OPTICAL MOISTURE MEASUREMENTS

BACKGROUND

Concrete production is the process of mixing together the various ingredients: water, aggregate, cement, and some additives to produce concrete. Typical composition by volume is about 10-15% cement, 60-75% aggregates and 15-20% water.

Careful proportioning and mixing of the ingredients is crucial to producing a strong, durable concrete. The quality of concrete can be maintained only if the formulation is carefully administered. The amount of added water has a direct effect on the strength and consistency of the concrete.

Coarse aggregates can contain 0-2% surface moisture by weight and fine aggregates even up to 10%. These numbers exclude absorbed water, which ranges typically from 0.5 to 4%. Moisture content of aggregates must be known to fractions of percent to minimise variability in concrete quality and to enable optimal usage of cement. Knowing the water/cement ratio has significant effects on mix design, workability, strength properties and durability properties.

MOISTURE MEASUREMENT TECHNIQUES

Currently the most widely used moisture measurement in concrete industry is based on capacitive or microwave sensors, if any. Capacitive and microwave sensors are installed typically in direct contact with the aggregate either in silos, silo feeders or even over a conveyor belt. The dipole nature of water molecule implies a high dielectric constant of water enabling simple detection in aggregates by coupling to a sensing electromagnetic field. Capacitive sensing produces often a fairly stable result. Nevertheless, direct contact to sample causes mechanical wearing of the sensor requiring occasional recalibration and finally replacement of either the sensor plate or the whole sensor.

Optical moisture sensors employ an active light source transmitting preselected wavelengths bands on the sample. The back reflected light is collected on a detector element for analysis. There are typically at least two wavelength bands in use so that one is on an absorption peak of water molecule and the other is used for a reference signal. The reflected amount of light at absorption wavelength is compared to the reference signal and this information is used to determine moisture content by calibration.

Optical detection of material moisture allows noncontact detection with clear advantages for concrete industry. There have been optical moisture sensors available for process industry over tens of years, but they have not been widely used in concrete plants due to their high price compared to microwave sensors. Recent advances in solid state light sources and detectors have enabled designing price competitive optical sensors which can be optimised for a given specific task.

TECONER MOISTURE MEASUREMENTS

The optical sensor produced by Teconer is called Water Content Monitor WCM411. The sensor is installed typically within 0.5 – 0.8 meters from the sample surface and can be provided with a dust protection tube.

Optical sensors offer several advantages:

- Measurements without contact
- Long lifetime due to robust design and lack of moving parts
- Easy calibration
- High accuracy
- Limited need for maintenance

Water content Monitor WCM411 sensor head

WCM411 sensor installed over a silo feeder belt

These features will help to deploy optical sensing to measure moisture in concrete and many other industrial aggregates.

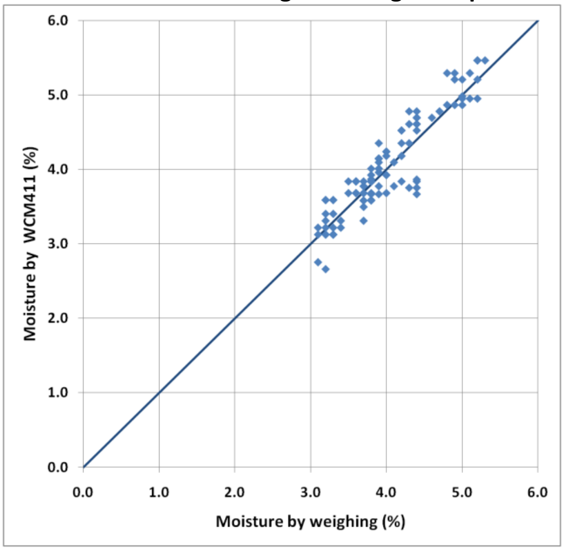
Performance

Repeatability and short time stability of the sensor is about 0.1% by weight. An absolute accuracy of about 0.3% is reachable with a careful calibration and homogeneous sample. This level of accuracy can be maintained for extended periods assuming dust protection of the sensor window is effective. The sensor does not have any moving parts and uses a long lifetime light source allowing an extensive maintenance free service life.

The detection area of WCM411 is fairly small, about 0.05 m by diameter at 1 m distance. As accurate measurements may not be reached with static samples, it is better to use a moving sample and calculate an average value to represent a larger amount of the sample. Most accurate calibration of the sensor with a given aggregate can be obtained by starting with about 1-2 % moisture and then adding water, e.g., in steps of 1 % up to about 5 %.

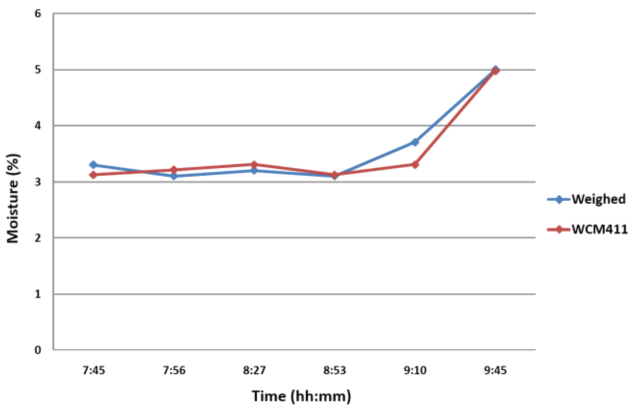
The graph "WCM sensor readings" shows the results of a long term test of in a plant environment. The data was collected within four months leaving the optical sensor untouched during the whole test period. The weighed reference values were collected by taking typically three manual samples from a given mixing batch and comparing water loss in drying to corresponding sensor readings.

WCM411 sensor readings in a long term plant test



Though the scatter in the data is larger compared to calibration data, the standard deviation of 0.25% in moisture is still fairly low. The most significant reason for the scatter is related to external reasons like manual sampling problems of the weighed reference data. For practical reasons the reference samples are on the order of 1 kilogram by mass representing only a tiny fraction of the whole batch and thus being sensitive to local variation. The sensor readings represent average values of a much larger part of the batch thus representing more likely the average moisture of the batch.

Comparison of sensor readings to a weighed reference value when a sudden variation occurs.



"Comparison of sensor readings" shows an example of sudden variation in a silo moisture. Up to about 9:00 the reference values and the sensor readings showed a fairly stable moisture around 3.2%. Suddenly both of the readings started to increase ending to 5% and over. The large and fast increase in silo moisture was probably caused by a heavy raining period a few days earlier. The rapid increase in moisture starting at 9:10 levelled off later during the same day. The example shows why it is important to follow aggregate moisture continuously instead of taking only one daily reference sample.

Customer experiences

The first WCM411 sensors were taken into use ten years ago and the units are still operational. There are system users currently in Finland, Sweden, Norway, France, Switzerland, Estonia, Belarus, Canada and USA. Part of these sensors have been delivered by our partner Polarmatic Oy under the trade mark Polarmoist.

ECONOMIC IMPLICATIONS OF MOISTURE MEASUREMENTS

Considerable savings may be gained by use of moisture sensors in the concrete industry worldwide. Currently it seems that measuring the moisture in the aggregates is far from being a systematic procedure.

The concrete strength is determined mainly by water to cement ratio (w/c). When the water in aggregate is not measured, it is assumed for safety reasons that there is a maximum amount of water. The amount of cement is adjusted to the target value of w/c. However, the real amount of water can be less than the estimated maximum value. The difference can be off by 2 % or even more corresponding to 20 kg of water in fine aggregate. With the water to cement ratio of 0.5 there will be a need to add 40 kg of cement per 1 m^3 in order not to fall below the chosen level of computational strength of the concrete. Approximately half of this can be saved with the help of a precise moisture measurement of the aggregates. Considering the cement price to be 100 EUR per ton, the loss is 2 EUR/m^3. For a small concrete plant which produces annually about 20000 m^3 this means a loss of 40 000 EUR per year. Typically 1-3 optical sensors are installed into one factory, and given these figures the payback time of taking into use of the optical sensor solution will be less than 1 year.

The world consumption of concrete is in the order of 4,2 10^9 m^3. Measuring moisture accurately in concrete production could save the cost of cement worth roughly 8 000 MEUR/year. This means also less CO_2 emissions.

In addition to the direct monetary loss there are indirect costs caused by the poor quality of the concrete and its shorter durability. Instead of a potential lifetime of 100 – 200 years, it can drop to around 50 or less if the quality of concrete will not be maintained.