Concrete in Practice

What, why & how?

NRMCA

CIP 36 - Structural Lightweight Concrete

WHAT is Structural Lightweight Concrete

Structural lightweight concrete has an equilibrium density ranging from 90 to 120 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 specified compressive strength should be greater than 2500 psi (17.0 MPa). The concrete mixture can be proportioned with combinations of normalweight and lightweight (coarse and fine) aggregates to achieve the desired equilibrium density.

Lightweight aggregates used in structural lightweight concrete are typically expanded shale, clay or slate (ESCS) materials that have been fired in a rotary kiln to develop a porous structure. Other products include expanded blast furnace slag.

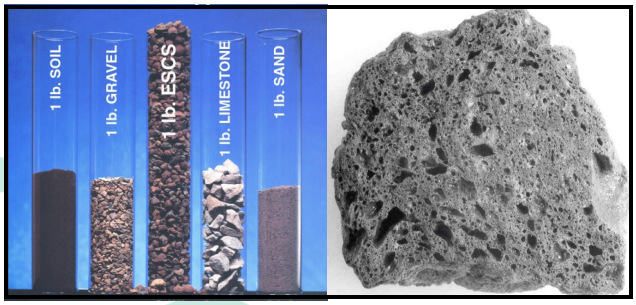
Other classes of non-structural lightweight concretes with lower density are made with other types of lightweight aggregate materials, like perlite, vermiculite, or pumice, and higher air voids in the cement paste, such as in cellular concrete. These are typically used for their insulation properties. 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 on a structure. This allows the design to reduce the size of columns, footings and load bearing members. Structural lightweight concrete achieve similar strength, mechanical and durability properties as normalweight concrete. Structural lightweight concrete provides a more efficient strength-to-weight ratio in structural members. The marginally higher cost of the lightweight concrete is offset by reduced size of structural members, thereby reducing the volume of concrete and quantity of reinforcing steel for similar structural capacity.

In buildings, structural lightweight concrete provides a concrete structure with a higher fire rating. The higher R-values in walls provides improved insulation and can result in energy savings. 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.

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 Lightweight Concrete Used

Lightweight concrete is typically manufactured with combinations of normalweight and lightweight aggregates. Using all coarse and fine lightweight aggregates in a concrete mixture can decrease the concrete density to less than 90 lb/ft^3 (1440 kg/m^3).

Structural design of lightweight concrete members relies on the *equilibrium* density; the condition in which some moisture is retained within the lightweight concrete. Equilibrium density is a standardized value that represents the approximate density of the in-place concrete when it is in service. Equilibrium density is defined in ASTM C567, and can be calculated from the mixture proportions or measured as described in the standard. The calculated value is more commonly used. Project specifications should specify the equilibrium density of the lightweight concrete. Field acceptance is based on measured density of fresh concrete in accordance with ASTM C138. A correlation between fresh and equilibrium density for a specific mixture should be agreed upon prior to delivery of concrete. Equilibrium density is approximately 3 to 8 lb/ft^3 (50 to 130 kg/m^3) less than the fresh density. The tolerance for acceptance on fresh density is typically ±4 lb/ft^3 (±65 kg/m^3) from the target value.

Lightweight aggregates should comply with ASTM Specification C330. Due to the cellular nature of lightweight aggregate particles, absorption is in the range of 6% to 30% by weight of dry aggregate. Lightweight aggregates are maintained in a wet condition prior to use to achieve a high degree of saturation. This will prevent absorption by dry aggregate and result in loss of slump. 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.

The porous nature of the aggregate makes it difficult to

separate the absorbed and free moisture for lightweight aggregate so as to estimate the mixing water content in a concrete mixture. Hence, the w/cm ratio of structural lightweight concrete cannot be precisely determined. While a maximum w/cm requirement for durability applies for conventional concrete, ACI 318 and ACI 301 waives this requirement and retains the minimum specified strength for lightweight concrete. Concrete producers may still proportion lightweight concrete mixtures using relationships between w/cm and strength or durability.

Lightweight concrete is typically air-entrained to achieve lower density. Air content of structural lightweight concrete must be closely controlled to ensure that the required density is being achieved. Testing for air content must be according to the volumetric method, ASTM C173. Underwriter Laboratory (UL) fire rating for most of the D9xx series requires air content to be in the range of 4 to 7%.

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 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. Requiring non-air entrained concrete because of finish requirements can result in non-compliance with specified density and impacts the fire rating of an assembly or the dead load assumptions used in design.

Moisture emission from concrete slabs and drying time to acceptable moisture levels for installation of floor coverings is sometimes an issue. With similar slab thickness, lightweight concrete has a higher total moisture content than does normalweight concrete. When comparing equivalent fire-rated floor assemblies studies have shown that drying time for lightweight concrete can be similar to that of normalweight concrete or can take longer by about two to three weeks. Admixtures and supplementary cementitious materials have been used to shorten the drying period of concrete slabs when necessary.

A modification factor (λ) is used in design of lightweight concrete members to reflect the lower tensile-to-compressive strength ratio compared to normalweight concrete. The factor varies between 0.75 and 1 depending lightweight aggregate content or equilibrium density. In some cases the designer may request tests of splitting tension and compressive strength to determine a mixture-specific λ-factor. Splitting tensile strength testing is not used as a basis for field acceptance of lightweight 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. ASTM Standards, *Annual Book of Standards*, Vol. 04.02, ASTM International, West Conshohocken, PA, www.astm.org
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3. *Lightweight Concrete and Aggregates*, T.A. Holm and J.P. Ries, ASTM 169D, Chapter 46, ASTM International, West Conshohocken, PA, www.astm.org
4. *Guide for Determining the Fire Endurance of Concrete Elements,* ACI 216R, ACI, Farmington Hills, MI, www.concrete.org.
5. *Pumping Structural Lightweight Concrete,* Pub #4770.1, Expanded Shale Clay and Slate Institute, www.escsi.org
6. *Finishing Lightweight Concrete Floors*, Pub #4640, Expanded Shale Clay and Slate Institute, www.escsi.org
7. *ESCSI Reference Manual for Properties and Applications of Expanded Shale, Clay and Slate Lightweight Aggregate*, Expanded Shale Clay and Slate Institute, 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 free-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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