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TechNote

Aggregate Suspension Mixture Proportioning Method

Keywords: durability; optimal grading; packing density; proportioning; shape-angularity factor; water-powder ratio; workability.

Introduction

This document describes the aggregate suspension mixture proportioning method. The method is suitable for normalweight concrete with workability ranging from zero-slump to self-consolidating. This method may not be suitable for mass concrete mixture proportioning. It is adapted from a method originally published by Koehler and Fowler (2007).

The aggregate suspension mixture proportioning method is based on the representation of concrete as a suspension of aggregates in paste and air, as depicted schematically in Fig. 1. All solid material finer than the No. 200 (75 µm) sieve is considered to be part of the powder and, subsequently, the paste.

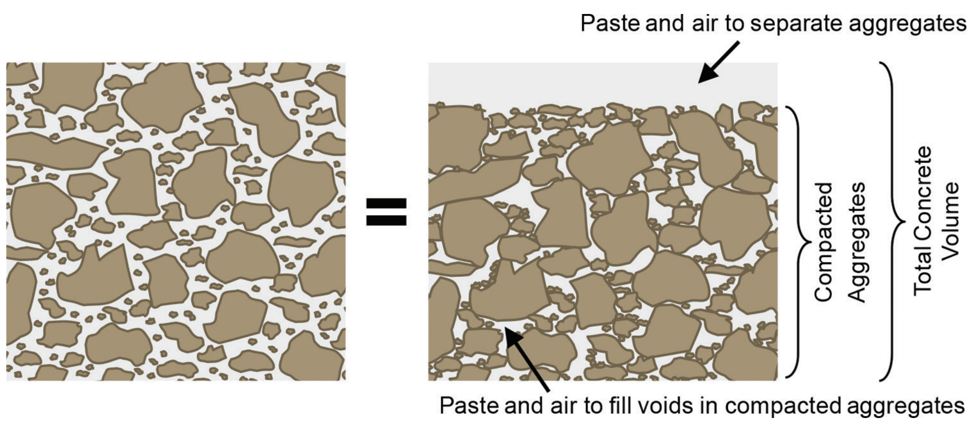

Fig. 1—Concrete as a suspension of aggregate in paste and air.

To proportion a concrete mixture, the optimal combination of aggregates for the application is selected based on grading, size, shape, angularity, and texture. Next, the total volume of paste and air required for the selected aggregates is determined. Then, the composition of paste and air—namely the relative amounts of water, each powder material, and air—is optimized to achieve the desired concrete rheology and hardened properties. Lastly, trial batches are used to make adjustments. Although this document discusses concrete rheology, measurements of rheology are not required to perform this method. Guidance on measuring rheology is available in ACI 238.1R.

Key features of the method include:

a) The aggregates are selected on a combined basis, rather than individually.

b) The volumes of aggregates and of paste and air are selected based on the properties of the combined aggregates. Aggregates with desired grading, shape, angularity, and texture for the application will typically result in less volume of paste needed.

c) All material finer than the No. 200 (75 µm) sieve is considered part of the powder content and, thus, part of the paste. This material includes fines from the aggregate and separately added fines, such as ground limestone filler.

d) The water-powder ratio (*w*/*p*) is considered when adjusting workability and the water-cementitious materials ratio (*w*/*cm*) is considered when aiming to achieve desired hardened properties. The difference between *w*/*p* and *w*/*cm* is attributable to noncementitious fines such as ground limestone filler and other mineral fillers.

Calculations should be performed in a computer application. Use of this method results in proportions based on aggregates in saturated surface-dry (SSD) condition. The user should make corrections for aggregate moisture content when making trial or production batches.

Use of this proportioning method may result in otherwise acceptable but different proportions than those determined in ACI 211.1.

Definitions

angularity—sharpness of corners and edges of a particle.

packing density—volume of solid particles divided by total bulk volume.

paste volume—volume of water and powder, excluding air.

passing ability—ease with which concrete can pass among various obstacles and narrow spacing in the formwork without blockage.

plastic viscosity—for Bingham materials, such as most concretes, the difference between shear stress and yield stress divided by shear rate.

powder—solid materials finer than approximately the No. 200 (75 μm) sieve, including cement, supplementary cementitious materials (SCMs), mineral fillers, and aggregate fines.

segregation resistance (stability)—ability of a material to maintain homogeneous distribution of its various constituents during its flow and setting.

shape—relative dimensions of a particle; common descriptors include flatness, elongation, and sphericity.

slump flow—a measure of workability of self-consolidating concrete determined by filling a slump cone with concrete, removing the slump cone, and measuring the horizontal diameter that concrete flows.

texture—roughness of a particle on a scale smaller than that used for shape and angularity.

yield stress—a critical shear stress value below which an ideal plastic or viscoplastic material behaves like a solid (that is, will not flow); once the yield stress is exceeded, a plastic material yields, whereas a viscoplastic material flows like a liquid.

Notation

$DRBD$ = dry-rodded bulk density, lb/ft^3 (kg/m^3)
m_{cement} = mass of cement, lb (kg)
m_{cm} = mass of cementitious materials, lb (kg)
m_{filler} = mass of filler, lb (kg)
m_{powder} = mass of powder, lb (kg)
m_{SCM} = mass of SCM, lb (kg)
p_i = volume of aggregate fraction *i* divided by the total aggregate volume
SG = specific gravity
SG_{cement} = specific gravity of cement
SG_{filler} = specific gravity of filler
SG_{OD} = oven-dry specific gravity
SG_{SCM} = specific gravity of supplementary cementitious material
SG_{SSD} = saturated surface-dry specific gravity
$SG_{SSD\text{-}coarse}$ = saturated surface-dry specific gravity of coarse aggregate
$SG_{SSD\text{-}fine}$ = saturated surface-dry specific gravity of fine aggregate
$SG_{SSD\text{-}intermediate}$ = saturated surface-dry specific gravity of intermediate aggregate
V_{air} = volume percentage of air, %
V_{coarse} = volume percentage of coarse aggregate, %
V_{fine} = volume percentage of fine aggregate, %
$V_{intermediate}$ = volume percentage of intermediate aggregate, %
$V_{minimum\ paste+air}$ = minimum volume percentage of paste and air, %
$V_{minimum\ spacing\ paste+air}$ = minimum volume percentage of spacing paste and air, %
V_{paste} = volume percentage of paste, %
V_{water} = volume percentage of water, %
w/c = water-cement ratio
w/cm = water-cementitious materials ratio
w/p = water-powder ratio
ρ_{water} = density of water, lb/ft^3, kg/m^3
$\%_{coarse\text{-}to\text{-}total\ aggregate}$ = coarse aggregate as a percent of total aggregate volume, %
$\%_{fine\text{-}to\text{-}total\ aggregate}$ = fine aggregate as a percent of total aggregate volume, %
$\%_{intermediate\text{-}to\text{-}total\ aggregate}$ = intermediate aggregate as a percent of total aggregate volume, %
$\%voids_{compacted\ aggregate}$ = percentage voids in compacted aggregate, %