Concrete in Practice
What, why & how?

NRMCA

CIP 36 - Structural Lightweight Concrete

WHAT is Structural Lightweight Concrete?

Structural lightweight concrete has an in-place density (unit weight) on the order of 90 to 115 lb/ ft^3 (1440 to 1840 kg/m^3) compared to normalweight concrete with a density in the range of 140 to 150 lb/ ft^3 (2240 to 2400 kg/m^3). For structural applications the concrete strength should be greater than 2500 psi (17.0 MPa). The concrete mixture is made with a lightweight coarse aggregate. In some cases a portion or the entire fine aggregate may be a lightweight product. Lightweight aggregates used in structural lightweight concrete are typically expanded shale, clay or slate materials that have been fired in a rotary kiln to develop a porous structure. Other products such as air-cooled blast furnace slag are also used. There are other classes of non-structural lightweight concretes with lower density made with other aggregate materials and higher air voids in the cement paste matrix, such as in cellular concrete. These are typically used for their insulation properties. This CIP focuses on structural lightweight concrete.

WHY Use Structural Lightweight Concrete?

The primary use of structural lightweight concrete is to reduce the dead load of a concrete structure, which then allows the structural designer to reduce the size of columns, footings and other load bearing elements. Structural lightweight concrete mixtures can be designed to achieve similar strengths as normalweight concrete. The same is true for other mechanical and durability performance requirements. Structural lightweight concrete provides a more efficient strength-to-weight ratio in structural elements. In most cases, the marginally higher cost of the lightweight concrete is offset by size reduction of structural elements, less reinforcing steel and reduced volume of concrete, resulting in lower overall cost.

In buildings, structural lightweight concrete provides a higher fire-rated concrete structure. Structural lightweight concrete also benefits from energy conservation considerations as it provides higher R-values of wall elements for improved insulation properties. The porosity of lightweight aggregate provides a source of water for internal curing of the concrete that provides continued enhancement of concrete strength and durability. This does not preclude the need for external curing.

Sprinkling Aggregate in a Stockpile

Structural lightweight concrete has been used for bridge decks, piers and beams, slabs and wall elements in steel and concrete frame buildings, parking structures, tilt-up walls, topping slabs and composite slabs on metal deck.

HOW is Structural Lightweight Concrete Used?

Lightweight concrete can be manufactured with a combination of fine and coarse lightweight aggregate or coarse lightweight aggregate and normalweight fine aggregate. Complete replacement of normalweight fine aggregate with a lightweight aggregate will decrease the concrete density by approximately 10 lb/ft^3 (160 kg/m^3).

Designers recognize that structural lightweight concrete will not typically serve in an oven-dry environment. Therefore, structural design generally relies on an *equilibrium* density (sometimes referred to as *air-dry* density); the condition in which some moisture is retained within the lightweight concrete. Equilibrium density is a standardized value intended to represent the approximate density of the in-place concrete when it is in service. Project specifications should indicate the required equilibrium density of the lightweight concrete. Equilibrium density is defined in ASTM C 567, and can be calculated from the concrete mixture proportions. Field acceptance is based on measured density of fresh concrete in accordance with ASTM C 138. Equilibrium density will be approximately 3 to 8 lb/ ft^3 (50 to 130 kg/m^3) less than the fresh density and a correlation should be agreed upon prior to delivery of concrete. The tolerance for acceptance on fresh density is typically ±3 lb/ ft^3 (±50 kg/m^3) from the target value.

Lightweight aggregates must comply with the requirements of ASTM Specification C 330. Due to the cellular nature of lightweight aggregate particles absorption typically is in the range of 5% to 20% by weight of dry aggregate. Lightweight aggregates generally require wetting prior to use to achieve a high degree of saturation. Some concrete producers may not have the capability of prewetting lightweight aggregates in cold weather if temperature controlled storage is not available. Some lightweight aggregate suppliers furnish vacuum saturated aggregate.

With the exception of bridges and marine structures, specifications for structural lightweight concrete do not typically have a requirement for maximum water-to-cementitious materials (w/cm) ratio. The w/cm ratio of structural lightweight concrete cannot be precisely determined because of the difficulty in determining the absorption of lightweight aggregate.

Air content of structural lightweight concrete must be closely monitored and controlled to ensure that the density requirements are being achieved. Testing for air content must be according to the volumetric method, ASTM C 173, or calculated using the gravimetric method described in ASTM C 138. Virtually all lightweight concrete is air-entrained.

Finishing lightweight concrete requires proper attention to detail. Excessive amounts of water or excessive slump will cause the lightweight aggregate to segregate from the mortar. Bullfloating will generally provide an adequate finish. If the surface for an interior floor is to receive a hard troweled finish, use precautions to minimize the formation of blisters or delaminations. See CIPs 13 and 20 for discussions on blisters and delaminations, respectively.

Due to the inherent higher total moisture content of lightweight concrete it typically takes a longer time than normalweight concrete to dry to levels that might be considered adequate for application of floor covering materials.

The splitting tensile strength of lightweight concrete is used in structural design criteria. The design engineer may request the information for a particular source of lightweight aggregate prior to the design. The splitting tensile strength corresponding to the specified compressive strength is determined in laboratory evaluations. Splitting tensile strength testing is not used as a basis for field acceptance of concrete.

Ensure that the requirements of the designer relative to fire resistance or insulation properties of lightweight concrete building elements are in conformance with applicable industry standards. For a successful project, information is available from the supplier of lightweight aggregate and the ready mixed concrete producer. With proper planning, structural lightweight concrete can provide an economical solution to many engineering applications.

References

1. *Guide for Structural Lightweight Aggregate Concrete*, ACI 213R, American Concrete Institute, Farmington Hills, MI, www.concrete.org.
2. *Guide for Determining the Fire Endurance of Concrete Elements*, ACI 216R, American Concrete Institute, Farmington Hills, MI
3. ASTM C 94, C 138, C 173, C 330 and C 567, *Annual Book of ASTM Standards, Volume 04.02*, ASTM International, West Conshohocken, PA, www.astm.org.
4. *Lightweight Concrete and Aggregates*, Tom Holm, ASTM 169C, Chapter 48, ASTM International, West Conshohocken, PA
5. *Pumping Structural Lightweight Concrete*, Info Sheet #4770.1, Expanded Shale Clay and Slate Institute, Salt Lake City, Utah, www.escsi.org

Guidelines For Pumping

Lightweight concrete placements frequently employ pumps and this can be done successfully when a few precautions are considered prior to the actual placement.

1. Aggregate should be adequately pre-soaked as pressure during pumping will drive water into the aggregate pores and cause slump loss that may result in plugging of the pump line and difficulties in placement and finishing.
2. Pump lines should be as large as possible, preferably 5-inch (125-mm) diameter, with a minimum number of elbows, reducers or rubber hose sections.
3. The lowest practical pressure should be used.
4. Pump location should be such that vertical fall of the concrete is minimized.
5. Adjustments to mixture characteristics, such as slump, aggregate content and air content may be necessary to ensure adequate pumpability for the job conditions.
6. Decide on where concrete samples for acceptance tests will be taken and what implications this would have on the concrete mixture proportions and properties as delivered to the jobsite.

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