ESCSI
Expanded Shale, Clay and Slate Institute
Rotary Kiln Structural Lightweight Aggregate

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The Team Approach to Internally Cured Concrete

The Simple, Economical and Sustainable Way to Improve Concrete Performance

Poor field curing along with concrete's inability to fully cure internally has robbed the industry and society of the maximum potential that concrete has to offer. Being the most used building material known to man, concrete still falls short of delivering its true value on many occasions. This poor performance can be minimized by the age-old internal curing technology that dates back to concrete constructed during the Roman Empire. We now have a more complete understanding of how internal curing (IC) works and a way to design for IC. We also have a better understanding of why IC increases the durability and service life of concrete in an economical, sustainable and practical way.

Internal curing provides something that most concrete needs and conventional curing cannot provide: additional internal water that helps prevent early age shrinkage (reducing early age cracking) and increases hydration of cementitious materials throughout the concrete.

Once concrete sets, hydration creates partially-filled pores in the cement paste which causes stresses that result in shrinkage. IC provides readily available additional water throughout the concrete, so hydration can continue while more of the pores in the cement paste remain saturated. This reduces shrinkage, cracking, early age curling/warping, increases strength and lowers the permeability of the concrete, making it more resistant to chloride penetration.

Internal curing has been shown to work well with supplementary cementitious materials (SCM), especially at higher dosage levels, because fly ash, slag and silica fume have increased water demand during their reaction, compared to hydrating portland cement.

Internal curing does not replace conventional surface curing, but works with it to make concrete more robust. Internal curing can also help compensate for less than ideal weather conditions and poor conventional curing that is often seen in the real world.

ACI defines internal curing (IC) as a *process by which the hydration of cement continues because of the availability of internal water that is not part of the mixing water*.

IC using prewetted expanded shale, clay or slate (ESCS) lightweight aggregate is the simplest and most practical way of supplying additional curing water throughout the concrete mixture. This is done by replacing some of the conventional sand in the mixture with an equal volume of prewetted ESCS fine aggregate. IC is often referred to as "curing concrete from the inside out."

IC is gaining momentum in all areas of concrete construction including concrete paving, concrete flatwork, bridges, structural units and mass concrete applications.

The following guidelines are intended to contribute to the success of the internally cured concrete project.

Aggregate Selection

The porous nature of ESCS lightweight aggregate allows for a high degree of water absorption compared to ordinary aggregates. Equally important to the internal curing process is the aggregate's rate of desorption, its ability to release the internal moisture into the concrete paste at the proper time. Any aggregate intended for the use of IC must meet the requirements of ASTM C 1761/C 1761M *Standard Specification for Lightweight Aggregate for Internal Curing of Concrete.*

Concrete Mixture Considerations

The amount of prewetted ESCS aggregate needed for internal curing is based on the absorption and desorption of the material being used. For most practical concrete applications, 7 lbs of IC water per 100 lbs of cement provides an appropriate value for the amount of IC moisture needed for portland cement concrete. Since SCMs like fly ash and slag are known to have higher water demand during their reaction than cement alone, in some applications it may be reasonable to do trial mixes with varying dosages of IC aggregate above and below the 7 lb value to determine a curve for optimum performance.

Knowing the target amount of IC water needed, and the aggregate's absorption and desorption, the amount of prewetted ESCS aggregate can be determined through the use of ESCSI's *Guide for Concrete Mixture Designs using Prewetted ESCS Lightweight Aggregates for Internal Curing* or by contacting the ESCS lightweight aggregate supplier.

Aggregate Saturation and Stockpile Management

Construct ESCS lightweight aggregate stockpile(s) at the concrete batching facility so as to maintain uniform moisture throughout the pile. Using an approved sprinkler system, continuously and uniformly sprinkle the stockpile(s) with water, turning or mixing the aggregate pile as needed to reduce moisture variation. Sprinkling should continue for a minimum of 48 hours, or until the absorbed moisture content of the stockpile reaches the recommended minimum as per the ESCS producer recommendation and determined by ASTM C 1761. If a steady rain of comparable intensity occurs, turn off sprinkler system until the rain ceases. At the end of the wetting period, or after a rain event, allow stockpile(s) to drain for at least 12 to 15 hours immediately prior to use. On occasions even after the recommended drain time, there still may be a high degree of free water on the aggregate at the base of the pile. If that is the case, it is recommended that the loader operator keep the bucket elevated about 6 inches to avoid charging the batch plant with material that is too wet.

Efforts should be taken to not over-wet stockpiles. Keeping the internal moisture of the fine lightweight aggregate (FLWA) at desired levels is the goal. All fine materials with excessive free moisture will cause handling issues at the batch plant. Once the FLWA stockpile has sufficiently drained to a typical free moisture range, as seen in regularly used normal weight sands, the FLWA will handle and flow very similarly to sand. FLWA in the stockpile will maintain high levels of internal moisture for an extended period of time. Stockpile management and weather conditions in your area will have the greatest effect on moisture loss. Periodic moisture checks and re-wetting of the stockpile is necessary during hot, dry and windy weather conditions, and when there are days of nonuse in the batching schedule. Moisture checks of the FLWA should always be conducted prior to batching and adjustments to the concrete mixture made, if changes in moisture levels occur. To maintain moisture uniformity, turn or remix stockpile(s) prior to testing and use.

Covering stockpile(s) with a non-permeable cover after saturation will help reduce evaporation and increase stockpile(s) moisture consistency.

Under steady operations, two stockpiles need to be maintained. One pile is receiving new FLWA that is to be prewetted and prepared for us. The second pile is already prepared and being used for batching.

Batch Plant Adjustments to IC Aggregates

Prior to batching, the internal moisture and the external or "free" moisture of the ESCS aggregate must be tested as per the ESCS producer recommendation and determined by ASTM C 1761. If necessary, adjustments must be made to the concrete batch weights. This will insure the proper amount of internal moisture is available to the concrete mixture for optimal internal curing. This is done by simply replacing more or less normal weight sand with the prewetted fine or intermediate ESCS aggregate, being sure to adjust by volume not by weight, to achieve proper yield of the concrete mixture.

Pumping

Since internally cured concrete mixtures are not lightweight concrete, no additional steps or precautions are necessary to successfully pump the IC concrete mixture, designed to be placed through a concrete pump.

Concrete Testing

Concrete testing is the same as with any normal weight concrete mix. Sample concrete as per ASTM C 172. If testing for entrained air, test as per ASTM C 231. The use of a volumetric air meter is not necessary. Concrete should be regularly tested as per ASTM C 138 to assure consistency of the mix.

Design Engineer

1. IC concrete is not structural lightweight concrete. Concrete mixture design, with the exception of the replacement of a portion of normal weight aggregates with the prewetted fine or intermediate ESCS aggregate, will be the same.
2. To establish the proper proportions of the concrete mixture needed to meet the required criteria, have the testing lab run design curves based on the maximum specified slump, air and amount of calculated IC moisture as per ACI 301.
3. Specify a pre-placement meeting with the following present: engineer, architect, contractor, concrete supplier, ESCS aggregate supplier, testing agency, admixture supplier and pumping contractor, if applicable.

4. On large jobs, these same people should be present at the first concrete placement.
5. Specify exactly where concrete shall be tested, preferably at the point of final discharge as per ACI 304.2R.
6. Realize that absorbed water does not affect the water/cement ratio, as defined in ASTM C 125.

General Contractor

1. Keep everyone communicating, this is a team effort!
2. Designate a laborer to assist the testing lab inspector.
3. Specify to the concrete supplier the number of yards needed per hour, not how many trucks.
4. Make an agreement with the concrete supplier as to how the quantity of concrete delivered will be determined.
5. Schedule placement days in advance so the concrete supplier has the ability to prepare and manage IC aggregate stockpiles.

Concrete Producer

1. Internal curing FLWA must be prewetted. Consult the ESCS lightweight aggregate supplier.
2. Manage and prepare FLWA stockpiles to be ready for use. A consistent amount of free moisture, as low as possible, is the key to success. Stay ahead of the demand.
3. Keep two stockpiles: one already prepared for the current day's use and the other for prewetting for future use.
4. Cover the prewetted piles with a tarp to reduce evaporation and increase consistency throughout the stockpile.
5. Designate an individual to be responsible for IC stockpile prewetting and management.
6. Remix stockpiles prior to testing and use.
7. Moisture checks must be made prior to batching and if necessary, adjustments made to assure the proper amount of internal moisture is present for optimal curing.
8. Give yourself time to perform the required steps to assure a successful placement.

Testing Labs

1. The field inspector shall be ACI Field Technician Grade 1 (or equivalent) per ASTM C 94.
2. Make sure the inspector has the proper tools, understanding and directions for the job.
3. On large jobs, use the same inspector for all concrete placements.

References

- ASTM C 1761/C 1761M *Standard Specification for Lightweight Aggregate for Internal Curing of Concrete*
- ASTM C 172 *Standard Practice for Sampling Freshly Mixed Concrete*
- ASTM C 231 *Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method*

- ASTM C 138 *Standard Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete*
- ASTM C 125 *Standard Terminology Relating to Concrete and Concrete Aggregates*
- ASTM C 94 *Standard Specification for Ready Mix Concrete*
- American Concrete Institute Publication 301
- American Concrete Institute Publication 304.2 R
- ESCSI's *Guide for Concrete Mixture Designs using Prewetted ESCS Lightweight Aggregates for Internal Curing*
- ACI (308-213)R-13, *Report on Internally Cured Concrete Using Prewetted Absorptive Lightweight Aggregate*
- ACI 213R-14, *Guide for Structural Lightweight-Aggregate Concrete*
- Bentz, D.P. and Weiss, W.J., *Internal Curing: A 2010 State-of-the-Art Review, NISTIR 7765, U.S. Department of Commerce,* February 2011
- Rao, C. and Darter, M., *Evaluation of Internally Cured Concrete For Paving Applications,* September 2013