As seen in the July/August 2009 edition of Concrete InFocus

# Sampling for Correct Decisions

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The failing test results came in to the concrete producer – the only ones he received on the project! The initial reaction always is: *was the testing done correctly?* Another important point to question is whether the concrete sample was obtained in accordance with standard practice.

In the concrete construction industry significant decisions and millions of dollars change hands based on results obtained from sampling and testing concrete ingredient materials or fresh or hardened concrete. A sample is a small portion of larger universe of material from which data are extracted to make a decision. These decisions can be to evaluate the acceptability of the material in accordance with a contract or to evaluate variation of the material to impact some change to the process to attempt to control this variation. The decisions made based on data extracted from samples will have significant economic implications to the parties involved, impact contractual relationships, project schedules and safety. For this reason, the person obtaining the sample should be cognizant of the purpose for which samples are obtained and follow a protocol defined in a sampling plan and

in accordance with standard practice. This is seldom the case! Sampling materials is often relegated to persons least trained and who are often not aware of the purpose of the testing or the implications of improper sampling procedures. The *convenience* of a sampling procedure almost always overrides the necessary skill and applicable expense. It is recognized that in some cases it is difficult and expensive to obtain a proper and representative sample and compromises need to be made. The reader is referred to references 1, 2 and 3 for excellent discussions and bibliographies on sampling.

A simple fact that should be recognized is that variation is a normal part of the production stream when making concrete – from the extraction and manufacture of ingredients, production of concrete and building the structure. Reference 4, based on an industry survey, outlines a rating of the variability of concrete ingredient materials and properties and then goes on to evaluate the impact on concrete performance attributes. The challenge to the concrete producer is to recognize the variation (by sampling and testing) of these ingredient materials and to manage this, within the constraints of available resources, to produce a uniform product to meet his contractual obligations. A quality system with a clearly defined sampling plan that assigns responsibilities is essential. The payback exists – some of it intangible – and should be quantified to justify this system.

The goal of obtaining a sample is to obtain an unbiased estimate of the characteristic of interest of the larger universe of the material. Often this universe is defined as a lot that could be a shipping unit, stockpile, silo, placed section of concrete or material delivered over a period of time. Variation exists with the material as a whole and also within a lot. To ensure that the sample is *representative* of the lot, every portion of the lot should have an equal chance (probability) of being selected as the sample. This is accomplished by following a random sampling procedure. Random sampling is often modified to ensure that a better representative sample is obtained – an example is obtaining a sample from the middle of a load of concrete rather than from the first or last portion of the discharge.

The purpose for the sampling often determines the procedure, frequency and size of the sample required. In some cases we want to measure the average property of a material, while in other cases we might want to evaluate the variability of a property. Statistical concepts enter the picture here. For example, if one knows from previous experience the typical variation of a material, one can determine the minimum number of samples that are needed to make a correct decision based on a statistically valid basis. The greater the variation of the material or lower the precision of the test method, the more samples and tests are needed. We seldom consider these aspects when making decisions based on sampling and testing.

The simplest type of sample is a *grab* sample. The sample is obtained in a single effort – such as one pass or one scoop. Grab samples will indicate the maximum variation of a production stream and has a high likelihood of being biased. To smooth out this variation a *composite* sample is put together by combining two or more grab samples. This tends to be more representative of the material and is more realistic in terms of estimating the property or variation of the material. Composite samples are obtained when we blend portions from different locations of an aggregate stockpile or two or more portions during the discharge of concrete from a mixer. Some key characteristics of cement might be measured on grab samples during production (for quality control), while others will be tested on the composite of several grab samples obtained during the day (for specification compliance reported on a mill test report).

## Sampling Aggregates

ASTM D75 covers sampling of aggregates. Due to the problem with segregation, the preference is to sample aggregates when it is being moved – from conveyor belts or discharge from shipping units. It is very difficult to obtain representative samples of aggregates, especially coarse aggregate, from a stationary location like stockpiles. Samples of wet sand are easier to obtain as it is less susceptible to segregation. To obtain representative samples, it is important to composite grab samples from different portions of the lot. A larger size sample is obtained in the field depending on the nominal maximum size of the aggregate and then reduced to a sample size required for testing at the lab using sample splitters or quartering procedures.

## Sampling Cementitious Materials and Admixtures

ASTM C183 covers sampling of hydraulic cement generally from acceptance testing standpoint and addresses procedures at several locations at which cement may be sampled. Some state highway agencies require modest retrofits to cement silos in ready mixed plants to sample cement used on state projects. Standards for fly ash, slag cement and silica fume also cover sampling procedures and frequency based on tonnage. Grab samples of cementitious materials obtained from shipping containers should be done with care since finer dust tends to be at the top of the container and contamination from previous shipments might remain at the bottom.

Standards for chemical admixtures, ASTM C494 and C1017 cover sampling of these materials for two purposes – acceptance testing and determining uniformity. Liquid admixtures should be agitated, or other methods used, to obtain representative samples. Grab samples are typically used to measure the uniformity within a lot.

## Sampling Fresh Concrete

ASTM C172 covers sampling freshly mixed concrete from truck or plant mixers and paving mixers. Note that ASTM C172 does not cover obtaining samples from placement devices like pumps, buckets or conveyor belts. The practice relies on composite samples (two or more portions of the uninterrupted discharge stream) and requires that these be taken from the middle of the load. This recognizes that the initial and final portion of discharge will not be representative of the load. The difficulty here is that as a matter of convenience, the initial portion of discharge is easiest to obtain; and if the properly obtained sample indicates a noncompliance, a significant portion of the concrete has already been placed. ASTM C94 allows for a preliminary sample to determine the slump and air content of concrete.

Many problems on test results of concrete can be attributed to improper sampling procedures. One example is when the contractor's personnel were directed to obtain samples from the initial discharge from truck mixers. The measured air content was low and the concrete plant was instructed to increase the air content. Ultimately, the concrete placed in the structure

was judged to have a high air content and low strength and the concrete producer was penalized for several thousand dollars.

The increasing problem is the requirement to achieve the specified fresh concrete properties at the point of placement, such as at the discharge from a pump. This situation is generally hard to resolve. The designer wants the specified characteristics of concrete in the structure but the slump and air content of concrete change depending on the placement method used. There is no standard procedure to obtain samples from placement devices. One recommended method is to obtain the sample after the concrete is discharged into the structure, because any attempt to control the discharge into a sampling container will result in a non-representative sample. A clarification being proposed in the commentary of ACI 318, *Building Code for Structural Concrete*, is to indicate that the specified air content is intended to be measured at the discharge from the truck mixer and not at the point of placement for both fresh and hardened concrete.

## Sampling Hardened Concrete

Hardened concrete is sampled for acceptance of a structure or to evaluate problems by referee testing. ASTM C823 covers sampling hardened concrete from structures. It is important to obtain several samples of hardened concrete from a structure and determine the average result – similar to the concept of composite samples. State highway agencies obtain cores from pavement lots to determine payment to the contractor when performance-related specifications are invoked. Cores from pavements should be taken from random locations within the lot. Edges or joints should be avoided. Cores are taken from concrete structures when standard strength tests fail the acceptance criteria. These cores should also be obtained with care – cores should not contain reinforcing steel; cores from the top of a wall will have a lower measured strength, etc.

## Sampling for Determination of Uniformity

Evaluating the variation of materials from a single source is an important aspect of controlling the variation of concrete. The variation of the predominant cement from a cement manufacturer is determined by the manufacturer by obtaining grab samples of cement from the shipment container at set frequencies and measuring the strength. ASTM C917 defines this practice and reports on uniformity of cement from a single source are available from the cement manufacturer. This better represents the variation of cement received by the concrete producer compared to a mill test report. ASTM C1451 is a similar standard applicable to other concrete ingredient materials.

ASTM C94 addresses sampling to evaluate the uniformity within a batch of concrete. The intent is to evaluate whether batching sequence or condition of the mixer impacts the homogeneity of concrete within a mixed load. In this case two samples are taken from distinct locations near the beginning and end of the discharge. ■

## Summary

As discussed briefly in this article, obtaining samples of concrete or concrete-making materials is not trivial. Improper sampling and data generated will impact decisions that have economic and other significance in concrete construction. Sampling protocols will vary depending on the purpose of the tests and their interpretation. Ultimately, the risk to the seller of getting acceptable product rejected and to the buyer of accepting unacceptable product should be minimized by proper sampling and testing.

## References


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