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What Slump is It?

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The infamous slump test is a time-honored ritual in concrete technology, performed by those who have been anointed, ordained and certified to do so. Like many sacred rites, its origins are shrouded in the mists of time. But, back at the dawn of the age of concrete, before there was fly ash, slag, silica fume, air entraining admixtures, and multiple flavors of plasticizers and water-reducing admixtures, for a fixed set of dry ingredients, slump was primarily dependent on the amount of free water in the mixture. Even in the current "Age of admixtures," we know that, regardless of other ingredients, adding water to concrete will increase slump. For a specific mix that is already at a particular slump, we might even be able to predict that adding something like 1 gallon of water per cubic yard can increase the slump by about an inch *(1)*.

But this handy, approximate rule of thumb does not allow us to say with any confidence that if we know the slump we therefore know the water content. The reality is that if we measure the slump, the only thing we really know at that point is the slump. Water content, w/c, w/cm, strength, air, shrinkage, pump-ability, response to the vibrator and slip forms, and finish-ability remain in the realm of conjecture. And not only conjecture, but a "pumpable" slump can depend on the pump and line, and one worker's "finish-able" slump is another finisher's candidate for water addition. In the absence of water-reducers, air and viscosity modifiers, knowing the slump might enable us to predict a mixture's vulnerability to segregation when placed. At slumps over 5 inches, we might worry about dropping mixtures from significant heights (about 5 feet) using only water that has not been diluted by admixtures, although 7-inch slump water-only mixes have been dropped successfully into drilled shafts. With the right combination of admixtures and combined aggregate grading, concrete with slumps over 9 inches have been dropped into deep walls and columns without segregation. With the dawn of using self consolidating concrete, the concept of slump has now evolved to slump flow or spread and the traditional slump test has less relevance.

So if slump does not tell us the water content or related properties, and is not a general indicator of risk of segregation, is there anything that slump can always be counted on to tell us?

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The slump test

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State highway engineers at the annual National Highway Institute course line up to test concrete

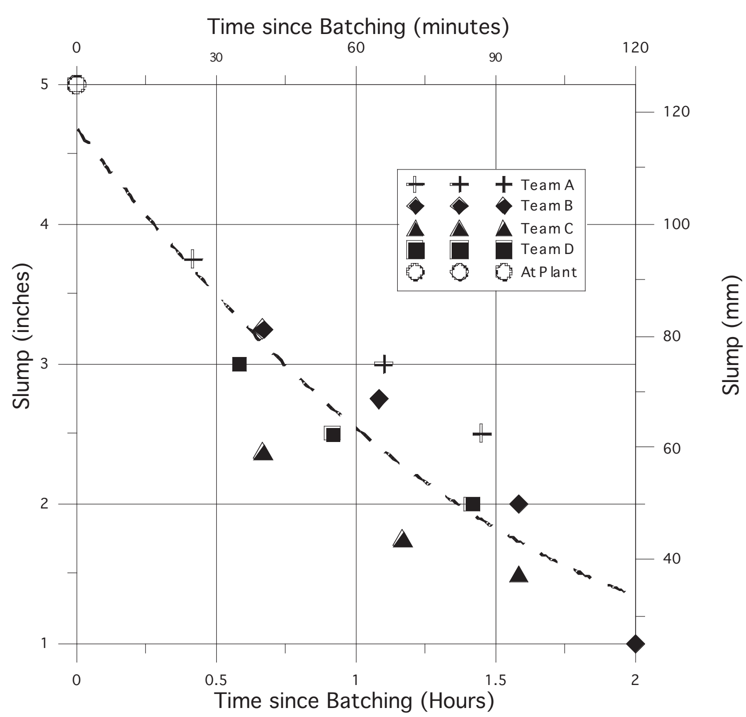
1. Content, proportions, chemistry, fineness, particle size distribution, moisture content and temperature of cementitious materials;
2. Content, proportions, size, texture, combined grading, cleanliness and moisture content of the aggregates;
3. Dosage, type, combination, interaction, sequence of addition, effectiveness of chemical admixtures;
4. Air content;
5. Batching, mixing and delivery methods and equipment;
6. Temperature of the concrete;
7. Sampling, slump-testing technique and the condition of test equipment;
8. The amount of free water in the concrete; and
9. Time since batching at the time of testing.

If the slump test worries you, the bad news is the same as the good news: slump is influenced by everything! But this can be used to your advantage. If slump is truly sensitive to this host of factors, then we might conclude that if measured slump does not change significantly from batch to batch or load to load, then NONE of these factors are changing significantly (or that compensating errors are at work). When slump results are consistent over multiple loads, we really don't know much about the concrete itself; but whatever it is, it is staying pretty much the same *(2).*

When you think about it, the slump test is small-scale soil test: filling a slump cone is like placing a granular, cohesive soil behind a sheet-pile retaining wall. After the soil is compacted in a standard manner, the retaining wall is quickly removed, and the severity of the resulting landslide is determined by measuring how far the top of the compacted fill dropped. One important difference with concrete is that the longer you allow the concrete to continue to mix before you compact it into the cone, the stiffer it will be and the less it will "slump" when the cone is removed. Likewise, the longer you wait between filling and removing the cone, the lower the slump. This simple observation reveals a great truth: sooner or later, all concrete mixtures will reach zero slump *(3),* with the exceptions of mixtures that have been accidentally overdosed with retarder, or when somebody forgot the cement. This is natural consequence of cement doing what we pay a current average of price of about $100.00 per ton to do—it reacts with water and this "hydration" binds the particles together. Slump-loss is a consequence of water reacting with cement, not the result of water evaporating from the fresh concrete.

Every year since 1989, the author has been conducting a "Test-a-thon" in which 20 to 30 highway engineers are asked to evaluate multiple properties of fresh and hardened concrete, and each year all samples are made from a single ready mixed concrete truck carrying 4 cubic yards of concrete. In addition to recording slump, the engineers test fresh concrete temperature, air by pressure and volume meters, fresh density, as well as perform a number of standard and in-place hardened concrete tests. Slump results from one of these sessions are shown in the figure below.

The four sets of symbols indicate that 4 "slump-teams" independently sampled and tested the concrete, with 14 separate measurements. The dark, vertical line at 90 minutes indicates the ASTM C-94 time limit, suggesting that any single slump value plotted to the left of that line could legitimately have been the one single test value recorded for this truckload—a range from about 1-3/4 to 3-3/4 inches, for an average of about 2-3/4 ±1-inch. While this typical 1-inch tolerance sounds about right, keep in mind that this is not a day-to-day, batch-to-batch, or truck-to-truck variation. This is a ±1-inch variability around the average slump for one single load. While not all participants were certified, certified examiners were present



with each team spotting and correcting errors, and even with this oversight Teams A and C consistently reported the highest and lowest slumps, respectively, at any given time, with usually more than 1-inch difference from team-to-team.

But in addition to providing data on variability of the test itself, the results show the clear influence of time since batching. For this particular mixture (611 lb cementitious per CY, average concrete temperature 75°F, continuously agitated), the concrete lost an average of 2 inches of slump per hour. (More like an average of 1.5 inches per hour after arrival on-site.) We can also see that since the official "slump" of this concrete could be reported as anywhere between 1-3/4 and 3-3/4 inches, its hard to characterize this mix by slump alone. The slump loss rate of 1-1/2 to 2 inches per hour may be a more useful identifying characteristic of this particular mixture.

But consider what happens if we try to use slump as a measure of uniformity of the material. Let's say someone was reviewing all 14 separate test results on individual test reports indicated in the figure and did not realize that they had all been taken from one single load. Let's add the condition that just like in the real world, the time at which the tests were actually performed, relative to batch time of the concrete, had not been recorded. The person reviewing the results might conclude that the concrete was non-uniform, and might therefore demand better control of materials, moisture contents and mixing! We can only prevent such a misdiagnosis of the situation by recognizing that slump changes with time! Perhaps one of the most effective, high-tech accessories for improving the precision of slump testing is a wristwatch. ■

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Notes:

(1) This rule of thumb is about right if you have a 1-inch coarse aggregate and the concrete is already at a 4-inch slump at the time of water addition and no extra water reducer or air entraining admixture is floating around. If you have a 3/4 inch coarse aggregate mix at 2-inch slump, it will take about two gallons per yard to nudge the slump up by an inch. If you have air-entrained concrete at 70°F, it will take less, and if you have 90°F concrete at 1-inch slump, there may not be enough water in the water tank to get a good slump.

(2) When slump results are too consistent, such as six trucks in a row at exactly 4.0-inch slump, we might want to find out if testing is real or virtual.

(3) Zero slump does not mean the concrete has necessarily reached initial setting; it just means that the concrete is at the limit of the measuring capacity of the slump test. Initial set usually occurs some time after the concrete has just reached zero slump.