C – 16: Fundamentals of Concrete Proportioning

Surface Area and Void Filling

For the purpose of this note, we will discuss the proportioning of a "normal weight" concrete mixture using "normal" aggregates (limestone or gravel), regular Portland cement, and purposely-entrained air.

First, why should we be concerned about "Surface Area" and "Void Filling?" The object of concrete mix proportioning is to "fill" 1 yd^3 (U.S. units) or 1 m^3 (Canadian units) with a dense mixture of concrete, designed to fulfill the requirements of the application for which it is intended.

What is "Surface Area?"
It is the surface of the aggregates that must be coated by the cement paste (cement and water).

Only by fully coating the aggregate particles will the cement be fully utilized. You can picture the surface area by imagining you are peeling each aggregate particle just like an orange, spreading the peelings out flat, and then measuring the surface area. Each peeling represents the surface area that must be coated with cement paste. It stands to reason that the smaller the surface area, the less cement it will take to do the proper job.

How do you reduce the surface area?
Use less fine aggregate in the concrete mixture. This can be done by using a well-graded coarse aggregate of the largest practical size. The larger the maximum size of a well-graded coarse aggregate, the less fine aggregate is needed in the mixture and the smaller the surface area.

What is "Void Filling?"
This is the filling of the void space between fine and coarse aggregates in the concrete mixture with cement paste. The smaller the void space between coarse aggregate particles, the less fine aggregate (sand) is required. When less sand is required, less cement paste and less cement are required.

When the sand content is reduced, typically the amount of water required is also reduced and this produces a stronger more durable concrete.

One other ingredient is the addition of purposely-entrained air in which millions of very tiny air bubbles are formed in the concrete during mixing. When the hardened concrete is exposed to below freezing temperatures while saturated with water, these tiny air bubbles provide an "escape" route for the water that expands while freezing and turning into ice.

These air bubbles are contained in the mortar portion (cement, sand and water) of the concrete mixture. As a general rule, 9% to

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10% of the **mortar fraction** should be entrained air in order to provide adequate protection against severe weathering.

How do you start proportioning a concrete mixture?

Several facts need to be known before starting.

These facts are:

1. The maximum water/cement ratio allowed;
2. The required compressive strength;
3. The required air content;
4. The sieve analysis, fineness modulus (FM), specific gravity or relative density, and the absorption of the fine aggregate;
5. The unit weight, specific gravity or relative density, absorption, sieve analysis, maximum aggregate size, and the particle shape of the coarse aggregate; and
6. The desired or specified slump range of the concrete.

Next we turn to the "bible" of concrete mix proportioning, "Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete: (ACI 211.1-91) by ACI (American Concrete Institute).

This guide provides tables for assistance in proportioning concrete mixtures once the above facts are known. There are tables in the guide for determining:

1. The approximate water demand;
2. The recommended air contents for different exposure conditions;
3. The recommended water/cement ratios for different compressive strengths and exposure conditions; and
4. The volume of coarse aggregate and the total aggregate volume of the mixture.

While these tables provide an excellent guide, there is no substitute for personal experience with a given set of concreting materials.

Once a mixture has been proportioned on paper, a trial mix should always be made to insure all the ingredients "fit" together as planned. Mix proportioning guides are based on perfectly graded aggregates with the coarse aggregate being "cubically" shaped if it is crushed and rounded if it is natural gravel.

Very seldom is a perfect aggregate found. The shape of the coarse aggregate particles can have a profound effect on the void content in a volume of coarse aggregate, especially if there are many pieces that are "flat" or "sliver" shaped. These pieces require more fine aggregate and more water to provide workable mixes.

Proportioning concrete mixtures is a combination of the use of scientifically formulated mix proportioning guides and experience with the local concreting materials used.