing Membrane Interlayer,* the blank should read "Membrane Interlayer".

Section 3

The first blanks will indicate the penetration or viscosity of the grades of asphalt cement specified. The second blank will indicate AASHTO M 20, ASTM D 946, AASHTO M 226, ASTM D 3381 or an appropriate local or state highway department specification.

The following table provides recommended grades of asphalt cement to be used in asphalt-rubber for different climates.

***ASPHALT CEMENT GRADE**

CLIMATE	AASHTO M 226 ASTM D 3381
Cold	AC-5, or AC-10 AR-1000 or AR-2000
Moderate	AC-10 or AR-2000
Hot	AC-10 or AC-20 AR-2000 or AR-4000

**The exact grade of asphalt cement shall be determined by the asphalt-rubber supplier dependent of the specific project requirements and conditions (climate and traffic).*

Section 3.5

Use of appropriate aggregate is essential for assuring proper performance of an asphalt-rubber SAM or SAMI. Generally, the type of aggregate required is clean, tough and durable particles of crushed rock, crushed gravel or crushed slag. A "single size", 3/8 inch or larger nominal aggregate is regularly used.

The following sections provide recommended minimum laboratory test requirements for the cover aggregate. If higher quality aggregates are available or are normally specified by the local agencies for similar applications, the higher quality aggregate should be specified.

Section 3.6.2.1

A minimum of 75% Fractured Faces is recommended.

Section 3.6.2.2

A maximum LA Abrasion of 40 is recommended. Higher quality aggregate (maximum LA Abrasion of 25) should be used for SAM applications whenever possible.

Section 3.6.2.3

The following presents recommended gradations for cover aggregate. It is likely that locally available aggregates may vary from these limits due to the numerous specific gradations which are used by various agencies. Some variations are acceptable on the coarser sieve sizes, 3/8 inch sieve for the 3/8 inch nominal aggregate and 1/2 inch for the 1/2 inch nominal aggregate.

It is extremely important that the limits for the finer sieve sizes be met. Excessive fine aggregate (sand size) can interfere with the proper embedment of the coarser sized particles. Fines (minus #200 sieve size) coat the larger aggregate and interfere with adhesion. Both of these conditions can cause early aggregate loss and flushing of the asphalt rubber binder.

3/8" SAM & SAMI Aggregate Gradation

Sieve Size	Percent Passing
1/2"	100
3/8"	70 - 100
1/4"	0 - 10
#8	0 - 5
#200	0 - 1

1/2" SAM & SAMI Aggregate Gradation

Sieve Size	Percent Passing
5/8"	100
1/2"	95 - 100
3/8"	0 - 20
1/4"	0 - 5
#8	0 - 2
#200	0 - 1

Section 3.6.2.4

Use of hot precoated aggregate is highly recommended. The precoating adheres to fines in the aggregate that would normally interfere with the adhesion of the asphalt-rubber to the aggregate. Hot precoating also removes most absorbed moisture from the aggregate, further promoting adhesion. The hot aggregate will embed better and will allow SAM and SAMI applications at lower pavement surface temperatures as specified in Section 5.2. Cold precoating may be used. For a list of precoating options consult your International Surfacing, Inc. representative. The aggregate should be precoated with just enough asphalt cement to tie up the fines in the aggregate. The precoated aggregate should have a "salt and pepper" appearance. Excess precoating can result in pickup by the aggregate spreader, rollers and/or haul trucks.

The blanks should be filled in with the allowable temperature range of the hot precoated aggregate at the site. A minimum temperature of 200°F and maximum temperature of 325°F is recommended. The minimum temperature should be increased up to 250°F if the length of the haul is not excessive. If cold temperatures are anticipated at the time of application, the higher minimum temperature should be specified.

Section 4.1

Self-propelled rotary power brooms are a must for all SAM and SAMI applications. The mobile pickup brooms may be deleted in areas where it would be allowable to leave the loose aggregate at the side of the road.

Section 5.2

Recommended asphalt-rubber application rates will vary depending on: (1) the type and severity of pavement distresses; and (2) the aggregate gradation which is utilized. As a general rule, under normal conditions the application rate will generally fall between 0.55 and 0.70 gallons per square yard. Higher application rates will be required for larger aggregates and more severely distressed pavements.

Section 5.3

Cover material quantities generally used have been 25 to 35 pounds per square yard (for aggregate with specific gravities between 2.5 and 2.9). The actual amount selected within this range on the project should be based on the appearance of the SAM or SAMI after initial rolling. The application rate should be kept to a minimum. Application of too much aggregate can interfere with the proper embedment of the aggregate and often results in continued aggregate loss over a long period of time. The need to increase the aggregate spread rate is often indicated by tracking of the asphalt-rubber binder by the cover material spreader or haul truck. Adjustments from the 25 to 35 pounds per square yard rate may be necessary for aggregates with high or low specific gravities such as slag and synthetic materials.

Section 5.8

A flush coat is strongly recommended for all SAM applications. The flush coat helps lock in the aggregate to minimize chip loss and provides a more uniform appearance. The following sections should be inserted for a flush coat:

5.8.1 General: For SAM applications, a fog seal shall be applied within 48 hours of the placement of the SAM.

5.8.2 Time of Application and Weather Conditions: The surface shall be dry and free of loose material at the time of application. This time may be extended by the Engineer when weather and/or traffic conditions are not favorable.

The flush coat shall not be applied when the surface is wet or when there is a threat of rain. The ambient temperature shall be at least 70°F and rising.

5.8.3 Materials: Emulsified asphalt, as specified by the Engineer, diluted 50/50 with water shall be used for the flush coat.

5.8.4 Preparation of Surface: Immediately before applying the emulsion, the area to be flushed shall be cleaned of all loose aggregate and/or foreign material. This will be accomplished by power brooms or pickup brooms supplemented by hand brooms if necessary. The fog seal shall not be applied until approved by the Engineer.

5.8.5 Application of Asphalt Emulsion: The diluted asphalt emulsion shall be well mixed before application. It shall be applied by a distributor truck, in sound mechanical condition and calibrated to insure accuracy of application. The application rate of the emulsion shall be 0.10 to 0.15 gallons per square yard. The exact rate shall be determined by the Engineer.

5.8.6 Protection of Treated Surface: The treated surface shall be protected by barricades, cones or other types of traffic control devices until the asphalt emulsion has cured and will not be picked up by traffic.

Section 6.1

The first blank should be filled in with the method of measurement and payment for the asphalt-rubber binder.

ISI recommends payment based on gallons or tons of asphalt-rubber binder. This will allow for adjustments to application rates in the field which may be necessary to account for differing pavement conditions. Payment may also be based on the square yard or square foot.

The second blank should be filled in with either "Membrane" or "Membrane Interlayer".

Section 6.2

If precoating is not to be required the words "asphalt cement precoating" should be deleted.

The blank should include the estimated quantity of cover material to be applied to the membrane. This value will vary with variations in the specific gravity, size and shape of aggregate in different areas. Contact your International Surfacing, Inc. representative for assistance in determining this value.

Asphalt-Rubber Binder

The asphalt-rubber binder shall meet the following criteria when reacted with asphalt cement at 350 degrees F for 60 minutes:

Specifications for Asphalt-Rubber Binder

Test Property		Test Value
Brookfield viscosity, Haake type viscosimeter, 350 degrees F, CP	Min Max	1,500 6,000
Penetration, 77 degrees F, 100gm 5 sec.: 1/10 mm (ASTM D5)	Min Max	25 75
Penetration, 39.2 degrees F, 200 g, 60 sec.: 1/10 mm (ASTM D5)	Min	10
Softening Point: F (ASTM D36)	Min	130
Resilience, 77 degrees F: % (ASTM D3407)	Min	20

Insert #1 Section 3.5 page I-2

Appendix 14J

Design of Hot-Mix Asphalt Laboratory Mixes from
"TXDOT Construction Bulletin C-14"

Appendix J was taken from Construction Bulletin C-14, Texas State Department of Highways and Public Transportation Construction Division, September 1985 with modifications.

DESIGN OF LABORATORY MIXES

The most fundamental and important factor in asphaltic concrete mix design is the proportion of the aggregate and the asphalt. The proportion of the aggregate and the asphalt affects the stability, the skid resistance, and the durability of the pavement. If the pavement has excess density, it will become unstable and will be lacking in skid resistance. If the pavement has insufficient density due to an insufficient amount of asphalt, an improper grade of asphalt, the mixture being too coarse, or the mixture being too cold, it will lack durability and will ravel. Inspectors are hereby cautioned that, while density problems can be caused by the mix, there are other reasons for low density. Inadequate compactive effort, not completing the rolling while the mix is still hot enough to be compacted to proper density, improper or an excessive amount of hand-raking behind the paver, improper paver operation, or using a paver that is not in good operating condition can also cause low density in the pavement. It is recommended that, if improper density is detected, both the plant and the road operations be thoroughly studied and immediate remedial action be taken.

The design asphalt content should be selected to produce a pavement which has good stability, durability, and skid resistance without sacrificing any one of the characteristics for the other; however, today's modern, high-speed traffic makes skid resistance a prime consideration in the design of asphaltic concrete pavements. Certain weather and traffic conditions may make it desirable to design slightly below the optimum density in order to maintain skid resistance, even at the risk of a slight loss in durability. It is obvious that the design asphalt content is a highly critical point and that a factor of such vital importance must be thoroughly understood and intelligently controlled.

In determining the optimum asphalt content it is necessary to design and mold asphaltic concrete test mixtures containing five different asphalt contents. Three specimens of each asphalt content should be mixed, molded and tested for density and stability. The average of these values for each of the five different mixtures is used in determining the optimum asphalt content. These mixes are small and must be controlled very accurately in order to insure against undesirable variables which would invalidate test results.

To insure adequate grading control for all test mixes, the mineral aggregates containing an appreciable amount of material retained on the ~~10~~ 8 mesh sieve should be cut into the following sizes and their percentages determined:

Retained on 7/8"
7/8" - 3/8"
3/8" - 4
4 - ~~10~~ 8
Passing ~~10~~ 8 mesh

Aggregates whose sizes are predominantly smaller than 10 mesh may be proportioned as they are, since a minimum of segregation occurs in the smaller sizes; for example:

The greater part of Aggregate A (crushed limestone, 3/8-inch maximum size) is retained on the 10 mesh sieve; therefore, it is cut into the following sizes:

Size		Per Cent by Weight
Retained 4 Mesh		68.3
4 Mesh to ~~10~~ 8 Mesh		30.5
Passing ~~10~~ 8 Mesh		1.2
	Total	100.0

Aggregate B will be separated into two sizes; from No. 4 Mesh to No. ~~10~~ 8 Mesh and minus No. ~~10~~ 8 Mesh and handled similarly to Aggregate A.

Aggregate C will not be separated into sizes since it is smaller than ~~10~~ 8 Mesh.

State Department of Highways &
Public Transportation
Construction Form No. 544 Rev. (2)

STATE DEPARTMENT OF HIGHWAYS & PUBLIC TRANSPORTATION
ASPHALTIC CONCRETE SIEVE ANALYSIS WORK SHEET

County Monroe Highway S. H. 2000 Project F 1(234) Control 5 6-7

Date 9-4-67 Time ______ Station ______ Sampled By ______

Spec. Item 3 4 0 Type D Design No. Selection of Grading

	Sieve Size	Aggregate A Bin No. 1 Weight (grams)	Total % ×	(a) 60.0 %	Aggregate B Bin No. 2 Weight (grams)	Total % ×	(b) 30.0 %	Aggregate C Bin No. 3 Weight (grams)	Total % ×	(c) 10.0 %	Bin No. 4 Weight (grams)	Total % ×	(d) %	Combined Analysis % (a + b + c + d)	Spec.
	~~1 3/4"-7/8"~~														
	~~7/8"-5/8"~~														
	~~5/8"-3/8"~~														
	1/2"-3/8"	33	2.3	1.4	0	0.0	0.0	0	0.0	0.0				1.4	0-15
	3/8"-4	952	66.0	39.6	0	0.0	0.0	0	0.0	0.0				39.6	21-53
	~~1/4"-10~~														
4-8	~~4-10~~	440	30.5	18.3	151	18.6	5.6	0	0.0	0.0				23.9	11-32
8	~~+10~~			59.3			5.6			0.0				64.9	54-74
8-50	~~10-40~~	9	0.6	0.4	365	45.0	13.5	3	0.8	0.1				14.0	6-32
50-100	~~40-80~~	6	0.4	0.2	136	16.8	5.0	225	56.2	5.6				10.8	4-27
100-200	~~80-200~~	3	0.2	0.1	72	8.9	2.7	163	40.7	4.1				6.9	3-27
	Pass 200	0	0.0	0.0	87	10.7	3.2	9	2.3	0.2				3.4	1-8
	Total	1443 gm	100.0%	60.0 %	811 gm	100.0%	30.0 %	400 gm	100.0%	10.0 %	gm	100.0%	%	100.0 %	

PER CENT MOISTURE IN AGGREGATES IN HOT BINS						
Bin No.	(a) Tare Wt. (gms.)	(b) Gross Wet Wt. (gms.)	(c) Gross Dry Wt. (gms.)	(d) Wt. Moist. (gms.) b-c	(e) Dry Wt. Aggr. (gms.) c-a	% Moist. $\frac{d}{e} \times 100\%$
1						
2						
3						
4						

Asphaltic Binder = ______ %

Total = 100.0%

John Doe

Inspector

J-2

Design By Weight

To design laboratory mixes containing the grading selected, it is necessary to use 60.0 per cent of Aggregate A, which has been cut into three sizes to eliminate segregation, 30% of Aggregate B, which has been cut into two sizes, and 10% of Aggregate C. Tabulating these percentages, we obtain:

Aggregate		Per Cent by Weight (Individual)	Per Cent by Weight (Cumulative)
Aggregate A	Ret.No. 4	41.0	41.0
(Crushed Stone)	4 - ~~10~~	18.3	59.3
	Pass ~~10~~ 8	0.7	60.0
Aggregate B	4 - ~~10~~	5.6	65.6
(Screenings)	Pass ~~10~~	24.4	90.0
Aggregate C			
(Blow Sand)	(Total)	10.0	100.0
	Total	100.0	

The asphalt contents for the five laboratory mixes shall be the maximum, minimum, midpoint and quarter points covered by the governing specifications. For example, assume a Type "D" Mix under Item 340, which requires from 4.0 to 8.0 per cent by weight of asphalt. Therefore, the asphalt contents for the five laboratory mixes will be 4.0, 5.0, 6.0, 7.0 and 8.0 per cent by weight.

The standard specifications for hot-mix asphaltic concrete set exact limits for each size of aggregate and the asphalt which comprise the total mixture. In other words, the laboratory mix employing 4.0 per cent asphalt will contain 96.0 per cent aggregate of the grading previously selected, and the 5.0 per cent asphalt mixture will contain 5.0 per cent asphalt and 95.0 per cent aggregate of the same grading and so on down the line through 8.0 per cent.

In order to select the optimum asphalt content for the grading selected, we must design the following mixes:

Mix No.	Asphalt (Per Cent by Weight)	Aggregate (Per Cent by Weight)
1	4.0	96.0
2	5.0	95.0
3	6.0	94.0
4	7.0	93.0
5	8.0	92.0

The design of all the above mixes will be identical so we will choose Mix No. 1 as an example.

We have selected the combined grading on Page 6, and on this page we calculated the percentages of the three cuts of Aggregate A, the percentages of the two cuts of Aggregate B, and the percentage of Aggregate C required to produce this selected combined grading. Mix No. 1 will consist of 96% aggregate and 4% asphalt. Therefore, if we multiply each percentage of individual cuts (See Page 8) by 0.96 and add the 4.0% asphaltic binder, we will have the proper proportions of all ingredients for Mix No. 1; for example:

Aggregate	Individual % by Wt. of Total Aggr. (See Page 8)		Individual % by Wt. of Total Mix	Cumulative % by Wt. of Total Mix
A - Ret. on 4	41.0	× 0.96 =	39.3	39.3
A - 4 - ~~10~~ 8	18.3	× 0.96 =	17.6	56.9
A - Pass ~~10~~ 8	0.7	× 0.96 =	0.7	57.6
	60.0		57.6	
B - Ret. on ~~10~~ 8	5.6	× 0.96 =	5.4	63.0
B - Pass ~~10~~ 8	24.4	× 0.96 =	23.4	86.4
C - (Total)	10.0	× 0.96 =	9.6	96.0
	100.0		96.0	
		Asphalt Binder	4.0	100.0
			100.0	

These proportions when multiplied by the total weight of Mix No. 1 will give the required amount of each cut and size necessary to produce a 1000-gram mix, for example:

Aggregate			Individual Weights	Cumulative Weights
A - Ret. on 4	39.3%	× 1000. grams =	393.0	393.0
A - 4 - ~~10~~ 8	17.6	× 1000. grams =	176.0	569.0
A - Pass ~~10~~ 8	0.7	× 1000. grams =	7.0	576.0
B - 4 - ~~10~~ 8	5.4	× 1000. grams =	54.0	630.0
B - Pass ~~10~~ 8	23.4	× 1000. grams =	234.0	864.0
C - (Total)	9.6	× 1000. grams =	96.0	960.0
Asphalt	4.0	× 1000. grams =	40.0	1000.0
			1000.0 grams	

Employing the weights calculated above:

(1) Make three 1000.0 gram mixes in accordance with Test Method Tex-205-F.

(2) Mold the three mixes in accordance with Test Method Tex-206-F. Be sure the height of each specimen is 2.00 inches plus or minus 0.06 inch.

(3) Determine the density of the three molded specimens in accordance with Test Method Tex-207-F. The use of paraffin will be optional.

(4) Package the three molded specimens carefully and ship them to the Austin Laboratory for stability tests. Form CX-101, Identification Slip for Asphaltic Concrete is to be properly prepared and is to accompany each set of specimens for proper identification.

The above procedure is followed in designing the 1000 gram mixtures for Mixes 2, 3, 4 and 5.

J-4

Design By Volume

After initial tests have been performed, as indicated in steps 1, 2 and 3 under the section headed Selection of Aggregate Grading, it can be determined if design by volume is necessary or possibly desirable. If the average bulk specific gravities vary more than 0.3, design by volume is required. As earlier discussed assume that bulk specific gravities, as determined in accordance with Test Method Tex 201F and 202F, be as follows:

(1) Aggregate "A" (Lightweight, 3/8 inch maximum) - 1.429
(2) Aggregate "B" (Limestone Screenings) - 2.554
(3) Aggregate "C" (Blow Sand) - 2.627

The Selection of Grading section selected values of 60% Aggregate "A", 30% Aggregate "B" and 10% Aggregate "C" to achieve the desired gradation. The breakdown of these aggregates at these percentages are depicted on the Form 544 Rev. in the Selection of Grading section. By assuming that the average bulk specific gravity of the whole aggregate is the same on individual screens, the gradation by volume is the same as by weight.

The next step is to go to weights of aggregate compared to one another. The weight comparison would be as follows:

Aggregate	% Volume		S.G.			% Weight
A	60	×	1.429	=	85.75	45.5 *
B	30	×	2.554	=	76.62	40.6 *
C	10	×	2.627	=	26.27	13.9 *
	100%				188.63	100.0%

* See Selection of Grading sheet pertinent to conversion to Weight from Volume.

The asphalt contents for the five laboratory mixes should be the maximum, minimum, midpoint and approximately the quarter points of the governing specifications. Specification Item 340 requires 9 to 19 percent by volume asphalt content for a Type "D" mix. The asphalt contents for the five laboratory mixes should be 9, 12, 14, 17 and 19 percent by volume. Since these are percentages by volume, conversion to weight is necessary. Mixes number one and two at 9 and 12% by volume would be converted to weight as follows:

Mix No.	Element	% Volume		% Vol. Mix		S.G.				% Vol. × S.G. = Σ = % Wt. Mix
(1)	Aggregate A	60 × 91%	=	54.6	×	1.429	=	78.023	=	43.1
	Aggregate B	30 × 91%	=	27.3	×	2.554	=	69.724	=	38.6
	Aggregate C	10 × 91%	=	9.1	×	2.627	=	23.906	=	13.2
	Asphalt			9.0	×	1.020	=	9.180	=	5.1
				100.0				180.833		100.0
(2)	Aggregate A	60 × 88%	=	52.8	×	1.429	=	75.451	=	42.3
	Aggregate B	30 × 88%	=	26.4	×	2.554	=	67.426	=	37.8
	Aggregate C	10 × 88%	=	8.8	×	2.627	=	23.118	=	13.0
	Asphalt			12.0	×	1.020	=	12.240	=	6.9
				100.0				178.235		100.0

Mixes numbered 3, 4 and 5 would be considered in the same manner.

Considering the breakdown as presented earlier relative to aggregates alone, Mix No. 1 will consist of 5.1% asphalt by weight or 9% by volume and the proportions of the individual aggregates are as follows:

Element	Individual % by Wt. of Total Aggr.	Individual % by Wt. of Total Mix	Cumulative %'s
A - Ret. #4	31.0 × .949 =	29.4	29.4
A - #4 - #~~10~~ 8	13.9 × .949 =	13.2	42.6
A - Pass #~~10~~ 8	0.6 × .949 =	0.6	43.2
B - #4 - #~~10~~ 8	7.6 × .949 =	7.2	50.4
B - Pass #~~10~~ 8	33.0 × .949 =	31.3	81.7
C - Pass #~~10~~ 8	13.9 × .949 =	13.2	94.9
Asphalt		5.1	100.0

Mix Number 2 at 6.9% asphalt by weight or 12% by volume.

Element	Individual % by Wt. of Total Aggr.	Individual % by Wt. of Total Mix	Cumulative %'s
A - Ret. #4	31.0 × .931 =	28.9	28.9
A - #4 - #~~10~~ 8	13.9 × .931 =	12.9	41.8
A - Pass #~~10~~ 8	0.6 × .931 =	0.6	42.4
B - #4 - #~~10~~ 8	7.6 × .931 =	7.1	49.5
B - Pass #~~10~~ 8	33.0 × .931 =	30.7	80.2
C - Pass #~~10~~ 8	13.9 × .931 =	12.9	93.1
Asphalt		6.9	100.0

In the example by weight a 1,000 gram mix was used as a starting point. This may be excessive considering the lighter materials within the mix by volume. One method which could be used would be to look at the combined average bulk S.G. of the aggregates in the mix with lighter materials relative to the example outlined in the section "Design By Weight." An example of this is as follows:

Average Bulk S.G. of aggregate combination including Lightweight.

$$\frac{100}{\frac{45.5}{1.429} + \frac{40.6}{2.554} + \frac{13.9}{2.627}} = 1.886$$

Average Bulk S.G. of aggregate combination in section "Design By Weight".

$$\frac{100}{\frac{60}{2.584} + \frac{30}{2.554} + \frac{10}{2.627}} = 2.579$$

A comparison of these average bulk S.G.'s and 1,000 grams could be made as follows:

$$\frac{1.886}{2.579} = \frac{X}{1000}$$ or approximately 730 to 750 grams.

* After molding a trial specimen at approximately mid range asphalt content, the height can be measured and an adjustment made to achieve the proper weight to height ratio.

The above procedure is also used to mold mixes numbered 3, 4 and 5. After converting to weight from volume and molding the specimens, the discussion relative to design by weight pertaining to density, stability and plotting of same is applicable. The G_t's and G_a's would be different of course.

* Mr. Gallaway suggest the Marshall procedure of sample preparation and testing as per The Asphalt Institute Publication MS-No.2.

Appendix 14K

Asphalt Emulsions: looking at the basics "Roads & Bridges", March 1995 Issue

APPENDIX K

Asphalt Emulsions: looking at the basics

Published by Roads & Bridges, March 1995 Issue

Using asphalt emulsions is an economical way to extend the service life of pavement on secondary roads, especially county roads. These types of surface treatments range from a single application of emulsified asphalt to multiple courses of alternation applications of aggregate and asphalt.

The application of emulsions to pavements is a cost-effective surface that offers good skid resistance, good visibility, and reduction of hydroplaning among others.

Single surface treatment, often called chip seal, may be used as an interim measure prior to application of a higher type of pavement or to correct surface raveling and oxidation of old pavements. The biggest draw back of single surface treatments is the difficulty of application in cold weather. It usually takes about one month of warm weather, a minimum of 60 degrees F during daylight hours, following construction of the surface treatment for the aggregate particles to properly embed in the membrane. Loose aggregate on county roads can cause windshield damage if the surface treatment is not given the time required for embedding and bonding to develop. [Windshield damage is not a problem with ESCS aggregate].

On the same note, if the temperatures are too high, the breaking time will be less, so the graded aggregate will have to be applied sooner. Application temperatures of the emulsion are universal, 168 to 198 degrees F.

A multiple surface treatment can produce a thickness of 0.50 to 0.75 inches. Some reinforcement may be added to this type of treatment and multiple surface treatments may give about three times the service life of a single surface treatment for about 1.5 times the cost. Because the coverstone for the second layer is smaller, the loss of particles experienced from a graded cover aggregate is significantly less with multiple surface treatments. But, multiple surface treatments do not add any significant strength to the pavement.

The major causes of failure of chip seal coat are too much clay or silt in the aggregate and excessive amount of raveling of the pavement surface being treated. Dirty chips are unable to form a sufficiently strong bond with the residual asphalt and are quickly dislodged by traffic, reducing the integrity of the seal. And, when too much of the residual asphalt is lost into the voids of the raveled pavement surface, the aggregate is not embedded properly and dislodges more easily with traffic.

Starting a project: Before beginning a project involving asphalt emulsions, an engineer or technician should have a seal coat design done to get an estimate of the volume and coverage of emulsion required and the chip or graded seal coverage needed for the demand of the road. The surface condition of the pavement slated for service must ve evaluated. The exact state of the pavement surface must be determined in order to establish the exact requirements for successful seal coats. The surface may need patching or require a pre-seal of emulsion and sand prior to application of the emulsion.

Cracks in the pavement should be corrected before a seal coat is applied. Some cracks may require more than a crack filler. Certain types of cracks, such as alligator cracks, are a result of a weak base and require an overlay of asphalt concrete in the form of a patch.

What to avoid: Some tips on what to avoid when applying asphalt emulsions include:

1. Try not to seal a dusty or wet surface. The dust or water will saturate the voids and make it difficult for the emulsions to penetrate the surface.
2. Don't use excessive amounts of asphalt. This causes bleeding.
3. Don't use insufficient amounts of asphalt. This causes loss of cover aggregate.
4. Don't allow excessive overlap of asphalt at longitudinal or transverse joints.
5. Do not allow variations in spray bar pressure along the length of the spray bar.
6. Do not drag broom the surface treatment. Proper aggregate spreading should make any redistribution of the aggregate unnecessary.
7. Do not permit traffic to travel at speeds greater than 25 mph on the treated surface for the first 24 hrs. following construction.
8. Do not expect to get satisfactory results if the application is done under anything but the most favorable weather conditions.

What to do: Some tips on what to do when applying asphalt emulsions include:

1. Do take precautions to avoid segregation of aggregate.
2. Do provide a fire extinguisher on the distributor truck. The safety of the crew and the work site is important.
3. Do check the spray bar frequently for clogged nozzles.
4. Do check the application rate frequently. This is especially true on the first shots. Apply any needed corrections to the application charts.
5. Do maintain proper spray-bar height while spraying.
6. Do clean the strainers on the spray bar each night after applications.
7. Do use the appropriate rollers for proper seating of the aggregate particles.
8. Do provide adequate traffic control measures. A comprehensive plan for the work site should be in place before the project begins, so that the crews and work-zone safety devices are in place before you begin.

For best results: Remember that good asphalt surface treatments require:

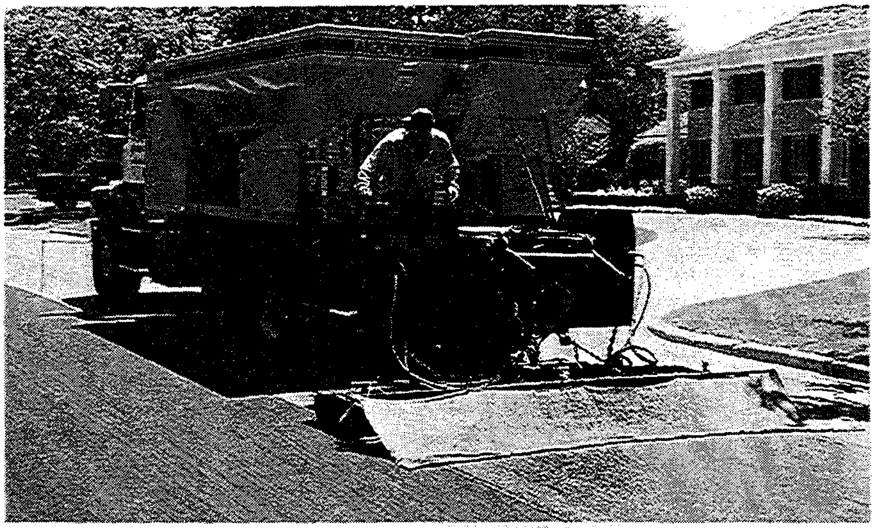
✓ Asphalt that is fluid enough to spray properly and cover the surface uniformly.
✓ After application, the asphalt should retain proper consistency to wet the aggregate.
✓ The asphalt should cure and develop adhesion quickly.
✓ After the asphalt is rolled and cured, it should hold the aggregate tightly to the road surface to prevent dislodging by traffic.
✓ When asphalt is applied in the right amounts, it should not bleed or strip with changing weather conditions.

A good long-lasting, cost-effective pavement can be produced with asphalt emulsions of either single or multiple layers, to meet the demands of your particular application.

Appendix 14L

"*An Introduction to Slurry Seal*" Akzo Nobel Newsletter, Spring 1997

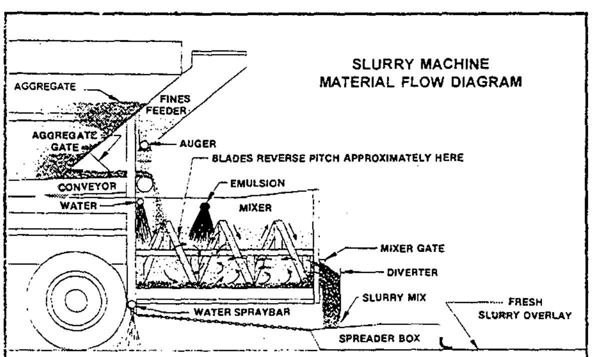
"An introduction to slurry seal"



A typical slurry seal operation with an Akzo Nobel HD 10 machine.

Slurry seal is often confused with other products. It is defined by ASTM D-3910 standard as a mixture of continuously graded fine aggregate, mineral filler (which is usually Portland cement, but can also be hydrated lime or other materials), emulsified asphalt, and water properly proportioned, mixed, and spread as a surface treatment.

When applied, the cured slurry seal should have a homogeneous appearance, fill cracks, adhere firmly to the surface, and provide a weather proof, high friction seal. Many times, the name slurry seal is used generically to mean an asphalt emulsion with a little bit of sand or clay mixed in to serve as a pavement sealer - a liquid sealer with a little bit of sand for abrasion or grit - but this is not the slurry seal we are talking about.



The slurry seal process is the continuous combination of aggregate, mineral filler, water, and asphalt emulsion through the truck-mounted mixing unit, which proportions, mixes and spreads the material in a continuous form until the truck is empty. Then the truck goes back to the stockpile to refill with more materials. Slurry is not made as batch, taken someplace, and applied; it is a continuous mixing and lay-down procedure.

SLURRY SEAL USE

Most slurries are ideally suited for residential-type streets. The slurry contractor will normally work from a stockpile in close proximity to the job site, using two or three truck-mounted units, so that while one is loading at the stockpile, the other is laying material on the street. The trucks keep shuttling back and forth. Aggregate is delivered to the stockpile, properly stockpiled, and then loaded, often with a rubber-tired front-end loader. Normally, there's not any heat involved with the slurry emulsion. It's used at ambient temperatures. However, sometimes contractors doing late fall or early spring work may put 80° to 100°F (27° to 38°C) to that asphalt emulsion, so it does not cool down too much. Generally, we're using the asphalt emulsion at ambient temperature. If it comes from the manufacturer too hot, it may set or break too quickly in the mixing action, and there's not enough time then to apply the material.

Water comes from a fire hydrant or tank. Mineral filler is normally supplied in bags and then is loaded by hand.

BASIC GRADATIONS

There are three gradations for slurry seals. Type I is normally applied at 6 to 10 lbs./sq.yd. (2.7 to 4.5 kg./sq.m.) of aggregate, with 10 to 16% residual asphalt cement.

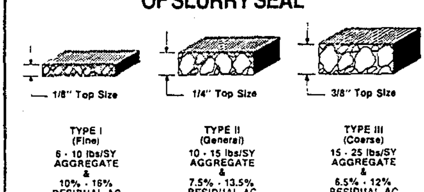
Type II is most commonly used in the U.S., applied at 10 to 15 lbs./sq.yd. (4.5 to 6.8 kg./sq.m.), with 7.5 to 13.5% residual asphalt.

As the gradation reduces in size, finer aggregate has more surface area, so more residual asphalt is needed to properly coat and bond that mix. As gradations get coarser, you'll see a drop in residual asphalt content.

Type III is the coarsest. It goes down at 15 to 25 lbs./sq.yd (6.8 to 11.3 kg./sq.m.), with 6.5 to 12% asphalt in the specification range.

The exact content of residual asphalt must be determined in a qualified laboratory for the particular type of emulsion and aggregate being used. The amount of asphalt may also vary according to the traffic count. The more asphalt we can put into the mixture, the more flexibility and the more life we'll have. The more traffic loading we put on a mixture, the less asphalt it is able to stand.

THE THREE BASIC GRADATIONS OF SLURRY SEAL



So with higher traffic counts, we have a little bit less residual asphalt in the mix, and with low traffic counts we can afford to be safe with a little bit more residual asphalt in the mix.

The application rate is very dependent on the texture of the surface we're laying the material on. If it's a very smooth surface, like a tabletop, we'll be laying at the low end, because there's no surface texture there to take the material. But, when we're doing a roadway that has had a previous surface dressing or chip seal that is very coarse-textured, we will then be applying slurry at the high end of the application range.

There's also a design method to predict the spread rate, based on the gradation of the slurry aggregate. It has to do with sand patch surface texture test. The sand is spread onto the roadway surface and measured as to how much area it covers. From that and the gradation of the slurry aggregate, we can predict an application spread rate.

When To Use It

If you ask most highway engineers, when they use slurry seal or chip seal as preventive maintenance — the most common answer is, "Well, when the pavement is 8 to 10 years old, it's looking very dry, and it's much lighter in color than when it was new. We're losing some of the fines, and perhaps some of the large aggregate has started to come out of the mix (raveling). Some cracking has developed. It's time to place the seal coat."

A study was done in Canada some years ago. They found out that over the first 75% of the pavement's life, on average, it lost 40% in quality. And over the next 12% of that pavement's life, it had an additional 40% drop in quality. Once it's oxidized, and it starts to open up so water and air can penetrate the pavement, it deteriorates very rapidly.

These researchers found that if they spend $1/unit of area to repair the pavement before it starts to show signs of aging, that's the most cost-effective. A short time later it may cost four or five times as much to repair.

Earlier in his career, Prithvi Kandhal studied, properly designed and constructed asphalt pavements in western Pennsylvania. He took cores and noted the visual surface condition of the roadway — he rated that surface condition. He took the cores back to the laboratory and extracted the asphalt, or bitumen, from the pavement samples, and ran low-temperature ductility tests on the extracted asphalt, determining how much stretch it had.

What Kandhal found was that when the pavement is new, the asphalt's stretch is good. When it becomes old, there's no stretch left. We say then it has age-hardened, it has oxidized, and lost its ability to flex and stretch.

If we've waited to do maintenance until we see these visual signs, we may have waited too long. Because the asphalt within that pavement most likely has already age-hardened to a point that we're just trying to buy some time.

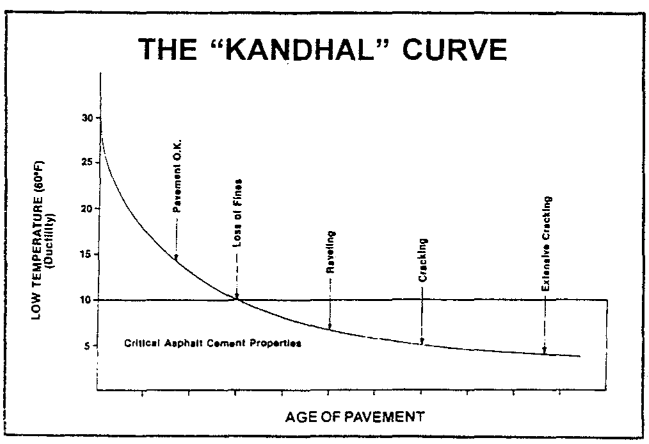
We're not very good at reconditioning the asphalt within an existing pavement. So, our industry promotes the idea that preventive maintenance needs to be early. It needs to be done when the pavement looks like it doesn't need anything done to it. Then it is really preventive maintenance, applied to extend the life cycle as long as we can.

When people ask me, "When is the proper time to use slurry seal or chip seal as preventive maintenance?" my answer is, "Normally when the pavement in the 2 to 3 to 4 yr. old range."

While most people are thinking they're doing it properly at 8 to 12 yrs., we'd like to see it done a lot earlier, because preventive maintenance is considerably more cost-effective in the long run.

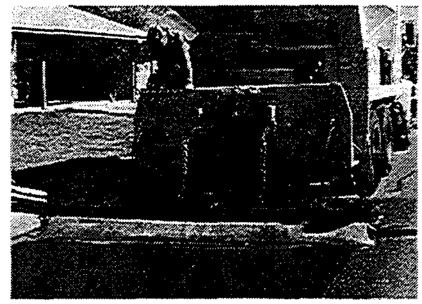
Corrective Maintenance

What about slurry seal and corrective maintenance? How can slurry seal fit into that program? What can it do, and what can't you expect it to do?



I define corrective maintenance as any activity or material used to correct a faulted pavement condition and bring it back to an acceptable level.

The most common examples of use in corrective maintenance might be crack sealing and pothole repair. I consider crack sealing corrective maintenance, because the pavement is cracked.



A "Type II" Slurry Seal application.

The Virginia Department of Transportation likes to use Type II slurry seal on their pavement shoulders. One of the two most talked about things at VDOT is if a truck gets over on the shoulder, there are no loose stones to be kicked up, as there would be if they had used chip seal. Since there are no loose stones to be kicked up that could break windshields, the Virginia DOT considers it a safety factor.

The other thing talked about is that slurry sealed-shoulders are more self-cleaning than chip-sealed shoulders. The surface is tighter and smoother, and the weather will help blow debris off the shoulders more readily than if the surface has a coarser-texture; such as chip seal.

Slurry has a unique ability to deposit a bituminous seal according to the demands of the surface.

In one pass, after cleaning out the cracks and cleaning the shoulder properly, we can fill the interface crack, and place a modest wedge with slurry seal, if the shoulder's a little bit low. By modest, I mean two to three times the size of the largest aggregate in the mixture. We can lay it a little thicker where needed because we're not running traffic on the shoulder.

We can place a weather-tight seal across the entire surface, fill all the surface voids, provide color texture delineation for the roadway and give good friction to the shoulder.

Effectiveness

Many lanes on roadways are variable in surface texture. The wheel tracks are a bit tighter and smoother than the outside edge and the center line of the roadway. There is usually a crack where the two pavement passes were joined, then a tighter, smoother surface in the

Continued on page 8...

...Continued from page 6
wheel tracks, then pavement that is coarser and a bit cracked on the outside edge.

If we use a thin, hot-mix asphalt pavement overlay, without properly preparing the surface, and we bridge over voids on the surface, the hot-mix is not going to filter down into the cracks and voids; it is going to bridge. If it does bridge, it creates a weak point, and those are very likely to reflect back through quickly.

If we use chip seal, we have a different problem. Chip seal most often will need 0.4 gal./sq.yd. (1.8 l./sq.m.) on the more textured areas of the pavement to fill the voids of the existing surface. But if we spray that much in the wheel track, it is too much.

What we have to do is try to average that out and make a decision; Do we want 0.4 or 0.45 or 0.5 gal. on the outside where there is more texture? We may shoot .45 gal., and be too rich in the wheel tracks, yet not quite rich enough to satisfy the demand of the existing surface while holding the cover aggregate in the more textured areas.

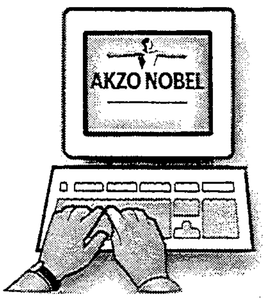
We're working to improve that and be able to apply different applications rates across an asphalt distributor bar. We want to shoot less material in the wheel track and shoot a heavier application on the outside edges. That technology is available, but not widely in use currently.

Since it is a fluid material, slurry has the unique ability to deposit the seal according to the surface demand better than any other process we know.❑

Contact Akzo Nobel for more information on:

- *Slurry Seal and Micro-surfacing machines*
- *Emulsifiers for Slurry Seal*
- *Slurry Seal Technology*

Visit us on the Internet



You can find our home page at
http://www.acm.org/~akzo

Where to Find Us

Australia
Camelia N.S.W.2142
P.O. Box 80
6 Grand Avenue
N.S.W. 2150 Parramatta
(Sydney), Australia
Phone: +61-2 6384 555
Fax: +61-2 6384 681

Brazil
Estrada Municipal Iva 118
Bairro São Roque da Chave,
P.O. Box 32
13210 Itupeva-S.P. Brazil
Phone: +55 11 4081130
Fax: +55 11 4081495

France
ZI. de Venette
P.O. Box 217
60202 Compiegne, Cedex, France
Phone: +33-44903000
Fax: +33-44903076

Germany
P.O. Box 100146
52301 Düren, Germany
Phone: +49-2421 5950
Fax: +49-2421 595200

Italy
80, Via E Vismara
20020 Arese (Milano), Italy
Phone: +39-2 935251
Fax: +39-2 93581181

The Netherlands
Stationsplein 4
P.O. Box 247
3800 Ae Amersfoort, The Netherlands
Phone: +31-33 4676324
Fax: +31-33 4676178

Singapore
510, Thomson Road
#15-02, SLF Building
Singapore 1129, Singapore
Phone: +65-2581333
Fax: +65-3546971

Spain
Autovia de Castelldefels, km 4.65
08820 El Prat De Llobregat
(Barcelona), Spain
Phone: +34-3 4784411
Fax: +34-3 4780734

Sweden
Sickla Industriväg 6, Nacka
P.O. Box 11536
S-100 61 Stockholm, Sweden
Phone: +46 8 743 40 00
Fax: +46 8 702 07 11

United Kingdom
Hollingworth Road, Littleborough
Lancashire OL15 OBA, United Kingdom
Phone: +44 1706 37 7731
Fax: +44 1706 37 2734

USA
4914 Fort Avenue
P.O. Box 7677
Waco, Texas 76710, USA
Phone: +1 817 772 7677
Fax: +1 817 772 7246

Adamsfield Business Center
7101 Adams Street, Unit #7
Willowbrook, Illinois, 60521 USA
Phone: +1 630 789 2494
Fax: +1 630 789 2506

AKZO NOBEL

Appendix 14M

Suggested Reference Reading

APPENDIX M

SUGGESTED REFERENCE READING

1. Herren, M., Mojadezadeh, K., and Morek, C. "Surface Treatments--Summary of Existing Literature". The Engineering Experiment Station, University of Illinois in Cooperation with Illinois Division of Highways and the U.S. Bureau of Public Roads, August, 1963.

2. Slotta, L.S. "Bituminous Stabilization of Wyoming Heat-Altered Shale". Highway Research Board Bulletin No. 282, 1961, pp. 84-97.

3. Wycoff, J.C."Suitability of Lightweight Aggregate for Bituminous Plant Mix". ASTM Bulletin No. 235, January 1959, pp. 33-36.

4. Lehmann, H. L. and Adam, Verdi "Use of Expanded Clay Aggregate in Bituminous Construction". Highway Research Board Proceedings, Vol. 38, 1959, pp. 398-407.

5. Lehmann, H. L. and Adam, Verdi "Use of Finely Ground Lightweight Aggregate as a Mineral Filler in Hot-Mix Asphalt Concrete Construction". Highway Research Abstracts, February 1956.

6. Haun, R. P. "Tar and Feathers Highway," Texas Highways, Vol. 10, No. 3, p. 7, 1963.

7. Kearby, J. P., "Thoughts and Theories on Penetration Surfaces". Texas Highway Department Construction and Maintenance Bulletin No. 11, 1952, pp. 43-65.

8. Benson, F. J. and Gallaway, B. M. "Retention of Coverstone by Asphalt Surface Treatments". Texas Engineering Experiment Station Bulletin No. 133, September 1953.

9. Downey, G. L. "The Mechanics of Stone Damage to Automobile Windshields". Highway Research Board Abstracts, Vol. 27, 1957, pp. 29-32.

10. Rushing, H. B. "Lightweight Aggregate Abrasion Study". HPS 1(18) U.S. Department of Commerce, Bureau of Public Roads and Louisiana Dept. of Highways, February 1963.

11. Woolf, D.O. "Toughness, Hardness, Abrasion, Strength and Elastic Properties". ASTM Special Technical Publications No. 169, 1956 pp. 314-324.

12. Gallaway, B. M. "Interim Report on the Use of Expanded Shale and Precoated Limestone as Coverstone for Seal Coats and Surface Treatments". Research Report 51-1 prepared in cooperation with the Texas Highway Dept. and the U.S. Bureau of Public Roads, August 1954.

13. Gallaway, B. M. and Harper, W. J. "Laboratory and Field Evaluation of Lightweight Aggregates as Coverstone for Seal Coats and Surface Treatments". Highway Research Record No. 150, 1966.

14. Gallaway, B. M. and Harper, W. J. "Interim Report on the Laboratory Considerations for the Use of Synthetic Aggregate for Hot-Mix Asphalt Pavements". Research Report 51-3 prepared in cooperation with the Texas Highway Dept. and the U.S. Bureau of Public Roads, November, 1966.

15. Gallaway, B. M. and Hargett, E. R.. "Blending Lightweight Aggregates With Natural Aggregates for the Production of Bituminous Concrete". Presented at the 1969 Highway Research Board Meeting.

16. Gallaway, B. M. "Skid Resistance and Polishing Type Aggregates". Texas Transportation Researcher, Vol. 5, No. 1, January 1969.

17. Epps, J. A., Gallaway, B. M., and Hughes C. H. "Field Manual on Design and Construction of Seal Coats". Texas Transportation Institute, Research Report 214-25, July 1981.

18. Herrin, M., Marek, C. R., Majidzadeh, K. "State of the Art: Surface Treatments Summary of Existing Literature". Highway Research Record, Special Report No. 96, 1968.

19. Estakhri, C. K. and Gonzalez, M. A. "Design and Construction of Multiple Seal Coats". Research Report 448-1F Texas Transportation Institute, Texas Dept. of Transportation and FHWA, November 1988.

20. McLeod, N. W. "Basic Principles for the Design and Construction of Seal Coats and Surface Treatments with Cutback Asphalts and Asphalt Cements" Proceedings of the Association of Asphalt Paving Technologists, Supplement to Volume 29, 1980.

21. "Skid Resistance of Highway Pavements". A Symposium Presented at the Seventy-Fifth Annual Meeting of the American Society for Testing and Materials, STP 530, Los Angeles, June 1976.

22. Gallaway, B. M., Epps, J. A. and Tomita, H. "Effects of Pavement Surface Characteristics and Textures on Skid Resistance". Texas Transportation Institute, Research Report 138-4, 1971.

23. Gallaway, B. M., et al. "The Relative Effects of Several Factors Affecting Rainwater Depth of Pavement Surfaces". Highway Research Record, No. 395, 1972.

24. Rose, J. G., et al. "Macro-Texture Measurements and Related Skid Resistance at Speeds from 20 to 60 mph". Highway Research Record, No. 341, 1970.

25. National Cooperative Highway Research Program. "Skid Resistance Synthesis of Highway Practice" No. 14, 1972.

26. Semmelink, C. J. "A Rational Design Approach for Single and Double Surfacing Seals Based on the Modified Tray Test". Transportation Record No. 1106, Vol. II, 1987.

27. Gallaway, B. M., Ivey, D. L., Hayes, G., Ledbetter, W. B., Olson, R. M., Woods, D. L., and Schiller, Jr., R. F. "Pavement and Geometric Design Criteria for Minimizing Hydroplaning". Federal Highway Administration, Report No. FHWA-RD-79-31, December, 1979.

28. Semmelink, C. J. "A Laboratory Study of the Aggregate Spread Rates of Seals". National Institute for Transport and Road Research, Council for Scientific and Industrial Research, RP/19, Pretoria, South Africa, February, 1986.

29. Thompson, M. J. "Performance of Bituminous Seal Coats: Measurement and Prediction". M.S. thesis. Pennsylvania State University, University Park, Aug. 1990.

30. Holmgreen, R. J. "A Seal Coat Design Method". Proc., Association of Asphalt Paving Technologists, St. Paul, Minn., Vol. 54, 1985.

31. Martin, Jr., R. S. "Chip Seal Practice" Proc., Twenty-Sixth Paving and Transportation Conference, Department of Civil Engineering, University of New Mexico, Albuquerque, Jan. 1989.

32. Shuler, R. S. "Performance of Polymer Modified Chip Seals". University of New Mexico Research Report OC 89/122, New Mexico Highway and Transportation Department HPR 87-04, Santa Fe, Aug. 1989.

Appendix 14N

SI (Modern Metric) Conversion Factors

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

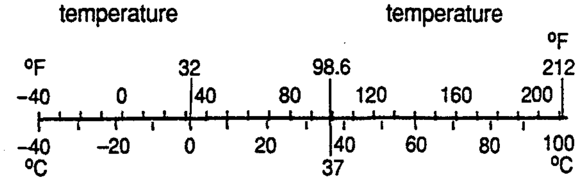
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
inches	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
AREA				
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
VOLUME				
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
TEMPERATURE (exact)				
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement.

NAPA: THE SOURCE

This publication is one of the many technical, informational, and promotional publications available from the National Asphalt Pavement Association (NAPA). To obtain a complete listing, please request on your letterhead a copy of our current publications catalog:

Publications Department, National Asphalt Pavement Association,
NAPA Building, 5100 Forbes Boulevard, Lanham, MD 20706-4413