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

SIGNIFICANTLY INCREASE CONCRETE DURABILITY AND SERVICE LIFE BY USING 100 YEAR OLD TECHNOLOGY

Owners and designers of many new structures currently specify a design life of 100 years or more to ensure durability and sustainability. Tourney Consulting Group, LLC (TCG) in Kalamazoo, MI, recently conducted a study to determine the effects of lightweight coarse and fine aggregates on the transport properties and other durability related properties of concrete. Tourney Consulting Group is a globally recognized leader in quantifying concrete durability, service life prediction, and developing service life solutions. Transport properties of concrete are measurements of the ability of ions and fluids to move through the material. Transport properties are used in several service life programs including STADIUM®, Life 365™, and analysis according to ***fib*** Bulletin 34: Model Code for Service Life Design. The STADIUM® results showed that the time to corrosion in a reinforced concrete structure will be increased by an average of approximately 22% when lightweight concrete mixtures are used compared to a comparable mixture with normalweight aggregates. The study also found that the replacement of normalweight sand with lightweight fines resulted in approximately a 32% to 88% increase in time to corrosion.

Ten expanded shale, clay and slate (ESCS) lightweight coarse aggregates from across the United States were used in concrete mixtures ("sand lightweight concrete") that were compared to a normalweight concrete with respect to transport properties. In addition, one mixture with normalweight coarse aggregate and lightweight fine aggregate (an "inverted mixture"); one mixture with lightweight coarse aggregate and lightweight fine aggregate ("all lightweight concrete"); and one mixture with normalweight aggregate with a partial replacement of normalweight sand with lightweight fine aggregate (an "internally cured mixture") were evaluated for transport properties. Each of the thirteen lightweight concrete mixtures and the normalweight control mixture used 658 pounds of Type I Portland cement per cubic yard of concrete. No supplementary cementitious materials, corrosion inhibitors, or corrosion resistant reinforcing bars were used so that the effect of lightweight aggregates alone on the transport properties could be demonstrated.

Using data from tests performed in the TCG lab, a bridge deck subjected to deicing salts in Detroit, MI, was modeled using Life 365™ and STADIUM® software. The STADIUM® software results showed that the concrete bridge deck service life would be increased compared to a normalweight concrete control mixture as follows:

- By approximately 22% for mixtures with lightweight coarse aggregate and normalweight sand ("sand lightweight concrete")
- By approximately 88% for mixtures with normalweight coarse aggregate and lightweight fine aggregate ("inverted mixture")
- By approximately 35% for mixtures with lightweight coarse aggregate and lightweight fine aggregate ("all lightweight concrete")
- By approximately 32% for mixtures with normalweight coarse aggregate and a partial replacement of normalweight sand with lightweight fine aggregate ("internally cured mixture")

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The Life 365™ analysis showed equivalent performance between the sand lightweight mixes and the control mix. As with the STADIUM® analysis, significant improvements were shown with the lightweight fines, up to a three times improvement with lightweight fine aggregate replacing normalweight sand.

While these results are encouraging, other studies have shown greater improvements in properties related to durability for different types of lightweight and internally cured concrete. Such results would indicate even greater increases in expected service life than are presented in the findings of this study.

These service life predictions are estimates for uncracked concrete. As part of their testing program, Tourney Consulting Group also evaluated properties of lightweight concrete related to cracking potential. The addition of a small quantity of lightweight fines for internal curing was shown to reduce restrained shrinkage cracking and to increase compressive strength and service life. Tourney's findings agree with studies by others (including the previously mentioned References) that find that lightweight concrete also has reduced potential for cracking compared to the control concrete, providing further benefit for increasing the service life of concrete structures that is not considered in the Life 365™ and STADIUM® analyses . For complete information on the tests performed to determine the transport and durability properties of concrete, as well as the assumptions used for the service life analyses, see the full report "Determination of Transport Properties of Lightweight Aggregate Concrete for Service Life Modeling."

Lightweight aggregate concrete made with ESCS has been used in concrete structures for over 100 years, demonstrating its superior durability and service life. Structural lightweight concrete has compressive strengths comparable to normalweight concrete, yet it is typically 20% to 25% lighter (and in some cases up to 33% lighter), offering design flexibility and substantial cost savings by reducing dead load, improving seismic structural response, allowing longer spans, providing better fire ratings, and by permitting thinner sections, decreased story heights, smaller size structural members, reduced reinforcing steel and lower foundation costs. These savings generally result in additional reductions of cost, energy, and emissions associated with the transportation of materials, and thus, less environmental impacts. The excellent durability performance of structural lightweight concrete and internally cured concrete is a result of a number of factors such as increased cement hydration (including supplementary cementitious materials reaction) and reduced permeability, autogenous shrinkage, early age cracking, modulus of elasticity, and coefficient of thermal expansion.