Microwave Moisture Measurement

The latest digital online moisture measurement is not only critical to the production of quality concrete, but also financially beneficial, as Rolf Laffan, chairman of Hydronix Ltd, explains

Sourcing suitable raw materials within an acceptable distance from quarry to plant is of prime importance to manufacturers dealing with the production of concrete and asphalt. However, the supply of these high-quality raw materials can be limited by the geology of the accessible area.

Increasingly, to help address this issue, the advantages of microwave moisture measurement systems in concrete, asphalt and aggregate applications are now not only considered beneficial, but also essential: both in terms of aspect of quality control and also the cost savings that can be achieved.

The ability to measure and quantify the amount of water present in bulk materials, such as sands and aggregates, was, in the past, extremely limited by the use of flawed technology. All the techniques used, whether infrared, electrical conductance or even nuclear, had significant shortcomings and disadvantages. The introduction of the microwave technique into the concrete industry in the late 1980s and early 1990s was the first major breakthrough.

Up to now, the industry that, worldwide, has benefited most from the implementation of moisture measurement systems using digital microwave technology, has undoubtedly been the concrete industry. The need to produce consistent quality concrete to a rigorous specification is ever increasing in line with the continuing developments in mix-design technology. In simple terms, what the end-user is seeking is a concrete with a consistent workability/slump that attains a consistent strength; whether it be a semi-dry mix for the production of paviors or a self-compacting concrete for on-site use.

One of the major causes of inconsistency in the batching of concrete is the ever-varying moisture content of the sand and aggregates from one batch to another. This may be ameliorated by adopting good housekeeping practices, but even for materials stored in covered silos the moisture will be forever changing due to the inevitable effects of drainage. Moisture content in stored sand and aggregates can have dramatic effects on the water/cement (W/C) ratio, the aggregate/cement (A/C) ratio, yield and the colour of the mix.

Typical installation of a digital microwave moisture sensor on a conveyor belt

Hitherto, considerable attention had been given to the capability of the batching system to weigh to an accuracy of around ±0.5% without appreciating that variations in the moisture content of the raw materials could easily introduce errors of up to ±2.0%, and in many instances very much more.

Today, however, this is a readily solvable problem. Designers would no more think of building a batch control system without a microwave moisture sensor system than building it without a computer.

Microwave moisture measurement systems were first introduced into the concrete market 25 years ago by an innovative UK company who received the much sought after British design award in 1992. This new product development fortuitously coincided with the computerization of batch controllers, making it possible to integrate the two systems. This allowed the batch control system to:

1. Provide online (real time) weight correction to compensate for the variable amount of water being weighed, thereby ensuring a consistent dry weight of material. This provides mixes with consistent A/C ratios.
2. Make sure that the appropriate quantity of water is added to the mix to ensure consistent workability and, in conjunction with 1. (above), consistent W/C ratios.

The above aspects of moisture ➤

measurement apply equally to other applications, such as asphalt, where there are three significant benefits:

—optimizing the use of the binder
—maintaining a consistent grading when blending aggregates
—saving energy in the drying process.

With fine sands holding between zero and 25% moisture, an asphalt producer will benefit by correcting the fine sand weight for moisture on a real-time basis. By measuring the inputs it is possible to effectively correct the aggregate grade proportioning in real time, tackling and resolving the cause of the problem rather than simply measuring and dealing with the symptoms. This will greatly improve the consistency of the materials entering the process.

Measuring the moisture of the blended aggregates on the cold-feed belt will allow the burners to be controlled to optimum efficiency, thereby saving considerable energy. This information may also be used to compare the 'burning efficiencies' of various plants, hence assisting in the selection of the most efficient burners for the process.

By measuring and controlling the moisture of the inputs, the correct recipe and a known volume can be maintained. This effectively ensures that the asphalt cement, RAP, binder and other inputs are correctly proportioned and ensures that the producer is maximizing the use of the materials by 'running lean' and to specification.

Once again, moisture measurement provides improved quality of product with financial savings.

The success of the microwave technique hinges on the unique properties of the water molecule, which resonates at certain frequencies when subjected to a microwave electromagnetic field. This is exemplified by the microwave oven, in which the water molecules absorb so much energy when resonating in an electromagnetic field and heat up to such an extent that they heat and cook the surrounding food.

Such is the success of this technique that it has now been adopted in one form or another by nearly all suppliers of moisture measuring equipment. Technology moves on, however, and more recently the original pioneers of the microwave technique have developed moisture sensors utilizing a 'digital' microwave technique. This, they claim, allows these sensors to measure more accurately over a wider range of moisture contents than had been possible hitherto. Other side benefits include ease of communication and ease of calibration.

Microwave moisture measurement system installed in a plant control panel

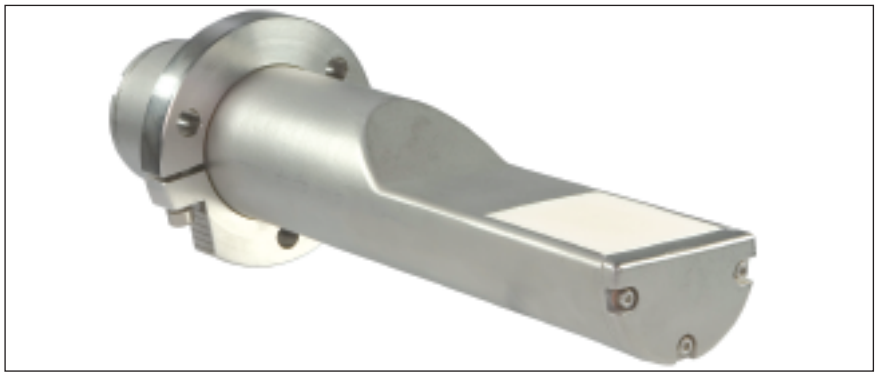
As with most things, once an idea is found to be successful, new manufacturers start to appear. So, when investigating possible suppliers of moisture measuring sensors or systems, what are the criteria for selecting a suitable system? Each manufacturer will claim that their system is better than their competitors' products, which can lead to confusion over which system to choose. Some might opt for a cheaper product and hope it works, while others will pay a bit more for a reliable product with a proven track record of good customer service and support. When choosing the right system for a particular requirement, it is important to ensure the system offers:

- An accurate system of measurement, almost certainly microwave, with a possible preference for a 'digital microwave' technique.
- Sensors, whether for measuring in bins, conveyors or in concrete mixers, must have a proven track record of robustness, reliability and longevity. One well known company has over 40,000 sensors installed in over 50 countries around the world.
- Ease of integration with the main control system, if being supplied separately or as an addition to an existing system.
- Ease of calibration. No matter how accurate the sensors may be, they are useless if incorrectly calibrated.
- Good after-sales service and technical support. This is possibly the most important consideration. A system, no matter how good it may be, is of little use if it is not working, cannot be fixed and help cannot be obtained. Examine the reputation and track record of the supplier.

Concrete and asphalt manufacturers are no longer asking the question: 'Do I need moisture measurement?', but rather: 'Which system should I choose?' Practical experience from end-users has confirmed that the cost savings achieved will, in many circumstances, pay for the investment within months. Clearly, these figures are dependant on many factors, such as the type of concrete being produced, the yield of the plant etc. However, once installed and up and running, most operators will be well satisfied by the difference it makes to their concrete and their profits.

To investigate the potential savings for a particular plant or application visit: www.hydronix.com ∎

Typical example of a digital microwave moisture sensor



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Moisture in Asphalt Production

When a panel of industry quality control experts was asked what automated measurements would add value to asphalt production, “moisture content on belts / in bins” and “automatic gradation and moisture measurement from belt sampling” came in the top 3. Do these sound like familiar measurements that would also add value to your asphalt production?

The increasing cost of raw materials and energy has made asphalt producers look into their production process in much greater detail than in the past. Proven in-line technologies are now available that can provide a very real economic benefit and allow greater process control reducing costly on-site testing and off-line forms of control. The necessity for more exact process control is further reinforced by moves towards more plant/process certification. Instrumentation has become a major part in allowing asphalt producers to differentiate themselves from others through repeatable quality, reliability and efficiency. This differentiation and ‘getting it right first time’ can be the difference between winning a job and losing an important customer.

Increased quality control and assurance has also been reflected by developments in national standards. In France, the asphalt standards have recently been updated to require producers to measure moisture continuously for the production of Level 2 asphalt (NF P 98 728). In the USA, NCAT (National Centre for Asphalt Technology) carried out an investigation into improving HMA production technologies and in their conclusions recommended the on-line belt-sampling of materials and moisture content compensation.

Sources of Variation in Moisture and Their Effects

Moisture contents can change in aggregates stored in cold feed bins, in the RAP (if used) and in the finished HMA or other “warm” asphalt. By measuring moisture in the incoming materials, the finished asphalt product can have its moisture controlled in a proactive real-time manner.

A change in moisture of the raw materials due to rainfall or dry weather will have a very large impact in the grading of the aggregates being loaded into the dryer and therefore on the quality of the asphalt produced. It also changes the energy consumption of the drier considerably and can result in under-yielding.

In practice, fine aggregates can hold considerably higher moisture than coarser gravels, and therefore it has been found that the greatest benefit in moisture measurement is usually achieved in aggregates with particle sizes lower than 10mm. Field trials have proved that by using Hydronix moisture sensors, measurement accuracies of ± 0.2% are achieved and that these more than exceed the industry requirement.

Typical Moisture Ranges for Aggregates

Size	Moisture % Range
Fine Sand	0 to 16
Course Sand	0 to 12
8mm	0 to 10
10mm	0 to 4
12mm	0 to 3
20mm	0 to 2
RAP	0 to 7

Batch Plant Operations

Uniform cold feeding of aggregates from the cold bins is necessary for several reasons, and moisture affects all of these:

- Large moisture variations in the aggregates in the cold feed can lead to moisture content changes in the HMA
- Moisture variations can lead to aggregates leaving the dryer at different temperatures. This can lead to incorrect temperatures of the materials in the pugmill or mixer
- Moisture variations can lead the dryer to work inefficiently, over-drying already dry aggregate or outputting insufficiently dry material
- Inconsistent feeding of aggregates from the cold bin can, in the extreme, lead to differential feeding of the hot bins resulting in some hot bins overfilling while others remain low on materials

By measuring moisture using a Hydronix Hydro-Probe II at the base of the cold bins or on the cold bin discharge belts, and integrating this measurement into a process control system, it is possible to achieve a real-time solution to the issues above. The benefits are:

- Ensure that the correct grading of materials is discharged
- Adjust the dryer rate taking into account the moisture content of the aggregates being fed, resulting in energy savings
- The correct aggregate temperature leads to optimum adhesion to binder

Without Moisture Measurement

✘ Unknown aggregate dry weights

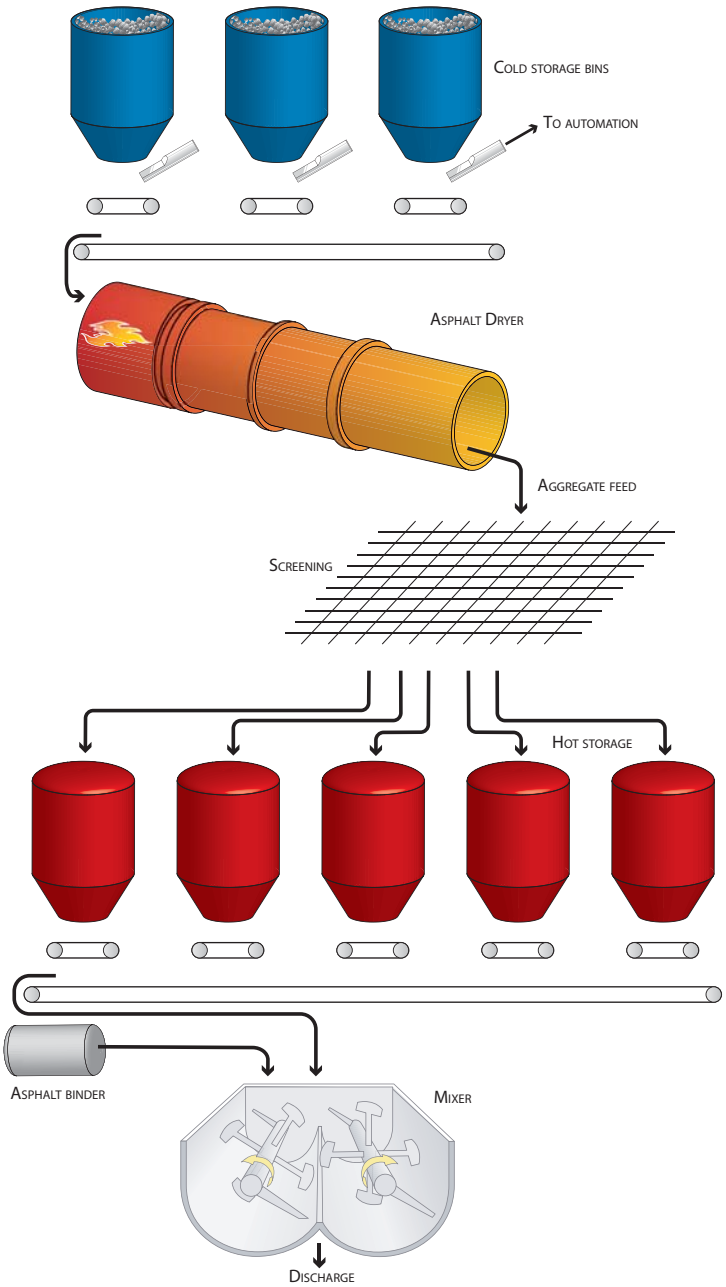
✘ Possible different moisture contents in different aggregates if left uncompensated

✘ Dryer rate is adjusted by the exhaust temperature in a retro active manner

✘ Occasional overflow and / or insufficient material in hot storage bins due to variations in the wet aggregate fed to the dryer

✘ Possibility of moisture variation in the finished product

Benefits of Moisture Control



With Hydronix Moisture Measurement

✓ Hydro-Probe II sensors measure moisture and feed data into the system

✓ Variable belt speeds can be adjusted in real time to ensure the correct dry weight proportioning of each aggregate

✓ Real time dryer rate optimisation for moisture contents of aggregates inside the burner

✓ Consistent hot storage bin levels

✓ Improved final product with moisture consistency

Continuous (Drum) Plant Operations

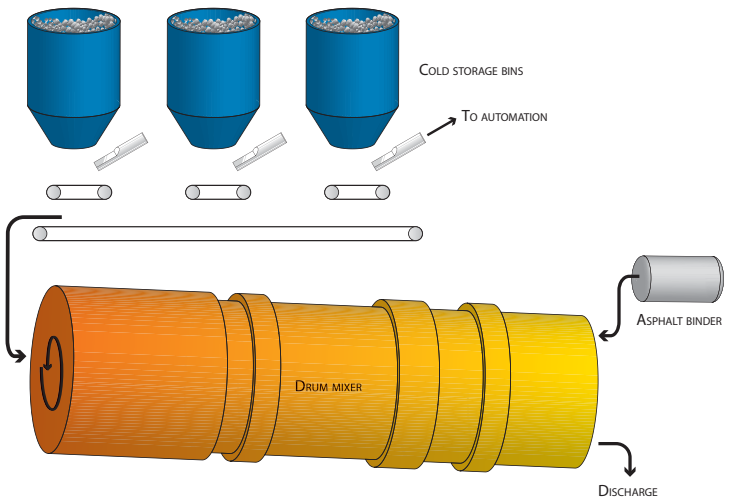
In the production of asphalt by drum mixing, aggregate gradation is controlled at the cold feed and therefore ensuring the cold feed's accuracy is essential. Installing Hydronix Hydro-Probe II moisture sensors at the belt weighers or at the base of the cold feed bins allows real-time feed adjustment ensuring that the correct dry weight of aggregates is loaded into the drum mixer, resulting in:

- Increased yield and reduced asphalt binder usage through correct aggregate gradation
- The burner rate can be adjusted to suit the moisture content of incoming materials, allowing efficiency monitoring
- Energy savings (see Return on Investment below)
- Control of final HMA moisture content
- Reduction in inadequate adhesion between asphalt binder and aggregates

Without Moisture Measurement

- ✘ Unknown dry weight in aggregates results in incorrect asphalt grading
- ✘ Possible over drying of aggregates
- ✘ Occasionally incorrectly graded asphalt

Benefits of Moisture Control



With Hydronix Moisture Measurement

- ✓ Real time "dry weight" grading
- ✓ Reduced asphalt binder usage
- ✓ Burn rates adjusted in real time avoiding over drying
- ✓ Well graded asphalt with correct HMA moisture content

Warm Asphalt Operations – Low Energy Asphalt and Foamed Asphalts

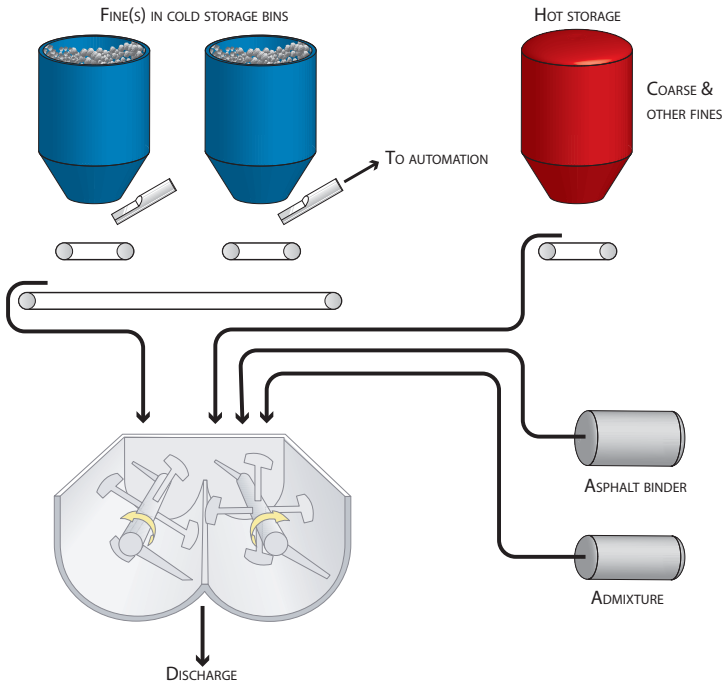
Warm asphalt production techniques require a higher degree of accuracy in aggregate gradation to ensure asphalt quality comparable with other HMA's. The role of water is essential to achieve the desired "foaming" effect when mixed with the bitumen, allowing the system to uniformly coat all the aggregates.

Hydronix equipment allows real-time and on-line moisture measurement of the aggregates before they are fed into the pugmill, mixer or drum. With a feed-forward automation system, producers can correct aggregate weights in real-time. For techniques that use the water in the aggregates themselves for the foaming effect, information about the quantity of water being fed into the mixer or pugmill can also be known.

Without Moisture Measurement

- ✘ Unknown dry fine aggregate weight loaded into the mixer
- ✘ Unknown water in fines added into the mixer
- ✘ Potential for incorrect foaming effect
- ✘ Fine aggregate gradation variation

Benefits of Moisture Control



With Hydronix Moisture Measurement

- ✓ Real time, automatic, variable speed belt adjustment to ensure the correct "dry weight" of fine aggregates fed into the mixer
- ✓ Real time data for water addition into the mixer
- ✓ Correct moisture information to allow the desired "foaming" effect

Return on Investment

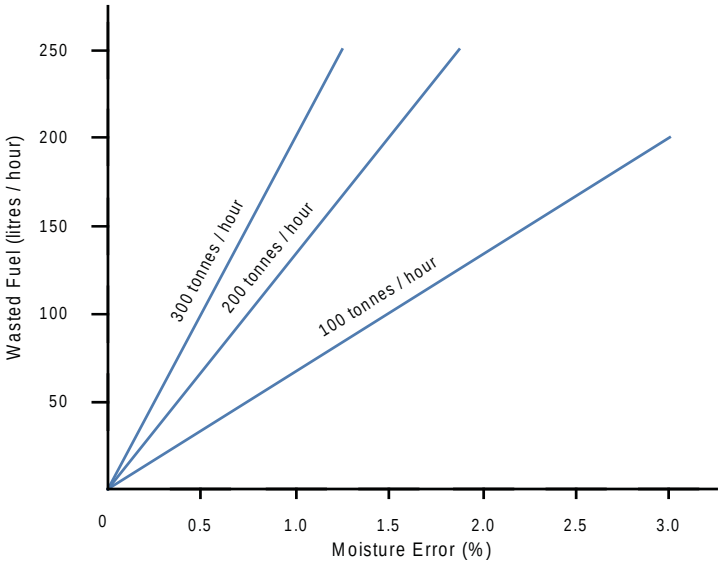
It has been found that an increase in 1% moisture in a tonne of aggregate can result in an additional 0.6 litres of fuel being consumed to evaporate it. At 6% moisture, 4 litres of fuel are required to dry 1 tonne of aggregate. Once dry, 3 litres of fuel are required to heat the aggregate to 150 degrees centigrade meaning that more energy is used in drying the aggregate than in heating it.

In practice the dryer or drum's exhaust temperatures are already measured and used for feeding back information into the burner control. However online moisture measurement allows real-time dryer/drum adjustments relating to the material *inside*, not the material already discharged. This reduces the process control time lag and ensures that the correct dry weights are being loaded into the dryer resulting in savings and quality improvement.

If a plant runs 300 tonnes of asphalt per hour at 6% moisture, it will be using 1,200 litres per hour of fuel to dry the aggregate before it is heated up to the correct temperature. If the moisture content then changed from 6% to 5% without the dryers being adjusted for one hour, that would equate to 180 litres of fuel being wasted in that one hour. Were this to be the case, Hydronix moisture measurement equipment would pay for itself in approximately 30 production hours. A reduced process control time lag continuously improves the efficiency of the plant. In most cases Hydronix moisture measurement systems will pay back within the first 3 to 6 months in operation.

Moisture measurement can also be used to evaluate the dryer's performance. Should the exhaust temperatures and incoming moistures not match (exhaust temperature increases with reducing moisture contents or vice-versa) there may be a requirement to tune the dryer.

There are other economic effects to moisture measurement. By knowing the correct moisture content in the aggregates, it is possible to maximise the efficiency of the drying process to reduce over drying and wasted production time, therefore increasing the yield of the plant. Customers using automated moisture measurement consistently report improved output rates.

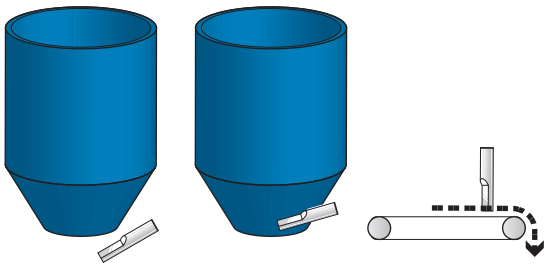


Potential Energy Savings due to Online Moisture Measurement

Installation and Commissioning of a Moisture Sensor

The wide range of digital moisture measurement sensors supplied by Hydronix can be used for installations in the base of the cold feed bins, on the feed belts, or alternatively on a loading "plate" as used by CETE (Centre D'Études Techniques de l'Équipement) in testing. It has been found in practice that the first two positions are generally the easiest installation locations.

Hydronix sensors take 25 readings per second, allowing them to measure changes in moisture immediately. Integration with the customer's control system is simple, via the use of standard analogue outputs. Full communication with the control system is also available via digital comms (RS485/RS232) and the latest asphalt plants are now using Hydronix Ethernet Adapters for communication with sensors.



Calibration consists of finding the linear correlation between the sensor's "unscaled" reading (always 0 in air and 100 in water, allowing easy sensor swap-out if required) and the moisture content in a particular aggregate. This is done by simply running material past the sensor's face and taking a reading of the sensor's unscaled value. A sample of the material is taken and then oven dried to find its moisture content as per the applicable standard. Once the above procedure has been carried out for a few points over the moisture range of the aggregate, the sensor will accurately read moisture – online and in real time.

It Pays to Invest in Moisture Control

Moisture is clearly not the only issue the asphalt producer has to contend with to ensure he meets quality control requirements within tight economical constraints. However it is a simple improvement that brings **immediate, quantifiable returns**. Accurate moisture measurement and control is now well established and proven to **directly reduce costs** as well as **ensuring a consistent quality product improving competitiveness.**

Hydronix Limited are the world leaders in microwave moisture measurement, and have supplied over 50,000 units into aggregate related applications using their unique digital microwave measurement technique.

For more information on Hydronix products please us on +44 1483 468900 or send an email to enquiries@hydronix.com. Our website has details of our offices in the US and Europe if you would prefer to contact these directly.

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Hydronix

Moisture Control in Clay Brick Production

Bricks have been in use for thousands of years and form the basic structures of our civilisation. Originally, the brick making process was manual and involved clay being moulded and then dried in the sun. Today, although this process still exists in some parts of the world, it is now mainly automated, using large machines to mix, cut and mould the clay to shape before firing in kilns.

All raw materials have a different capacity for holding moisture. This can depend on the geographical location of the source material, how it is stored, the humidity in the atmosphere and also the different particle size. Moisture levels can also vary between batches from the same source. Because raw materials are so variable in their moisture content, each batch of bricks will require a different amount of water to be added to the mix to ensure the right consistency at the end of the mixing process.

Why moisture measurement is important

The moisture content of the mix is crucial if a quality end product is required and to produce consistent results with every batch. The correct water to aggregate ratio will allow good, dense compaction of the clay, and the brick will release easily from the mould. Too little water and the brick will crumble, too much water and the brick will sag or fall apart.

For centuries, the brick industry has been striving to find a method of maintaining a consistent moisture content in the extrusion or forming stage of manufacture. Traditionally, the consistency of the clay has been controlled manually using the power consumption of the mixer. Problems such as the effects of temperature and mixer-blade wear make this controlling method unsuitable, and means the manufacturer is unable to guarantee a consistent mix batch after batch.

Ideally, a moisture control system should be able to accurately detect moisture in raw materials, preferably at different stages of the manufacturing process, be easy to maintain and tough enough to withstand the harsh, abrasive nature of the raw materials and the mixer environment. Customers requiring accuracy in their mix have successfully used Hydronix Hydro-Mix microwave sensors, to automatically control the moisture addition throughout their process and improve both consistency and throughput of production. This application note describes how Hydronix sensors have successfully been used during processing at a brick factory in Europe.

Benefits of moisture measurement

Consistency: Correct mix consistency is easily repeatable, batch after batch to the required quality standard.

Cost Reduction: If moisture content is known during processing this will assist manufacturers to calculate the required drying time before firing. This reduces the number of rejects and therefore increases production levels.

Environmental: If moisture levels are known, then the amount of fuel required to remove any excess moisture during firing can be accurately calculated and adjusted if required. This can lead to reduced levels of energy used and further cost savings.

The brick manufacturing process from raw material to finished product

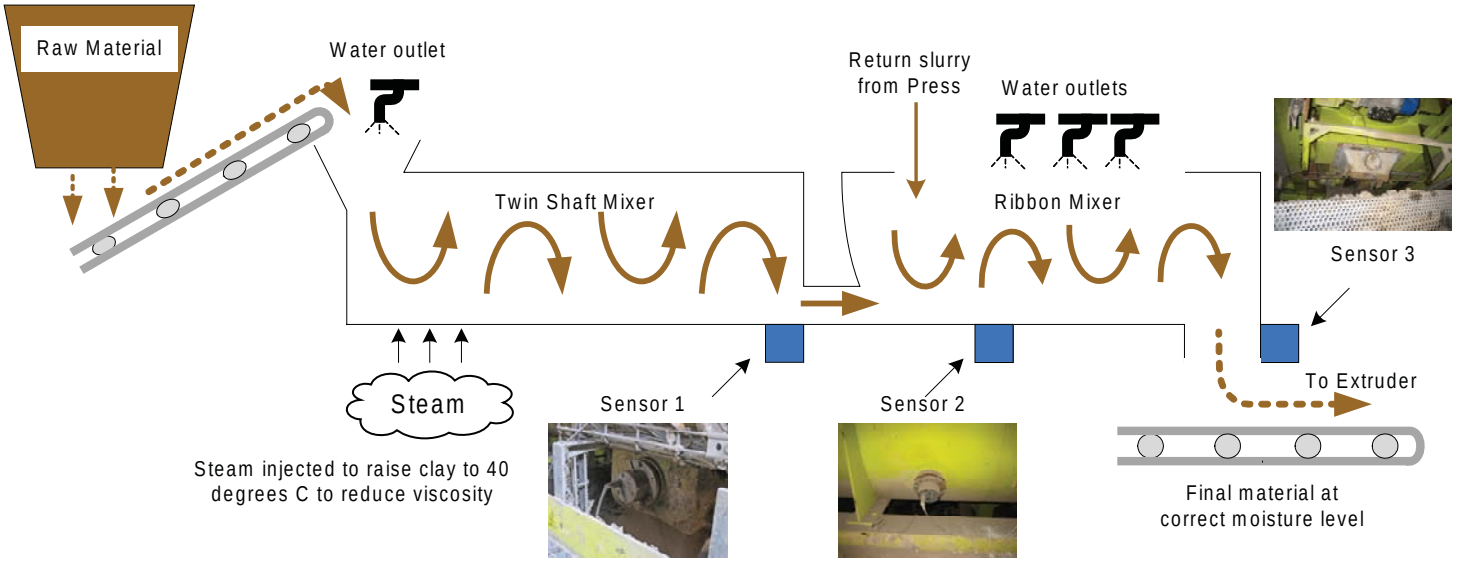
A typical brick making process can be simplified down into several stages

1. The raw material is transferred from the stock pile into a storage bin. The bin is opened and the raw material is transferred by conveyor belt to the next stage of the process. This may be to a grinder where the aggregates are ground to the correct particle size or direct to a twin shaft mixer.
2. Water is added at the first mixer stage, and steam is injected to heat the material to reduce it's viscosity. With the addition of water, the raw materials at this stage can now be called clay.
3. The clay is transferred to a ribbon mixer where additional water is added to achieve the correct consistency. This final mix (with approximately 20% moisture depending on individual manufacturer's requirements) is extruded from the mixer outlet and cut into small lumps ready for pressing.
4. The lumps of wet clay are fed through the press and shaped into bricks. Excess material, called slurry is scraped off and returned back into the mixer to be re-processed. The green bricks are stored for drying before firing in a kiln and finally completing the manufacturing process.

Typical locations for installing moisture sensors

Three Hydro-Mix sensors were installed at this plant in Europe to provide accurate moisture control throughout the entire mixing process. Installation of the sensors is simple: a small hole is cut into the side or floor of the mixer and a fixing plate welded. The Hydro-Mix is then fitted into place with adjustment to height made if required. An RS485 cable sends the sensor readings back to the control system. Designed for permanent installation, the Hydro-Mix sensor can be removed if required for maintenance.

The simple process diagram below shows where the sensors have been installed at this plant, although the exact location and positioning of the sensors will vary from site to site depending on plant equipment.



Sensor 1: - At the output of the twin shaft mixer

Water is added to the raw material as it enters the mixer at the start of the mixing process. Readings from the Hydro-Mix sensor are used by the control system to maintain consistent moisture levels in the raw materials.

Sensor 2 - Halfway along the ribbon mixer

Sludge from the press is pumped back into the mixer, which changes the moisture content of the clay and it's consistency. The readings from the Hydro-Mix sensor are used to ensure that the correct amount of water is added in the ribbon mixer.

Sensor 3 - At the output of the ribbon mixer

A further Hydro-Mix sensor is installed at the outlet of the ribbon mixer to make the final check on moisture before the clay is passed through the extruder. The readings from this sensor should confirm that the mix consistency is correct.

Hydro-Mix sensors

Hydro-Mix sensors were originally designed for use in mixers in the concrete industry, but perform equally well in other types of mixer as well as chutes or screw conveyors. They are built of rugged, hard wearing steel with a ceramic faceplate and easily withstand the turbulent environment of a mixer, so are ideally suited to brick manufacture. The Hydro-Mix sensor is flush mounted with the surface and has a flat faceplate, so that the material can flow freely over it as it passes along the manufacturing process without causing any build up.

How microwave technology works

The sensors radiate an extremely low powered electromagnetic microwave field which detects changes in moisture content almost instantaneously. Readings are taken 25 times per second, and with a potential accuracy of up to + / - 0.1% moisture (depending on materials) very precise measurements can be taken. These are converted into "unscaled units" which are then scaled by a process of calibration to provide a precise readout of the moisture present. These readings are fed back to the control system in real time allowing the system controller to automatically adjust the process as required.

About Hydronix

Hydronix is the world's leading manufacturer of digital microwave sensors for on line moisture measurement. Established in 1982 and with over 50,000 systems installed worldwide, Hydronix is the preferred choice for manufacturers in the Concrete, Aggregate and Asphalt industries. It's continued success in reducing cost and waste is leading manufacturers in industries such as animal feed, grain, sugar and other similar materials to incorporate Hydronix sensors into their own systems.

Conclusion

Many brick manufacturers are now participating in quality management programmes as well as looking at ways to increase production levels while reducing costs. The installation of a Hydronix microwave moisture control system can help them to achieve consistent, quality products while reducing costs in the reduction of wasted materials and potentially lower fuel costs.

Further information on Hydronix range of products and other applications can be found on our website: www.hydronix.com

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