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Standard Practice for Selecting Proportions for Structural Lightweight Concrete (ACI 211.2-98)

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This standard describes, with examples, two methods for proportioning and adjusting proportions of structural grade concrete containing lightweight aggregates. The weight (pycnometer) method uses a specific gravity factor determined by a displacement pycnometer test on the aggregates (Method 1). The weight method also employs the specific gravity factor to estimate the weight per yd^3 of the fresh concrete. The damp, loose volume method uses the cement content-strength relationship for the design of all lightweight and sand lightweight concrete (Method 2). Examples are given for systematic calculation of batch weights; effective displaced volumes; and adjustment to compensate for changes in aggregate moisture content; aggregate proportions; cement content; slump, air content, or both

Keywords: absorption; **adsorption**; air content; air entrainment; cement content; coarse aggregate; fine aggregate; fineness modulus; grading; lightweight aggregate; **mixture proportioning**; moisture; slump test; specific gravity factor.

ACI 211.2-98 (Repproved 2004) supersedes ACI 211.2-91 and became effective March 1, 1998.

CONTENTS

CHAPTER 1—INTRODUCTION

1.1—Purpose

The purpose of this standard is to provide generally applicable methods for selecting and adjusting mixture proportions for structural lightweight concrete. These methods are also applicable to concrete containing a combination of lightweight and normalweight aggregate.

1.2—Scope

Discussion in this standard is limited to structural grade, lightweight aggregates, and structural lightweight-aggregate concrete. Structural lightweight-aggregate concrete is defined as concrete which: (a) is made with lightweight aggregates conforming to ASTM C 330, (b) has a compressive strength in excess of 2500 psi (17.2 MPa) at 28 days of age when tested in accordance with methods stated in ASTM C 330, and (c) has an equilibrium weight not exceeding 115 lb/ft^3 (1842 kg/m^3) as determined by ASTM C 567. Concrete in which a portion of the lightweight aggregate is replaced by normalweight aggregate is within the scope of this standard. When normalweight fine aggregate is used, it should conform to the requirements of ASTM C 33. The use of pozzolanic and chemical admixtures is not covered in this standard.

CHAPTER 2—FACTORS AFFECTING PROPORTIONING OF LIGHTWEIGHT AGGREGATE CONCRETE

2.1—Aggregates (absorption and moisture content)

2.1.1 The principal factors necessitating modification of proportioning and control procedures for lightweight-aggregate concrete, compared with normalweight concrete, are the greater absorptions and the higher rates of absorption of most lightweight aggregates.

2.1.2 Damp aggregates are preferable to dry aggregates at time of mixing, as they tend to absorb less water during mixing and therefore reduce the possibility of loss of slump as the concrete is being mixed, transported, and placed. Damp aggregates have less tendency to segregate in storage. Absorbed water is accounted for in the mixture-proportioning procedure.

2.1.3 When concrete is made with lightweight aggregates that have low initial moisture contents (usually less than 8 to 10%) and relatively high rates of absorption, it may be desirable to mix the aggregates with one-half to two-thirds of the mixing water for a short period before adding cement, admixtures, and air-entraining admixture to minimize slump loss. The supplier of the particular aggregate should be consulted regarding the necessity for such predampening and for mixing procedure.

2.1.4 Concrete made with saturated lightweight aggregates may be more vulnerable to freezing and thawing than concrete made with damp or dry lightweight aggregates, unless the concrete is allowed to lose its excess moisture after curing, before such exposure, and has developed adequate strength to resist freezing.

2.1.5 When producing trial batches in the laboratory using the specific gravity method, the specific gravity of the lightweight aggregate should be determined at the moisture content anticipated before use.

2.1.6 For most concrete mixture proportions to be practical, aggregate proportions should be listed at a moisture condition readily attainable in the laboratory and in the field. In structural lightweight concrete, the main problem is accounting properly for the moisture in (absorbed), and on (adsorbed), the lightweight aggregate particles as well as for the effects of absorption for a specific application. Traditionally, concrete technologists have assumed, for aggregate moisture content correction purposes, that aggregates are in one of the four conditions at the time of use. These four conditions are shown in Fig. 2.1.

Most concrete mixture proportions are reported with aggregates in either saturated surface-dry (SSD) condition or oven-dry (OD) condition. In the field, aggregates are usually in the air-dry (AD) or wet condition. Lightweight aggregate, however, usually presents a unique situation. Most structural lightweight-aggregate concrete mixture proportions are reported in the OD condition; however, in the field they are not SSD, but in a damp or wet condition. This condition is usually achieved by sprinkling, soaking, thermal quenching, or vacuum saturation. The result is sometimes referred to as the "as-is" condition (Fig. 2.2).

Table 2.1—Comparison of fineness modulus by weight and volume for typical lightweight aggregate

Sieve size, no.	Opening, in. (mm)	Percent retained by weight	Cumulative percent retained by weight	Bulk specific gravity, SSD basis	Percent retained by volume	Cumulative percent retained by volume
4	0.187 (4.75)	0	0	—	0	0
8	0.0937 (2.38)	22	22	1.55	26	26
16	0.0469 (1.19)	24	46	1.78	25	51
30	0.0234 (0.59)	19	65	1.90	19	70
50	0.0117 (0.30)	14	79	2.01	13	83
100	0.0059 (0.15)	12	91	2.16	10	93
Pan	—	9	100	2.40	7	100

Note: Fineness modulus (by weight) = 3.03; fineness modulus (by volume) = 3.23.

The main problem for the concrete technologist is to have an easy method of using field data to convert the oven-dry laboratory trial proportions to proportions in the "as-is" moisture condition.

2.2—Aggregates (gradation)

2.2.1 Grading of the fine and coarse aggregates and the proportions used have an important effect on the concrete. A well-graded aggregate will have a continuous distribution of particle sizes, producing a minimum void content and will require a minimum amount of cement paste to fill the voids. This will result in the most economical use of cement and will provide maximum strength with minimum volume change due to drying shrinkage.

2.2.2 In general, the largest total volume of aggregate in the concrete is achieved:

(a) when the coarse aggregate is well graded from the largest to the smallest sizes;

(b) when the particle is rounded to cubical in shape; and

(c) when the surface texture is least porous.

Conversely, concrete containing coarse aggregates that tend to be angular in shape, more porous in surface texture, and possibly deficient in one or more particle sizes, will require a smaller volume of aggregates.

These same factors of grading, particle shape, and texture also affect the percentage of fine aggregate required with a minimum percentage of fine aggregate being associated with a rounded or cubical shape and smooth texture. It is common that when a well-graded, normalweight sand is used to replace lightweight fine aggregate, the proportion of coarse lightweight aggregate may be increased. The proportion of coarse aggregate should approach the maximum consistent with workability and placeability, unless tests indicated that a lesser proportion provides optimum characteristics.

In some cases, strength may be increased by reducing the nominal maximum size of the aggregate without increasing the cement content.

2.2.3 For normalweight aggregates, the bulk specific gravities of fractions retained on the different sieve sizes are nearly equal. Percentages retained on each size indicated by weight

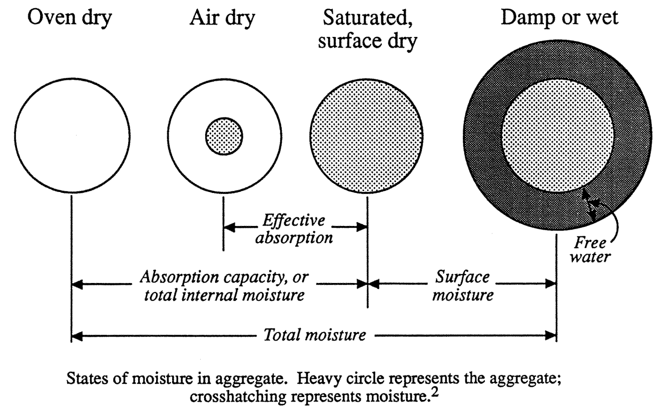

Fig. 2.1—States of moisture in aggregate.

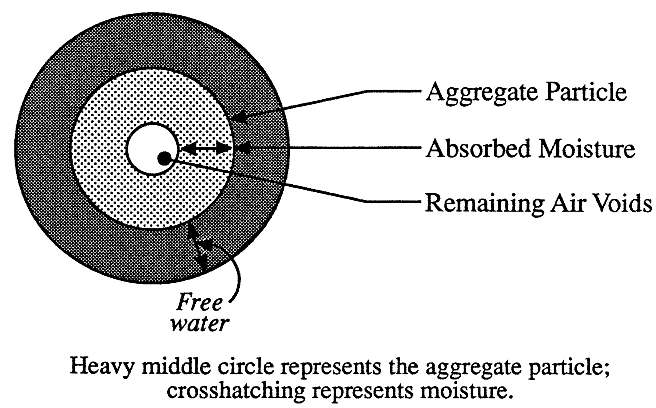

Fig. 2.2—"As-is" condition.

give a true indication of percentages by volume. The bulk specific gravity of the various size fractions of lightweight aggregate, however, usually increases as the particle size decreases. Some coarse aggregate particles may float on water, whereas material passing a No. 100 sieve (0.15 mm) may have a specific gravity approaching that of normalweight sand. It is the volume occupied by each fraction, and not the weight of material retained on each sieve, that determines the void content and paste content, and influences workability of the concrete. For a fine aggregate with a specific gravity of 1.89, the percentages retained on each sieve and fineness modulus, by weight and by volume, are computed for comparison in the example illustrated in Table 2.1.

A fineness modulus of 3.23 by volume in the example indicates a considerably coarser grading than that normally associated with the fineness modulus of 3.03 by weight. Therefore, lightweight aggregates require a larger percentage of material retained on the finer sieve sizes on a weight basis than do normalweight aggregates to provide an equal size distribution by volume.

2.2.4 As indicated in Section 1.2, concrete containing some normalweight aggregates, such as normalweight sand, is classified as lightweight concrete, provided the strength and unit weight requirements are met. The use of normalweight sand usually results in some increase in strength and modulus of elasticity. These increases, however, are made at the sacrifice of increased weight. The mixture proportions