# MONITORING OF WATER CONTENT IN MASS CONCRETING WORK USING A WIRELESS EMBEDDED MOISTURE SENSOR (EMS)

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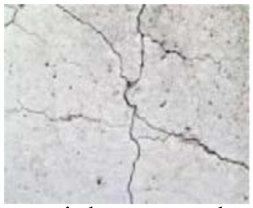
**ABSTRACT**

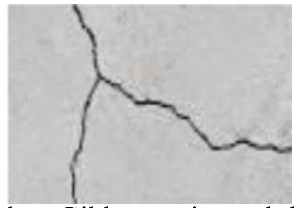
**This paper describes an innovative design of a using wireless passive embedded sensor to determine the water content in mass concreting work. The main purposes of there are so many factors which affect the building structure. Due to those factors affecting the failure will occur and strength of the structure will reduce. Apart from all factors concrete mixing is the major factor for mass concreting structure. In mass concreting work mixing of concrete in different water cement ratio. The water presents a major role in the concrete mix. The water becomes less or more percentage its forms a crack then it will cause the failure of building. To prevent that sensor was embedded in concrete samples so that the internal water content of the samples could be measured with an antenna by tracking the changes in the sensor's resonant frequency. Since the dielectric constant of water was much higher compared with that of the test samples, the presence of water in the samples increased the capacitance of the LC circuit, thus decreasing the sensor's resonant frequency. Finally the results converted into digital form. Using signal system through transmitted the water content percentage value of our mobile phone in the form of messaging system to identifying the water content value for mass concreting work.**

**Key words: wireless Embedded Moisture Sensor (EMS) water cement ratio, mass concreting work, LC circuit, digital form.**

## INTRODUCTION

Concrete it is a mixture of cement, coarse aggregate, fine aggregate and water. Any one of the ingredients of concrete is not correct proportions it affect the strength of the building. In small construction work we have need small quantity of material and there is no much consideration is needed for maintenance and strength of the building but large construction work that is mass concreting work need for huge amount of material and certain period time is given for complete the work. Mass concrete is defined in ACI 116R as "any volume of concrete with dimensions large enough to require that measures be taken to cope with generation of heat from hydration of the cement and attendant volume change to minimize cracking." The design of mass concrete structures is generally based on durability, economy, and thermal action, with strength often being a secondary, rather than a primary concern. In between the completion of work we have facing many problems in the form of factors affecting the construction work. The main factors are soil condition, selection of material, quality of material, mixing of materials, quality of work, cost, time period etc. out of all factors in my project only paying attention on the water content level in concrete. The main purpose of this project is we have seen more no of building to form a crack. Crack formation one of the responsible for lack of durability of concrete it will reduce the life time of the structures. Cracking can be the result of one or a combination of factors such as drying shrinkage, thermal contraction, restraint (external or internal) to shortening, sub grade settlement, and applied loads. Cracking cannot be prevented but it can be significantly reduced or controlled when the causes are taken into account and preventative steps are taken.



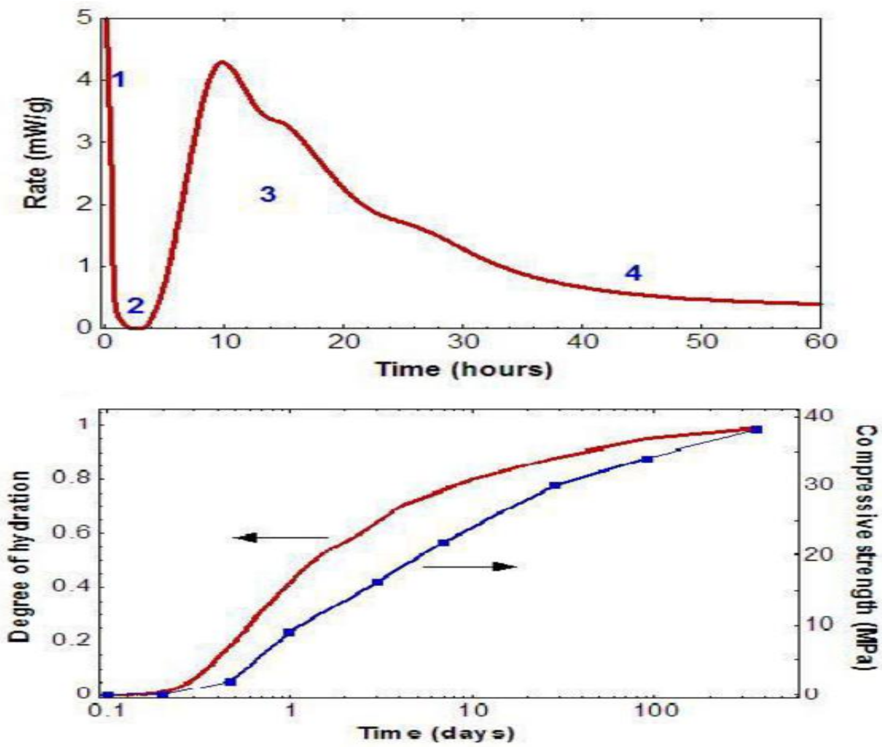


The crack formation mainly occurs due to high and less amount of water content present in the mixing of fresh concrete as well as hardened concrete. Mainly water mix with concrete is bonding of material as well as heat of hydration process. The factors to be considered for water present in the concrete is a not correct proportion the following problems to be occurring.

## HYDRATION OF CEMENT

The reaction of cement with water is exothermic. This process of liberation of heat is called heat of hydration. Formation of heat will increase the surrounding temperature and affect the environmental condition. To reduce the heat of hydration to follow the process is called curing after hardening of concrete. curing can be described the process of maintaining the satisfactory moisture content and a favourable temperature in concrete during the period immediately following placement, so that hydration of cement may continue until the desired properties are developed to a sufficient degree to meet the requirements of service. As interior temperature of mass concrete rises due to the process of cement hydration, the outer concrete may be cooling and contracting. If the temperature differs too much within the structure, the material can crack. The main factors influencing temperature variation in the mass concrete structure are the size of the structure, the ambient temperature, the initial temperature of the concrete at time of placement and curing program, the cement type, and the cement contents in the mix. Heat of hydration is important for concrete dams and mass concrete construction. In reinforced mass concrete structures also cracking will develop, if the difference in temperature between the interior and exterior is large. However, the appropriate dealing the reinforcement could be made to control the width and spacing of cracks. Fitz Gibbon estimated that the temperature rises that adiabatic condition is 12 degree Celsius per 100 kg of cement per cubic meter of concrete, regardless of the type of cement used, for cement content used between 300 to

600 kg/$m^3$. It has been observed that the temperature in the interior of large mass construction is 50 degree Celsius above the original temperature of the concrete mass at that time of placing and this high temperature is found to continue for a prolonged period. On mixing cement with water, a rapid heat evolution, lasting a few minutes occurs. The hydration process is not instantaneous one. The reaction is faster in the early stage period and continues indefinitely as a decreasing rate. Complete hydration cannot be obtained under a period of one year or more unless the cement is very finely ground and reground with excess of water to exposure fresh surface at intervals. Otherwise, the product obtained shows unattached cores of tri-calcium silicates surrounded by a layer of hydrated silicate, which being relatively impervious to water, renders further attacks slow. It has been observed that after 28 days of curing, cement grains have been found to have hydrated to depth of only 4 microns. It has also been observed that hydration under normal conditions is possible only for cement particle smaller than 50 microns. In the field and actual work, it is a different storey. Even though a higher water/cement ratio is used, since the concrete is open to the atmosphere, the water used in the concrete evaporates and water available in the concrete will not be sufficient effective hydration to take place. So reduce the water content level it affects the strength of the fresh concrete.




## WORKABILITY

A concrete is said to be workable if it is easily transported, placed, compacted and finished without any segregation. Workability is a property of freshly mixed concrete, and a concrete is a mixture of cement, aggregate, water & admixture. Due to this all the properties of concrete, whether in fresh state or hardened state, is affected by these ingredients and their proportions. The factors which help concrete to have more lubricating effect to reduce internal friction for easy compaction are given below. Water content, Aggregate/cement ratio, Size of aggregate, Shape of aggregate, Grading of aggregate, Surface texture of aggregate, Use of admixture. One of the factors considers for water content it affect properties of the concrete. Workability of concrete is increases with increase in water. Higher the water content per cubic meter of concrete, the higher will be the fluidity of concrete, which is one of the important factors affecting workability.

## WATER–CEMENT RATIO

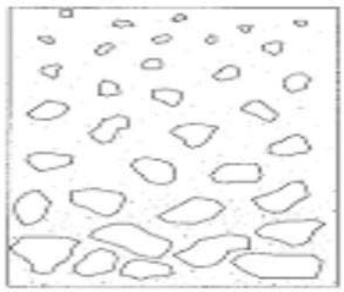
The water–cement ratio is the ratio of the weight of water to the weight of cement used in a concrete mix. A lower ratio leads to higher strength and durability, but may make the mix difficult to work with and form. Workability can be resolved with the use of plasticizers or super-plasticizers Concrete hardens as a result of the chemical reaction between cement and water (known as hydration, this produces heat and is called the heat of hydration). For every pound (or kilogram or any unit of weight) of cement, about 0.42 pounds (or 0.42 kg or corresponding unit) of water is needed to fully complete hydration reactions.

However, a mix with a ratio of 0.42 may not mix thoroughly, and may not flow well enough to be placed. More water is therefore used than is technically necessary to react with cement. Water-cement ratios of 0.45 to 0.60 are more typically used. For higher-strength concrete, lower ratios are used, along with a plasticizer to increase flow ability. Too much water will result in segregation of the sand and aggregate components from the cement paste. Also, water that is not consumed by the hydration reaction may leave concrete as it hardens, resulting in microscopic

Bleeding that will reduce final strength of concrete. A mix with too much water will experience more shrinkage as excess water leaves, resulting in internal cracks and visible fractures (particularly around inside corners), which again will reduce the final strength.

**SEGREGATION**

Segregation usually implies separation of: (a) coarse aggregate from fine aggregate, (b) paste from coarse aggregate, or water from the mix and the ingredients of the fresh concrete no longer remain uniformly distributed. Some of the causes of Segregation on Site are poorly graded aggregate & excessive water content is the major cause of segregation. A badly proportioned mix, where sufficient matrix is not there to bond and contain the aggregate cause aggregates to settle down. Insufficiently mixed concrete with excess water content shows a higher tendency for segregation




**BLEEDING**

Concrete bleeding is defined as the appearance of water on the surface of concrete after it has consolidated but before it is set. This is a type of segregation where water appears at the concrete surface after placing and compacting, but before it is set. Water may also form a film under aggregate and reinforcing bar. Some bleeding is useful for finishing operations and to reduce plastic shrinkage cracking.


These above the factors and some factors occurring mainly due to the water content present in the concrete in excess or low level. To prevent that development of new methods of monitoring and measuring the moisture content of construction materials is both commercially and scientifically important. Using a wireless water detect sensor to measures the water content level for mixing of concrete as well as hardened concrete for curing time application. The monitoring water content value through how much of water is present in the concrete is known and water is need or excess in that place.

**SENSOR DETAILS**

**WIRELESS EMBEDDED MOISTURE SENSOR (EMS)**

EMS sensors are used to detected moisture content through capillary absorption in masonry materials. Sensors are embedded in concrete to detect relative moisture content through capillary absorption. Two sensor grades are used such as Commercial Grade Sensor and Research Grade Sensor. Commercial Grade Sensor are used to published a “a and b” calibration values for the wood specimen is used. Research Grade Sensor are individually calibrated to actually relate gravimetric moisture content with electrical moisture content. Typical sensor elements are based on Western Hemlock, a hardwood with favourable characteristics.

## GENERAL DESCRIPTION

The Embedded Moisture Sensor (EMS) is an indirect moisture measurement device also known as a Duff Gauge, Surrogate Moisture Sensor or Wood Resistance Humidity Sensor. The EMS sensor is used to perform an indirect measurement of moisture levels in materials not compatible with standard measurement techniques, much as gypsum, concrete, masonry and insulation. The EMS sensor uses known moisture and temperature response curves of Helm lock as a baseline and is further calibrated by correlating the electrical characteristics with gravimetric measurements. Sensors are embedded in the material to be monitored to obtain the relative moisture level of the surrounding area through capillary absorption. Sensor readings are acquired by the *WiDAQ*, a precision data acquisition device, and transmitted to the Building Intelligence Gateway where sensor specific temperature compensated calibration curves are applied. Two sensor grades are available. Commercial grade sensors use published *a* and *b* calibration values for the wood species used. Research grade sensors are individually calibrated to accurately relate gravimetric moisture content with electrical moisture content. Typical sensor elements are based on western hemlock, a hardwood with favourable characteristics.

## FEATURES

- ✓ The EMS is available in both block and plug styles. The cylindrical plug sensor is suitable for monitoring stone, concrete, and masonry, where drilling a hole to the appropriate depth is the most practical access. The block style is suitable when a cut-out at the correct location is feasible, for example, in rigid insulation and gypsum sheathing. Further details and customizes are available on request.
- ✓ Measurement capabilities beyond typical Relative Humidity Sensors. Typical RH sensors are limited to non-condensing moisture. Sensor interfaces to SMT Industrial or Mobile WiDAQ unit.
- ✓ Sealed and rugged design allows for deployment in harsh construction environments
- ✓ Integrated temperature sensor used for temperature compensation and for reporting temperature sensor data.
- ✓ Research grade EMS units are individually calibrated to produce *a* and *b* calibration constants for an accurate moisture content calculation.

## FUNCTIONAL SPECIFICATIONS

The functional specifications are:

- ❖ Electrical characteristics
- ❖ Environmental characteristics
- ❖ Physical characteristics

## ELECTRICAL CHARACTERISTICS

| | |
|---|---|
| Operating Voltage | 2V to 12VDC |
| Resistance Measurement Range | 100Ω to 1GΩ |
| Thermistor Measurement Range | -40ºC to 125ºC |
| Thermistor part number | MF52C1104F4150 |
| NTC Thermistor Beta Value | 4150K |
| BiG/Analytics Sensor Configure | Thermistor:MF52 (C)<br>Moisture: Moisture (%) |

## ENVIRONMENTAL CHARACTERISTICS

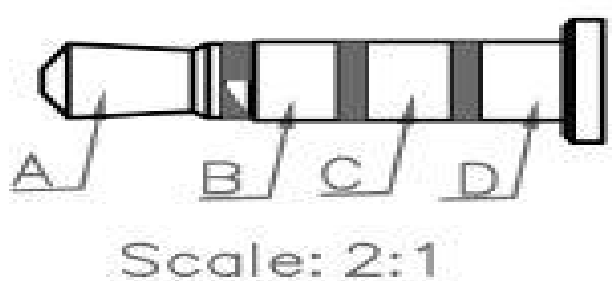
| | |
|---|---|
| Operating Temperature | -40 ºC to 50 ºC |
| Application Temperature | 5 ºC to 50ºC |
| Storage Temperature | -40 ºC to 50 ºC |
| Storage Humidity | 30% to 70% RH |

## PHYSICAL CHARACTERISTICS

| | |
|---|---|
| Dimensions Plug | 38mm x Φ13mm (1.5” x Φ 0.5”) |
| | Block: 50 x 38 x 19mm (2” x 1.5” x 0.75”) |
| Wiring<br>22 AWG 4 conductor stranded (typical | Custom Sizes and Configs Available Upon Request |
| | 22 AWG 4 conductor stranded (typical) |

## WIRE DIAGRAM

| WIRE | EMS | AUDIO | CAT5 | FUNCTION |
|---|---|---|---|---|
| 1 | A | Red | Blue | Moisture |
| 2 | B | black | Orange | Thermistor |
| 3 | C | yellow | White/orange | Thermistor(com) |
| 4 | D | green | White/blue | Moisture(com) |



## CABLE SPECIFICATION

| | |
|---|---|
| 6' stereo cable | EMS-001 -006-02 |
| 6' leaded cable | EMS-001 -006-01 |
| 30' leaded cable | EMS-001 -030-01 |
| Calibrated 6' stereo cable | EMS-011 -006-02 |
| Calibrated 6' leaded cable | EMS-011 -006-01 |
| Calibrated 30' leaded cable | EMS-011 -030-01 |

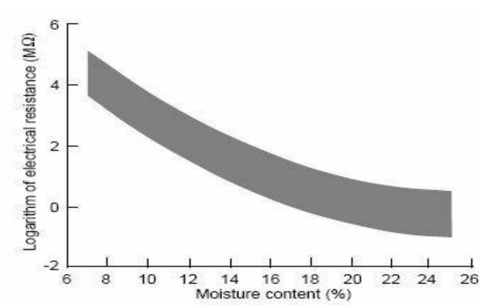
## TYPICAL APPLICATION


Figure: 1 Installation of EMM plug

### INSTALLATION INSTRUCTIONS

- ❖ Drill hole ½" in diameter into material
- ❖ Drill depth at least 2" so that sensor is completely enveloped by material. Additional depths are at the discretion of the user. Moisture will take longer to penetrate to the core of the sample.
- ❖ Using the dust from the drill hole to fill any spaces created around the plug .
- ❖ Seal the top of the plug with epoxy or caulking.

## MOISTURE CONTENT CALCULATION




Change in electrical resistance of wood with varying moisture content levels for most wood species; 90%of test values are represented by the shaded area.

$$MC = \left[ \frac{R_s + \left(0.567 - 0.0260x + 0.000051x^2\right)}{0.881(1.0056^x)} - b \right] \div a$$

Where
MC moisture content at 23°C
R resistance to moisture based on above graph
x temperature of the wood (°C), and
a,b species correction regression coefficient.

## CONCLUSION

1. An additional advantage is gained if the wireless sensors are passive, without an internal power supply such as battery, to avoid sensor battery life-time issues and to minimize cost.
2. Using the wireless embedded moisture sensor (EMS) to determine the water content level of the fresh and hardened concrete.
3. Sensor was embedded in concrete samples so that the internal water content of the samples could be measured with an antenna by tracking the changes in the sensor's resonant frequency.
4. Since the dielectric constant of water was much higher compared with that of the test samples, the presence of water in the samples increased the capacitance of the LC circuit, thus decreasing the sensor's resonant frequency.
5. Finally the results converted into digital form. Using signal system through transmitted the water content percentage value of our mobile phone in the form of messaging system to identifying the water content value for mass concreting work.

6. It helps the knowing water content of concrete at desirable days to measure the value of water content.
7. Based on the known water content value through minimize the factors affecting for concrete.

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