

Batching, Mixing, and Job Control of Lightweight Concrete

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This report covers many of the practical aspects of batching of lightweight aggregate concrete and includes comments on mixing and job controls. Procedures for batching are covered in detail, enabling the user to achieve proper yield under varying conditions of moisture and unit weight of aggregates. Absorbed water and free water are explained. Pertinent details of mixer operation and job controls are also covered to assure a quality product meeting applicable job specifications.

Keywords: absorption; aggregates; air entrainment; batching; bulk density; coarse aggregates; density (mass/volume); fine aggregates; lightweight aggregate concretes; lightweight aggregates; mixers; mixing; mix proportioning; moisture content; quality control; saturation; slump tests; voids; water; weight measurement; wetting.

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Measuring, mixing, transporting, and placing operations for lightweight concrete are similar to comparable procedures for normal weight concrete. However, there are certain differences, especially in proportioning and batching procedures, that should be considered to produce a finished product of the highest quality. The weight and absorptive properties of lightweight aggregates are different and should be properly considered. Every effort has been made to coordinate these batching methods with the basic principles set forth in ACI 211.2. Other batching methods currently being used in various locations may also be employed. This report also describes batching methods for the coarse lightweight aggregates to correct for changes in weight and moisture content to insure proper yield. It also covers batching of lightweight fine aggregates using a modification of the method used for coarse lightweight aggregates.

Quality control for plastic lightweight concrete requires special emphasis with regard to yield, aggregate measuring, and batching methods along with the control of water for slump and for aggregate absorption.

CHAPTER 2 -- MEASURING AND BATCHING**2.1 -- Free water and absorbed water**

One of the first considerations in batching lightweight concrete mixtures is a proper understanding of the water used in the mixture. The total water used per unit volume is divided into two components. One is the water absorbed by the aggregates while the other is similar to that in normal weight aggregate concrete and is classified

as free water. Free water controls the slump and, when mixed with a given quantity of cement, establishes the strength of the paste. The amount of absorbed water will vary with different lightweight materials, presoaking, and mixing times. Absorbed water does not change the volume of the aggregates or concrete because it is inside the aggregate. Most importantly, absorbed water does not affect the water-cement ratio or the slump of the concrete.

2.2 -- Absolute volumes

Lightweight concrete uses lightweight aggregate particles in place of normal weight aggregates to the extent necessary to achieve the total weight desired in the hardened concrete. The space that the aggregates occupy within the concrete is called their absolute volume. The sum of the absolute volumes of all the ingredients including air must equal the required volume of mixed concrete.

By definition, the absolute volume of a loose granular material is the net volume of solid material after removing the voids or air spaces between the particles. The absolute volume may be calculated by either of the following formulas:

$$\text{Abs. Vol. in ft}^3 = \frac{\text{Weight of loose material in lb}}{\text{Specific gravity of material} \times 62.4}$$

$$\text{Abs. Vol. in m}^3 = \frac{\text{Weight of loose material in kg}}{\text{Specific gravity of material} \times 1000}$$

2.2.1 Bulk specific gravity (specific gravity factor, dry) of coarse and fine aggregate -- The methods used to determine the bulk specific gravity of normal weight aggregates cannot be used with lightweight aggregates because of their variable absorption rates and the resulting difficulty of determining their displaced volume in water. Methods described in Appendixes A and B of ACI 211.2 for measuring the specific gravity factor (dry) and the moisture content give reliable results.

For coarse lightweight aggregate, this method consists essentially of immersing a suitably sized sample (about 1000-1500 g) for 24 ± 4 hr in water, allowing it to surface dry in air or spin drying it in a centrifuge, and then measuring its apparent specific gravity in this saturated-surface-dry (SSD) condition with either a pycnometer or by the displacement method described in ASTM C 127. Half of the SSD sample is oven dried to determine its percentage of absorption. The SSD specific gravity is then reduced by the percentage of absorption to obtain the oven dry bulk specific gravity or the specific gravity factor (dry).

For example, if the SSD specific gravity is 1.41 and the absorption is 13.6 percent, the oven dry bulk specific gravity is:

$$\frac{1.41}{1.0 + 0.136}$$

=

$$\frac{1.41}{1.136}$$

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For lightweight fine aggregate, the oven dry bulk specific gravity is determined in much the same manner as for the coarse lightweight material. However, it is difficult to visually determine the SSD condition and the spin dry procedure or ASTM C 128 may give more satisfactory results. Another procedure for determining the bulk specific gravity using all dry materials, which employs a flow cone sand testing apparatus, is described in [Reference 10](#).

2.2.2 Unit weight variations -- The unit weight of lightweight aggregate varies depending on the raw materials used and the size of the aggregate. Smaller particles usually have higher densities, specific gravities, and unit weights than larger particles. Unit weights also vary due to changes in absorption or moisture content. If the lightweight aggregates are batched without adjusting for these variations in unit weight, problems of over or under yield of the concrete can result. To prevent such problems, various field adjustments are suggested in the standard on proportioning lightweight concrete, ACI 211.2. Essentially these field adjustments consist of changing the batch weights of the lightweight aggregates, both coarse and fine, to insure that the resulting concrete produces the intended volume or yield.

The dry loose unit weight of aggregate depends on its specific gravity, on the grading, and on the shape and size of the particles. Angular shaped crushed aggregates have more voids or unfilled spaces between the aggregate particles than rounded or spherically shaped pieces. Poorly graded aggregate (i.e., all one size) generally has more voids than a uniformly graded material which has enough smaller pieces to fit into the voids between the larger particles.

Numerous routine tests of both natural and lightweight aggregates show an amazingly close correlation of the void content for specific products being produced by a given plant over a long period. If changes are made in the source of raw materials, in crushing or screening equipment, or in production methods, this could result in a different void content. With no such major changes, the variation in the void content will generally result in less than 1.0 percent change in yield of the mixture. Different sized materials from the same production facility may have a different, but also a relatively constant void content. Each production facility has its own characteristic void content value for each size aggregate being produced, and this information can usually be obtained from the source.

The absolute volume of the specific lightweight materials in a given container would be a volume of material remaining after the volume of voids has been subtracted from it. In other words, if the unfilled void space was 44 percent or 0.44, then the absolute volume would be $1.00 - 0.44 = 0.56$ or 56 percent. Every loose unit volume of lightweight aggregate in this case will add only 56 percent of that volume as net solids or absolute volume to the total volume of the concrete.

The absolute volume, or the displaced volume in the

concrete, for a given lightweight material will remain the same even though its density changes or its moisture absorption changes.

The proper usage of these basic principles makes it possible for any ready-mixed concrete producer to batch and deliver lightweight concrete at the proper slump and yield for any job.

2.3 -- Batching coarse aggregate

2.3.1 Mix proportions -- For illustration purposes, a typical lightweight concrete mixture prepared in a laboratory is shown in Table 2.3.1. This mixture was proportioned by the weight method described in ACI 211.2. The quantities per cubic yard and per cubic meter of concrete are shown separately. The specification requirements for the lightweight concrete and the properties of the lightweight coarse and fine aggregate are given as follows:

Specifications: 3000 psi (20.7 MPa) at 28 days, slump 3-4 in. (75-100 mm), air entrainment 6 ± 1 percent, air dry weight, max., 100 lb/ft³ (1602 kg/m³), wet plastic weight, max., 105 lb/ft³ (1682 kg/m³), maximum size aggregate $\frac{3}{4}$ in. (19 mm).

Aggregate properties on laboratory, samples: Lightweight coarse: Gradation meets ASTM C 330, oven-dry, loose weight = 45.5 lb/ft³ (730 kg/m³), specific gravity factor (dry) 1.40, absorption 12.6 percent. Lightweight fines: Gradation meets ASTM C 330, oven-dry, loose weight = 59.7 lb/ft³ (956 kg/m³), specific gravity factor (dry) 1.74, absorption 13.4 percent.

The quantity of lightweight aggregate is shown in [Table 2.3.1](#) on an oven-dry basis with the absorbed water shown as a separate item. In this example, the batch weights (based on the given dry, loose unit weight) are tabulated and the loose volume of the dry coarse and fine aggregates is shown. The absolute volume is calculated from these batch weights using the oven-dry specific gravity factor.

To obtain proper yield of concrete, it is necessary to maintain the same absolute volumes of lightweight aggregates in each batch of concrete by adjusting the batch weights to compensate for changes in unit weights. This may be done by making standard unit weight tests on the lightweight aggregates frequently during batching operations and adjusting the batch weights to reflect any changes that may occur in these unit weights. Although this practice is followed successfully in many areas of the country, it may be rather time consuming in a busy production facility. The alternate batching system described in this report has been developed as a faster method. Either method produces satisfactory results. The principal difference in the two systems is that the latter method uses a much larger container for measuring the unit weight -- the weighing hopper. In addition, it provides automatic yield adjustments for every single batch of lightweight concrete.

2.3.2 Calibrating the weighing hopper -- The system can be set up for virtually any batching facility that employs