PROPERTIES OF FRESHLY MIXED CONCRETE AND CONCRETE TESTING

WORKABILITY OF FRESHLY MIXED CONCRETE

Freshly mixed concrete remains plastic for only a short time. Plastic concrete properties are important because they affect the quality and in-place cost of the hardened concrete. For most applications, fresh concrete should flow sluggishly without segregating. Workability is the term used to describe the relative ease or difficulty of handling, placing, and consolidating concrete.

WATER OF CONVENIENCE

More water is used in mixing concrete than is required for complete hydration. "Water of convenience," as it is sometimes called, is needed in order to make the concrete plastic and workable. If the paste is thinned with excessive water of convenience, the concrete's quality is adversely affected. For strong, durable concrete, as little water as is practical should be used.

BLEEDING

Bleeding is the movement of mix water to the surface of freshly placed concrete. It is the result of settlement of the heavier cement and aggregate particles in the mix, allowing water to rise to the surface. Generally, non-air-entrained concrete bleeds more than air-entrained concrete. Wet concrete tends to bleed more than concrete placed at a medium slump. Excessive bleeding increases the water-cement ratio at the surface. A weakened, less durable concrete surface may result, particularly if finishing operations take place while the excess water is present on the surface.

TESTING CONCRETE

Concrete is a precisely engineered and manufactured product. Several control tests and evaluations are required to obtain predictable, high-quality concrete. The construction community demands concrete that is workable, durable and in compliance with all applicable specifications. Regular monitoring of raw materials, the production process and testing of the end product are necessary to provide a quality product. Some of the important tests conducted on concrete are: *strength, temperature, slump, air content* and *unit weight.* Each test reveals important information about the material's properties, its conformance to job specifications and its ultimate performance potential.

Many companies expect their batch plant operators to become certified concrete field technicians, trained in the proper procedures for running quality control tests. Certified or not, all plant operators should understand what these tests mean and the fundamentals of the test procedures. Available training videotapes and publications can help ready mixed concrete employees learn more about quality control testing.

Common testing procedures to measure specific concrete properties include:

SAMPLING

Obtaining a proper sample of fresh concrete is the first step in concrete testing. The quality of a large volume of concrete is routinely judged on the basis of tests performed on a small sample, so the integrity of that representative sample is critical. Follow these procedures when sampling concrete:

1. When molding strength specimens (cylinders or flexural beams), the minimum sample volume must be at least one cubic foot of concrete. Smaller samples taken for air content, temperature and slump tests are permissible.
2. Do not take a sample for strength specimens from the first or last one-half yard of concrete discharged from the truck mixer. Sometimes, small samples are taken from the initial discharge for verification of air content, temperature, slump, etc. This concrete should not be used to mold strength specimens. Adjustments to the mix, e.g. the addition of water or an admixture, should not be made after a significant portion of the concrete has been discharged.
3. Sample concrete at two or more intervals during the discharge of the middle portion of the load and mix the portions together to form a composite sample.

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4. The composite sample must be obtained over an elapsed time of no more than 15 minutes. The concrete must be protected from rapid evaporation of moisture. Cover the sample with plastic or wet burlap between sampling and testing operations, if necessary due to sun, wind or extreme temperatures.
5. Take the sample by intercepting the entire flow of concrete from the truck chute with a bucket or other container, or by diverting the flow completely so that it discharges into a wheelbarrow or sample container.
6. Transport the composite sample to the testing location. Remix the concrete before starting the tests.

CONCRETE TEMPERATURE

Most project specifications call for fresh concrete temperatures to be within certain limits. Concrete for highway work and commercial construction often must be between 55° F to 90° F at the point of discharge from the truck, for example. As the concrete temperature increases, the concrete will:

1. Set faster. Extremely hot concrete tends to set very fast. Because concrete sets faster, it loses slump faster at higher temperatures. The customer may need more manpower to work faster in higher temperatures.
2. Lose air content. Unless the air-entraining admixture dosage rate is increased, the air content of hot concrete will often be lower than cooler concrete. More air-entraining admixture is usually required in the summer.
3. Have higher early strengths. Concrete that sets quickly, gains its initial strength quickly. The 28-day strengths, however, are usually lower than cool or moderate temperature concrete.
4. Require more water to obtain a given slump. If water is added to make up for the slump loss, the strength will go down.

As the concrete temperature decreases, the concrete will:

1. Set slower. Because it sets slower, it will not lose slump quickly.
2. Have lower early strengths. The 28-day strengths may be higher than normal.
3. Hold its air content much longer. Less air-entraining admixture is often required in the winter.

Follow these procedures for taking the temperature of fresh concrete:

1. Use an approved, calibrated thermometer that can read to the nearest one degree Fahrenheit.
2. Insert the stem of the thermometer into the concrete. At least three inches of concrete cover in all directions must be around the sensing end of the thermometer.
3. Read the temperature after the thermometer has been in place for at least two minutes or until the temperature reading has stabilized.
4. Record the temperature to the nearest one degree Fahrenheit.

SLUMP

The purpose of the slump test is to measure the consistency or stiffness of the fresh concrete. Slump tests do not precisely measure, but can serve as a good indicator of the water content of a batch of fresh concrete. The slump requested by the customer depends to a certain extent on where and how the concrete will be placed.

Slump is neither a direct measure of workability nor a precise indicator of the water-cement ratio. Slump is merely a universally understood means to describe the consistency of concrete mixtures.

When concrete is delivered at a specified slump, and water is added to increase the slump, the extra water has these effects on the concrete:

1. The strength of concrete goes down.
2. The mix may tend to segregate; the coarse aggregate separates from the finer material.
3. The concrete will shrink more as it hardens, increasing the likelihood of cracks.
4. A concrete slab will have less wear resistant.
5. The concrete will set more slowly, requiring more finishing time.
6. The concrete becomes less resistant to freezing and thawing.
7. The concrete becomes less watertight.
8. The air content may increase, causing a further decrease in strength.

Follow these procedures to perform the slump test:

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1. A representative sample of concrete must be obtained (See Sampling above).
2. The slump cone must be clean and damp, but not soaking wet. The cone is filled in three layers of equal volume. Each layer is compacted 25 times with a rod that is 5/8-inch in diameter and has a rounded end.
3. The concrete which spills around the base of the cone should be cleaned away.
4. The cone is slowly raised and lifted from the concrete in 3 to 7 seconds.
5. The entire operation from start to finish, should take 2 ½ minutes or less.
6. The slump is the distance that the concrete has fallen (slumped) form the original 12-inch height of the sample/cone. Slump is measured between the top of the slump cone and the mid-point of the original top of the concrete sample. Slump is measured and recorded to the nearest ¼-inch.

COMPRESSIVE STRENGTH CYLINDERS

The purpose of making strength testing cylinders is to check the strength potential of the concrete for construction project quality control. Concrete is usually purchased on the basis of its 28-day designed strength. Test cylinders molded at the job-site are then stored in a prescribed manner until they are broken in a compression machine to determine their strength. While 28-day old cylinders are usually used to determine the acceptability of the concrete, cylinders may also be molded and broken at different ages to determine when to remove forms or when a structure may be put into service. Depending on the circumstances, 3-day, 7-day or 56-day tests are also quite common. Concrete test cylinders are made by following these procedures:

1. Cylinder molds should be filled in three equal layers. Each layer of concrete is rodded 25 times using the same rod as for the slump test.
2. The sides of the mold should be tapped between each layer to close the rod holes. The tapping may be with a light mallet or the palm of your hand.
3. The concrete shall be struck off even with the top of the mold. Use the rod, a float or a trowel to level off the top or the cylinder.
4. The cylinders should be initially cured (protected from heat and cold) for 20 to 48 hours. Cover the top of each cylinder so the concrete does not dry out.
5. Cylinders used for quality assurance have special curing requirements. For up to 48 hours, the cylinders should be stored at a temperature between 60° and 80°F. Generally after one day, the cylinders are carefully transported to laboratory for subsequent curing and testing.
6. Cylinders made for estimating the in-place strength of concrete are placed next to the concrete they represent. These cylinders are given the same curing as the concrete in the structure. They should not be sent to the lab until it is time to be broken.

Air, slump, and temperature tests should accompany all cylinders tests.

AIR CONTENT

Project specifications often call for air-entrained concrete. Entrained-air greatly improves concrete's resistance to damage from freezing and thawing. An air-entraining admixture added to concrete can generate millions of microscopic air bubbles. Entrained air usually reduces the required mixing water by three or four gallons per cubic yard. Air-entrained concrete can also be easier to work with and finish than plain concrete. Entrained-air increases the yield, since the bubbles add volume to the concrete. One cubic yard of concrete must yield 27 cubic feet, so an air entrained mix generally is designed with less water and sand than a comparable non-air-entrained mix. A high air content, 9% or 10% for example, can significantly reduce concrete's compressive strength. Specifications often limit air content to 4% to 7%, or a similar range, by volume of the concrete. Because of the many factors affecting entrained air, it is important to regularly check concrete's air content. Air content can be tested by either the pressure method or the volumetric method. The pressure meter cannot be used for concrete made with lightweight aggregates. The volumetric air meter (roll-a-meter) can be used for all concrete, including lightweight. Changes in air content are also reflected by unit weight changes.

Follow these procedures to measure air content with the pressure meter:

1. Fill the pressure meter bowl the same way as for the unit weight test.
2. Strike-off the concrete with a flat bar or plate.
3. Attach the top of the meter.
4. Fill the pressure meter slowly with water.

5. Pump up the meter to the starting line. Close all the valves.
6. Release the pressure. Read the air content on the gage to the nearest 0.1%.

Follow these procedures to test for air content using the roll-a-meter:

1. Fill the roll-a-meter bowl the same way as for the unit weight test.
2. Strike-off the concrete with a flat bar or plate.
3. Attach the top of the meter.
4. Fill the pressure meter slowly with water using the funnel.
5. Remove the funnel, adjust the water to the zero mark, and attach the cap.
6. Shake the meter for at least 45 seconds.
7. Immediately tilt the meter and roll it for 60 seconds.
8. Let it stand still until the water level stops dropping. Read the water level to the nearest ¼ of 1%.
9. Repeat Steps 7 & 8 until two readings do not change by more than ¼ of 1%.
10. Remove the foam (if any) by using isopropyl alcohol.
11. Read the water level to the nearest ¼ of 1%. Add the number of cups of alcohol added in Step 10. For example, a reading of 3.5 after adding two cups of alcohol indicates an air content of 5.5%.

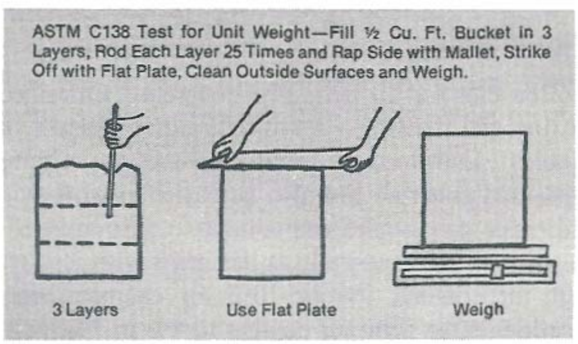
UNIT WEIGHT

The unit weight test is used to determine the mass of one cubic foot of concrete. Unit weight is measured in pounds of concrete per cubic foot, which is abbreviated: lb./cu. ft. Most normal weight concrete has a unit weight between 140 and 150 lb./cu. ft. Concrete made with *lightweight aggregates* will typically have a unit weight of 110 to 120 lb./cu. ft. The unit weight test is used to determine the *yield,* and can be used to calculate the *air content,* and *cement factor* of the concrete.

Follow these procedures to determine the unit weight of fresh concrete:

1. Use a ¼ or ½ cubic foot bucket. Record the weight of the bucket. Dampen the bucket.
2. Fill the bucket in three equal layers by volume. Each layer of concrete is rodded 25 times.
3. The sides of the bucket should be tapped with the mallet between filling each layer to close the rod holes.
4. The concrete shall be struck off even with the top of the bucket. Use a flat plate to strike off the bucket.
5. Clean the top edge and sides of the bucket. Weigh the bucket with the concrete in it.
6. Use the formulas in Figure 2-1, Table 2-1 and Figure 2-2 to calculate unit weight and yield.

UNIT WEIGHT TEST



$$\text{Unit Weight, lb./cu.ft.} = \frac{(\text{Weight of Concrete} + \text{Bucket}) - (\text{Weight of Bucket})}{\text{Bucket Volume}}$$

$$\text{EXAMPLE:}\quad \text{Unit Weight} = \frac{(89.3) - (19.0) = 70.3}{0.495\ \text{cu. ft.}} = 142.0\ \text{lb./cu.ft.}$$

Figure 2-1: Unit Weight Test

YIELD OF A BATCH IN CUBIC YARDS

The actual volume of freshly mixed concrete produced in a batch of ready mixed concrete is determined by calculating the sum of the weights of all ingredients going into the mixer, divided by the measured "unit weight" of the concrete in pounds per cubic foot. After the Unit Weight has been determined using the ASTM C138 procedure, the yield of a batch can be calculated as shown in Table 2-1.

YIELD CALCULATIONS

$$\text{Yield} = \frac{\text{Sum of weights of all materials in a batch}}{\text{Unit Weight}}$$

$$\text{Yield (cu. ft.)} = \frac{\text{Sum of batch weights in lbs.}}{\text{Unit Weight, lb./cu. ft.}}$$

$$\text{Yield (cu. yd.)} = \frac{\text{Sum of batch weights in lbs.}}{\text{(27) x Unit Weight (lb./cu. ft.)}}$$

EXAMPLES

If batch weights (lbs.) = Cement 4,140 + Total Agg. 25,460 + Batch Water 1,650 + Added Water 83 = 31,333 then:

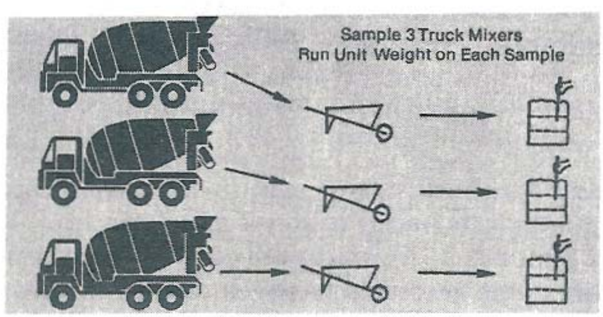
$$\text{Yield (cu. ft.)} = \frac{31{,}333}{142.0\text{ lb./cu. ft.}} = 220.1\text{ cu.ft.}$$

$$\text{Yield (cu. yd.)} = \frac{31{,}333}{(27) \text{ x } (142.0) = 3834} = 8.17\text{ cu.yd.}$$

Table 2-1: Yield Calculations and Examples

A single unit weight test provides a good spot-check for the yield of a given load of concrete. However, a thorough yield check per ASTM C 94, *Standard Specification for Ready Mixed Concrete,* requires the unit weight to be measured from three different batches of concrete of the same mix design. The average unit weight from the three tests is then used to calculate yield (See Figure 2-2). This approach minimizes the effects of variation, wherein a single, non-representative test could be used to calculate yield of concrete as delivered.

YIELD SHOULD BE DETERMINED USING UNIT WEIGHTS FROM 3 BATCHES



$$\text{Average Unit Weight} = \frac{(U1 + U2 + U3)}{3}$$

$$\text{EXAMPLE:} \quad \frac{(142.0 + 140.8 + 141.5)}{3} = 141.4\text{ lb./cu.ft.}$$

Figure 2-2: Determining Yield by Averaging 3 Unit Weight Test Results

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