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Controlling water in self compacting concrete production

With the growing popularity of specialist concretes such as self-compacting concrete (SCC), the requirements for information about the raw materials has increased considerably for manufacturers. The processes used to produce these concretes have also had to be considered to ensure they allow the correct proportioning, mixing and placing at the plant or on site. It is now clear to most concrete producers that the need for adequate quality control is much more critical with SCC than in the case of conventional concretes. Further, the production of SCC's requires greater competence from those involved as well as good control of materials and equipments used for production.

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The importance of water

The control of the water content in the production of any concrete is essential but as will be looked at in this article, it is even more crucial in SCC production. Its direct effect is measurable in terms of strength, fresh properties and durability. These effects can be broken down into all the main characteristics of concretes including strength, workability or flowability, rheology, stability and durability.

Sources of water variation

Water content changes can originate from different parts of the concrete production process with differing effects:

- natural moisture content variation in aggregates
- accuracy of water feeding system into the concrete mixer, although this is not usually an issue in modern concrete plants
- uncovered material transport or storage systems allow increments of water content by rainfall or their reduction by evaporation

Clearly the most significant source of moisture variation is the natural aggregate moisture content.

The effect of water variation

Variation of water affects the production of concrete in many ways. For a greater understanding of these effects it is helpful to consider the influence on the individual constituents and the concrete properties that are affected by it. Moisture will have an effect on:

Dry aggregate weights

A variation of 1 % moisture content in a dry aggregate by weight results in a change of 10 Kg of aggregate loaded into the mixer for every 1000 Kg of dry aggregate weighed. Therefore the greater the variation in moisture, and the greater the weight of aggregate used, the more serious this condition becomes.

Table 1 - Typical moisture ranges for concrete aggregates

Size	Moisture % Range
Fine Sand	0 to 16
Coarse Sand	0 to 12
8 mm	0 to 10
10 mm	0 to 4
12 mm	0 to 3
20 mm	0 to 2

As can be seen from Table 1 above, the range of moistures which different size aggregates can 'hold' as free water, increases with the fineness of the aggregate. This occurs due to the increased aggregate surface area by weight. Due to proportionally high use of fine aggregates in the production of SCCs (usually 48-55% of total aggregate weight), the potential effects of moisture variation increases in relation to ordinary concretes.

The volume of water dispensed into the mixer

Associated to the effect of changing dry weights of aggregates, the volume of water fed into the mix will change with aggregate moisture variations. Assuming a density of 2400 Kg/m³, a 1% change will result in 24 litres of water change, which will have considerable effects on a SCCs performance.

Concrete strength

Variations in water contents by weight will directly lead to changes in the w/c ratio or

w/b (water/binder ratio) of the concrete being produced. This in turn will usually affect the compressive and tensile strengths of the concrete.

Concrete durability, cracking and creep

Creep is related to a concrete mix w/c ratio and therefore moisture can be indirectly detrimental to durability. Autogenous shrinkage may also occur from varying water contents as it is caused by the internal consumption of water during hydration.

Issues associated with a SCCs stability (see below) may also affect the finished surface's permeability having an effect on durability.

Consistence

Changes in water content affect the flowability of an SCC in various ways. The free water content itself will directly affect the flowability of the concrete, but there are other indirect effects. One of these indirect effects of water on flowability is the change in aggregate grading (see effects of dry aggregates above). A change in aggregate grading will lead to a change in the flowability characteristics of a concrete. The relationship between fine aggregate and the total weight of aggregate (S/A) has also been found to have a significant effect.

Another indirect effect is also caused by the change in dry aggregate grading variations but relates to the aggregate surface area changes and how these interact with the high-range water reducers used.

The use of viscosity modifying agents has mitigated to some extent the issues occurring from moisture variations. Even so, a major concrete admixture chemicals producer reported typical 'safety margins' of 15 litres of water when producing SS3 concretes and 7-10 litres of water when producing SCC concretes in precast plants.

Mix stability

Maintaining the proportions envisaged and tested in the mix design is important to avoid

bleeding, segregation and plastic settlement. Tight water control would help control the occurrence of these issues.

Cost benefit of moisture measurement

As well as improvements in quality, the use of moisture control also allows improved profitability for a concrete production operation. By avoiding over- or under-cementing the concrete producer will reduce cement costs and increase production yield. Although more difficult to quantify than the over-cementing, the resulting reduced number of sub-standard batches from moisture control also increases profitability. The improvement is such that the general consensus from Hydronix customers is that the equipment's return on investment period is of between 3 to 6 months.

Options for moisture measurement in concrete production

Hydronix is the world's market leader for microwave moisture measurement instrumentation. Supplying moisture measurement solutions for both aggregates and fresh concrete during mixing, Hydronix products measure 25 times per second digitally offering market-leading accuracy and speed of response.

The microwave technique has emerged as the most suitable for measurement of moisture in concrete production, mainly due to its accuracy (usually in the range of $\pm 0.2\%$ to $\pm 0.4\%$ depending on the quality of the calibration), its lack of influence by dust or colour, and the competitive cost-benefit relationship of this type of equipment.

Measuring moisture in aggregate bins, hoppers and conveyor belts

Aggregate moisture measurement is usually carried out using a Hydro-Probe II sensor near the gate of the aggregate hopper in question. Once the Hydronix sensor has been set up correctly, moisture readings can be taken as an average for each batch, and the plant's control system can adjust the correct dry weight of each aggregate in real time.

Digital microwave sensors may also be placed on a feeder belt under the hopper as shown below in Figure 3.

Measuring moisture in mixers

Measuring the moisture of fresh concrete in a mixer allows the concrete producer to have full control over the final moisture content before the mix is discharged. This ensures that variations due to aggregate wetting/drying during transport from the hopper to the mixer, or variable water pressure, are dealt with in real time. The digital microwave technique is used by Hydronix for their mixer sensors as well. The measurements from the Hydro-Mix sensor for mixer floors or from the in-mix Orbiter sensor are used to calculate the correct volume of water addition required to achieve constant total water contents of the mixed concrete, batch after batch.

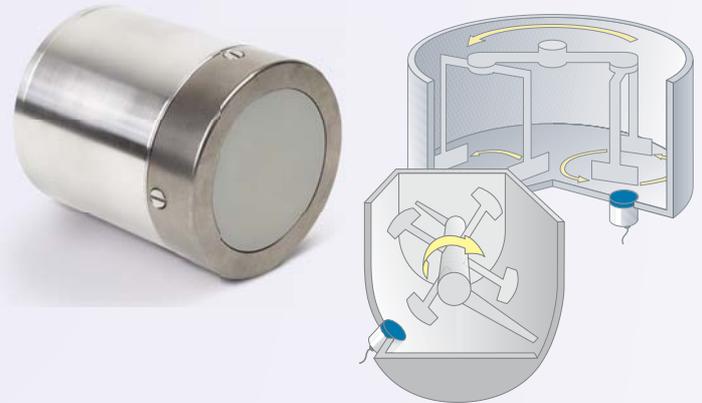


Figure 1: Typical moisture sensor

Moisture Measurement Systems for Mixers

New from Hydronix

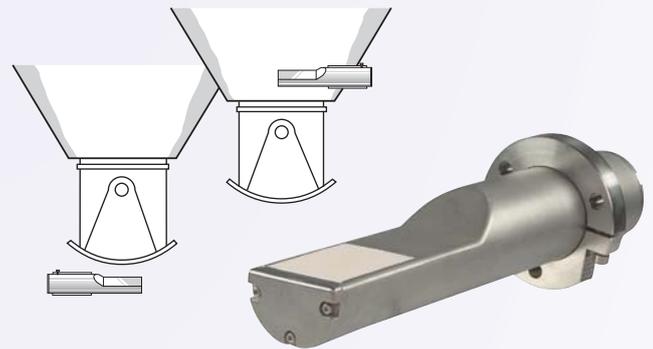
The Hydro-Mix VII



The most popular digital moisture sensor for mixers has been improved to include:

- Advanced Digital Signal Processing
- Choice of Measurement Modes
- Redesigned Ceramic Faceplate
- 2 Analogue Outputs

Moisture Measurement for Aggregate Bins



The Hydro-Probe II is the World's most robust, cost effective and versatile sensor available for moisture measurement in concrete, asphalt and aggregates.

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Figure 2: Sensor installed under a bin

Hydronix mixer sensors now offer 3 measurement modes, making them unique in the market. The choice of measurement mode is especially important in the production of SCC where fresh concrete densities vary greatly with the addition of the superplasticisers in the mixer. The new measurement modes offered by Hydronix sensors are ground-breaking improvements which offer new options in measuring moisture accurately in the production of these concretes.



Figure 4: Hydro-Mix sensor



Figure 3: Typical installation positions for a Hydro-Probe II

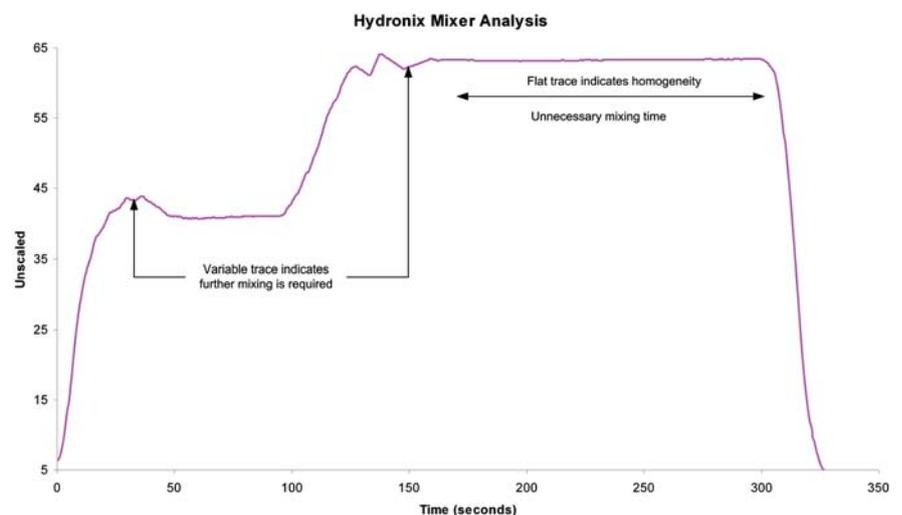


Figure 5: A typical mix cycle as seen by a Hydronix mixer sensor (Hydronix data)

Homogeneity control using moisture

Using moisture as an indicator of the degree of homogeneity achieved by the concrete mixer at any stage of mixing is also possible using microwave mixer sensors. To do this, moisture is in effect used as an indicator of material dispersion. Therefore when materials are loaded onto the mixer the sensors 'see' variable moisture contents over time as usually aggregates will be wet and cementitious materials will be dry. As these materials mix with the added water and admixtures, gradually a flatter trace is achieved as the water disperses evenly over the entire mix. A flat trace output from the mixer sensor indicates that homogeneity has been reached (see Figure 5). Using homogeneity control also allows the optimization of mix cycles. Once the producer can evaluate whether the mix is homogenous or not, he can then adjust the mixing time to ensure that only the time required to homogenize the mix is used. This in turn has large benefits in terms of reduced power consumption, reduced wear of parts, and increased production output.

Conclusion

The requirement for adequate quality control is more critical with SCC than in the case of a conventional concrete. A simple and cost-effective improvement to reduce fluctuations in the fresh and hardened concrete is to install accurate, digital moisture measurement equipment in the aggregate hoppers and inside mixers in the manufacturing process.

It is important to continuously monitor the moisture content, aggregate gradation and variations in fines content of the aggregate in order to produce SCC with constant characteristics. National institution and customer experience suggests that the moisture in sands should be controlled for every batch and that the moisture in coarse aggregates must also be taken into account. As well as moisture being important to SCC production, it is also straightforward to use the same equipment to control mix homogeneity before it is discharged from the mixer.

The use of Hydronix digital microwave moisture sensors allows high degrees of accuracy, repeatable results and simple integration to the control system. The unique digital microwave technique also allows Hydronix to offer 3 measurement modes for measuring moisture in mixers, a feature which is extremely valuable when working with SCC's.

Finally, not only is there a high degree of improvement in quality derived from the use of moisture measurement in SCC production but the increase in profitability is such that the equipment's return on investment is made in a matter of months.



FURTHER INFORMATION



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Easy cleaning gives higher efficiency. This is why Haarup have developed their highly efficient wash-out system ensuring better cleaning and quicker mixing cycles.



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Haarup manufacture all their equipment in their own factory in Denmark. Haarup counterflow mixers are available in 11 different sizes from 300 litre to 4500 litre.



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