HAHN READY MIX

Variability & Specification Tolerances

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What does Variability mean in concrete?

The first thing that is often misunderstood amongst the lay population is that concrete is a composite material and NOT manufactured like a machine part. Small changes in the ingredient materials can have effects on the concrete slump, air content, temperature, color, set time, bleed rates, and eventually strength. Because of this, concrete is designed and accepted to perform within a range... for example, a mix may be designed with a target air content of 6%, but is acceptable within 4.5-7.5%. Specifications, when properly instituted, are intended to allow for normal variability while limiting more substantial fluctuation that can impact concrete performance.

What kind of things cause variability in concrete loads?

Every ingredient in a concrete mix and the conditions the concrete are subjected to can affect the mix as a whole. We'll go through the list of common concrete constituents and what variability might exist in those materials.

Cement is a manufactured product that is closely monitored down to an elemental level to be homogenous and consistent. While there can be differences in cement temperature, it is very rare that cement moves directly to loadout from the mill while still excessively hot. Typically, cement spends some period in storage or transit where temperatures can cool and normalize load to load. Cement manufacturers do sometimes change additives or grinding aids that can affect concrete properties, but this affect is more like turning on a light switch than variability batch to batch.

SCMs like fly ash and slag are byproducts and thus can be subject to more variability. We don't see much change in slag, but fly ash can be highly variable depending on the source. If a coal-burning power plant gets coal with different chemistry or has any kind of variability in burn or ash collection, it can have a major effect on concrete set times, strengths, and air contents. One thing of particular concern is small changes in the carbon content, also known as Loss on Ignition (LOI), of fly ash can have significant changes in the necessary dosage of air entraining agents. This happens because carbon interrupts the bubble stabilization happening in the initial mix of the concrete. Higher LOI means you need more AEA to achieve the same air. Luckily for us, our two major fly ash sources are very consistent and we don't see load to load differential in LOI. Sometimes however, fly ash comes from a storage facility and may be six months to a year older than current ash. In this situation, tiny cumulative LOI changes could show up all at once.

Aggregates such as rock or sand are highly variable load to load. If you ran a gradation on every load of rock, it would be a little different every time. Similarly, moisture changes throughout the day and throughout a pile. Aggregates can have variable particle shape, absorption, and even specific gravity. All of these characteristics affect concrete, but moisture changes are the biggest culprit for slump variability. Aggregates can also be variable in temperature, particularly in the winter when some aggregate may be in a protected plant overnight and other aggregate is sitting outside.

Water is pretty consistent with the exception of temperature. Water chillers and heaters can impact concrete temperature and performance.

Beyond the materials, other factors can affect concrete variability. Ambient temperatures influence concrete temperature which can influence air contents, slump and set times. Air builds best around 50° F, concrete sets twice as fast with every 20° F increase in concrete temperature, and of course concrete will lose slump faster if it is warm. Drum speed in transit can have a big effect on air content, slump retention and temperature. This can easily be variable load to load. Load size can make a difference, as the mixing dynamics of a partial load are very different from a full load.

What do we do to minimize this variability?

Ready mix producers spend a substantial amount of time attempting to mitigate the potential for variability. The best way to do this is test, test, test. More specifically, we test daily for aggregate moistures and calibrate sand probes that capture real-time moisture of sand going into the load. Our loader operators are careful not to dig into the bottom of an aggregate pile where moistures might be higher. We test for concrete temperatures and make temperature adjustments when necessary to provide as much temperature consistency as we can. We also utilize on-demand water heaters at most of our plants that can hold a constant temperature much better than water tanks. We test air contents often to make sure that seasonal temperatures or other factors have not changed our necessary air dosage. Our drivers are expected to do a visual examination of the slump of every load to help with slump consistency. At our wet batch plants, the batcher can keep record of the amperage pulling from the motors spinning the drum. A similar mix design with the same size load will read a consistent amperage if the slump is the same.

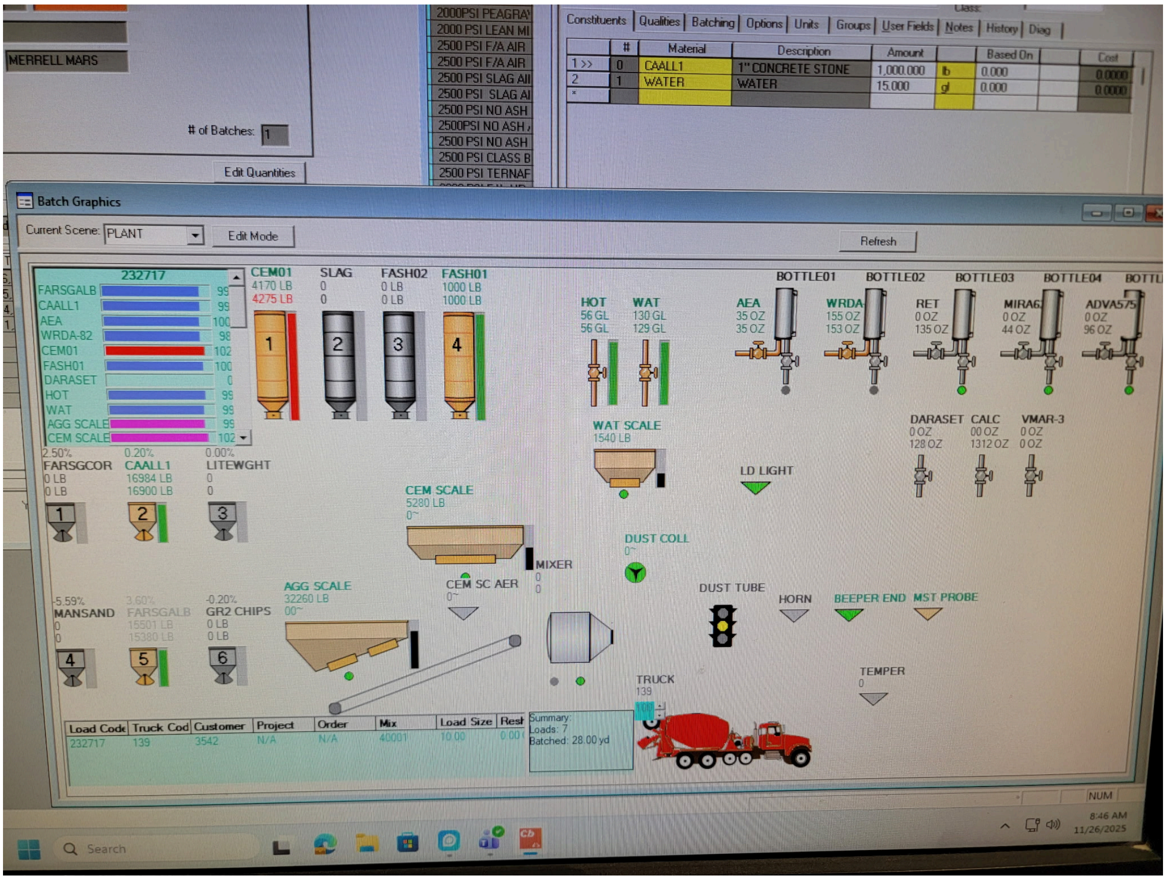
Batch Tolerances

Another source of some level of variability is batch tolerances. Essentially, when each of the constituent materials in a concrete load are weighed up, the percentage difference from the target weight must be within a set margin of error. It is possible to get nearly exact batch weights that match target weights, but to do so would completely obliterate any kind of batch speed or efficiency. Thus, batch targets are set up where the tolerance can allow the focus to be on mix performance and batching speed. Most of these tolerances are established by ASTM C94 Section 11.

Cementitious Materials +/- 1%
Water +/- 1%
Admixtures +/- 3%
Aggregates +/- 2%

For example, a load of concrete may require 5640 lbs of cement. An acceptable tolerance range for this batch would be 5584-5696lbs. Often with cementitious materials, this margin of error is much tighter than the 1%. Admixtures are the one constituent that might be commonly seen to be out of tolerance on the batch ticket. This is because dosages are sometimes so low, that even a small over- or under-dose is outside 3%. For example, if a mix calls for 1oz/cy of AEA for a 2 yard load, if the air weighs up 2.25oz, that's technically a 12.5% deviation. In this case, the extra air is unlikely to be problematic.

One particular thing to note, most ready mix plants are optimized for full loads. Small loads, particularly under 3cy, are more often out of tolerance. This is why all trial batches we perform are at least 3 cy.



Specification Tolerances

We have established many of the sources of variability in concrete loads, and in large part, that is why specifications have ranges of acceptability. When a mix design is created or submitted it often has a target slump, air content, and water/cement ratio. On the jobsite, the range of acceptability should be *at least* +/- 1.5% for air content and +/- 1.5" for slump. In an ideal world, the target slump of a mix design should be at the center point of the specification range. Unfortunately, often a specification will provide a slump range of something like 2-4" slump on site. First of all, such a specification is not compliant with ASTM C94 as it is a 2" range and not 3". Beyond that, the contractor will likely ask for a design that is at the maximum allowed slump. If thoroughly enforced on site, this leaves very little room for natural variability load to load and can result in needless rejected loads.

KINDS OF CONSTRUCTION	MAX. SLUMP	MIN. SLUMP
Reinforced footings	3 in.	1 in.
Plain footings, caissons, substructure walls	3 in.	1 in.
Slabs, beams, reinforced walls	4 in.	1 in.
Building columns	4 in.	1 in.

Project specifications for temperatures and water cement ratios can be restrictive, but tend to have a minimum or maximum rather than a narrow range. While we don't often run into this issue, concrete strength specifications also provide a tolerance of acceptability. According to ASTM C94, concrete meets strength if every running average of three tests (each test an average of two cylinder breaks) meets or exceeds the required strength as specified, as long as no single test is more than 500psi below requirements. It works like this: for a 4000psi specification, breaks of 4200, 3900, and 4100 would average 4067psi and would be compliant. If, however, the breaks were 4650, 3450, and 4100, the average strength is exactly the same but the 3450psi break would mean that it fails acceptance criteria.

Water Addition

Recently, we have seen more projects with a restrictive slump specification, contractor desire to pour with the maximum allowable slump, and a prohibition where no water is allowed to be added on site. This combination is contrary to established standards and lacks an understanding of the natural variability in concrete production and delivery. ASTM C94 states that a single retempering on site is allowed as long as the maximum water-cement ratio is not exceeded, the concrete is not over 90 minutes old, the maximum slump is not exceeded, and the concrete is mixed for 30 revolutions after water addition. If you run into this situation, it's a good idea to call a meeting between the engineer, general contractor, concrete contractor, testing lab, and ready mix producer prior to any critical pours. Hopefully such a meeting can find common ground on a reasonable solution that allows for placement and performance to be prioritized.

Tech Bulletin Update

This is the final monthly Tech Bulletin, as we are struggling to come up with enough topics to keep this cadence. We'll publish new Tech Bulletins when there are new or exciting changes in the industry or new topics arise that we feel we should cover. If you have any topic ideas, please send them our way!

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