Automatic Curing System for Concrete Structures

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***Abstract*—**This paper presents the development of an automatic curing system for concrete structures. Strength and durability of concrete is attained only by proper curing. It is very essential to maintain proper moisture content in concrete throughout the hydration process. Curing helps in mitigating cracks that affect the durability and life of concrete. Thus curing is essential process in concrete structures. The research focuses on monitoring the moisture and temperature levels using sensors in a concrete structure and to maintain the threshold levels throughout the curing period. Water will be supplied only when the sensor values goes below the threshold level. Wireless networks for this system enables safe and reliable communication between field sensors and the controller and thus increase the flexibility of the system. Proper water management is possible with the proposed system thus wastage of water can be minimized. Also there is very less human interaction required for this system.

Index Terms*—Curing, Concrete, Moisture and temperature sensors, Solenoid Valve, Xbee ,mbed, WSN.*

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I. INTRODUCTION

One of the most versatile materials for use in construction is concrete. The present civilization is hallmarked by use of concrete in construction. This material is ultimately flexible in its practical applications. Coarse aggregates, fine aggregates, cements and water constitutes the main components of concrete. These components can be mixed in various proportions to get different grade of concretes, which possess different strength and durability, and also other factors. The mixing of cement products and water result in a reaction called the hydration process. As important as maintaining the proportional balance of the components during mixing, it is essential to ensure the correct amount of moisture remains available throughout the hydration process in order to fully hydrate the cement and not leave un-reacted cement present within the hardened product. The latent heat produced in the hydration process is necessary to maintain/accelerate the strength gain development, but also has the undesired effect of dissipating moisture content from the mix.

Curing is a procedure that is adopted to promote the hardening of concrete under conditions of humidity and temperature which are conducive to the progressive and proper setting of the constituent cement. It's a process for maintaining proper moisture and temperature throughout the strengthening period.
Watering the concrete is thus essential.[1],[2]

Temperature and moisture certainly affects the curing and also the damage process in concrete. Moisture transfer during construction could prevent concrete from developing its full strength and might lead to high shrinkage stresses. In addition, self-desiccation due to temperature of the hydrated cement paste causes an additional decrease of moisture content at early ages, thereby influencing the properties of the young concrete as well as its long-term behaviour, i.e., deformation caused by self-generated stresses, stability and durability.[3] Temperature and high moisture content can also promote deterioration processes of concrete structures and could jeopardize their integrity and long-term durability. The monitoring of temperature and moisture level will provide crucial information about the hardening and setting process of cement concrete.

Undesired water content cause internal heating and results in cracks. Also there is no control on amount of water used thus water wastage is also a concern. But unskilled labours and undesired amount of water usually stand as a problem in curing. This may lead to unbalanced moisture and temperature levels which affects the strength and durability of concrete. So an efficient mechanism for curing is needed.[4][5]

Ever since the development of different sensors automation has become very common. Automation has reduced human involvement and has made it easier for production and management. Automation in civil engineering is increasing along with use of different sensor systems for monitoring and controlling different functions [6],[7]

MEMs systems are used to measure the relative humidity and temperature using cantilever beams and moisture sensitive polymers. Even though they have effective measurements with high sensitivity long term behaviour and repeatability of MEMs embedded into concrete, require further investigation. New techniques have been developed via WSN systems.[5]

Moisture and temperature sensors are used for many application. Agricultural engineering has become predominant in using these. These sensors are useful in concrete systems for monitoring the moisture and temperature within and outside the structure. SHT series are most commonly used sensors for humidity and temperature measurements.

This paper presents the development of an automatic curing system for concrete structures. The research focuses on monitoring the moisture and temperature levels in a concrete structure under construction and to maintain the initial levels throughout the curing period. The proposed technique uses SHT15 to measure temperature and internal relative humidity (RH).The durability and the sensing capability of the sensors were investigated analytically and experimentally. Wireless version of the system was demonstrated usingXBee. Based on the obtained results, it was found that the proposed system is helpful in monitoring the moisture and temperature inside the concrete and curing can be automated.

An analysis on moisture and temperature readings of 3 different grades of concrete blocks is done and it shows how different admixtures react and how fast the hydration occurs in them. A steady analysis help in calculating different properties of the concrete blocks.

However, long term exposure of sensors to concrete will damage the sensors. A shielding is given to protect the sensors from the internal chemical reactions and stress inside the concrete. WSN for this system helps in providing real time data

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and helps to connect multiple devices easily. WSN is helpful when we need to monitor the moisture and temperature of structures installed in isolated areas.

Even then many limitations need to be overcome such as long term exposure of sensors into concrete, stability and durability, protection mechanism of electronic components etc.

II. METHODOLOGY

A. Hardware Description

The fundamental block diagram of the proposed framework is demonstrated in Fig.1.

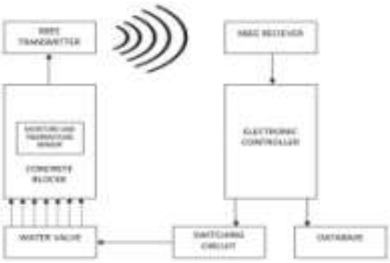

Fig. 1. Proposed System Block Diagram.

The basic agenda behind this system is to monitor the moisture and temperature inside a concrete block and to control a solenoid valve depending on the sensor readings. Since a normal concrete block need to keep $22^{\circ}C$ as its temperature at the curing period and it should also possess the initial moisture content during mixing throughout the curing period. The concrete was moulded with a hole in which the sensor is kept. Sensor used here is SHT 10, shown in Fig 2

The sensor can't be inserted as such since during setting of concrete many internal reactions takes place and it can damage the sensor completely. Soil moisture sensors utilized as a part of this model are sht1x series (soil moisture and humidity) based sensor. The sensor has a copper sintered work over the

Fig. 2. SHT 10.

electronic system as shown in Fig.3, to enhance anticorrosion performance as it is kept inside the concrete. Thus the sensor is protected from internal reactions and stress during the setting period.

Fig. 3. Soil Moisture Sensor.

The Soil Moisture Sensor utilizes capacitance to measure the water content. The sensor is kept inside the concrete block. The sensor monitor the moisture content and temperature inside the cube. The sensor output is taken by an Mbed board. The Mbed Microcontrollers are an arrangement of ARM microcontroller improvement sheets intended for quick prototyping. The Mbed NXP LPC11U24 Microcontroller specifically is intended for prototyping minimal effort USB gadgets, battery fuelled applications and 32-bit Arm Cortex-M0 based outlines. It is bundled as a little DIP structure component for prototyping with through-gap PCBs, strip board and breadboard, and incorporates an implicit USB FLASH programmer [4].

As mentioned above optimal temperature range should be near to $22^{\circ}C$and moisture should be within the range of initial values. This condition is programmed in our microcontroller. Whenever the readings get beyond the specified range the controller activates the solenoid valve and water will be sprayed till the reading gets the highest threshold limit.

A solenoid valve is operated electromechanically. There is a solenoid coil in the valve and the valve is controlled by passing an electric current through it. The solenoid valve is controlled by regulating the water flow through it. Here the sensor takes the initial moisture reading during mixing and that is set as the threshold value for moisture.

Only after 1 day of setting we start the curing process. Curing period is usually 7-10 days. So now the electronic system need to run continuously for that period. Whenever the temperature goes above $22^{\circ}C$ or moisture goes below the threshold level the solenoid valve will be open and water is pumped to the concrete blocks. Fig 4 shows the acquisition system without solenoid part.

Fig. 4. Sensor mounted in concrete and data acquisition.

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B. WSN Implementation

To avoid regular visits to the unit, remote access to the data is essential. Also the control system can be kept away from the manufacturing unit. WSNs considerably reduces cost of wiring. It is usually beneficial in large production units and in mass construction sites.

Xbee is used as wireless communicator between sensors and control unit. The XBee module includes a hardware equipment and a corresponding software part (protocol). The modules are designed and developed as separate integrated circuits and they does not need to be soldered to be mounted into the board. The data being transmitted and received are monitored continuously.

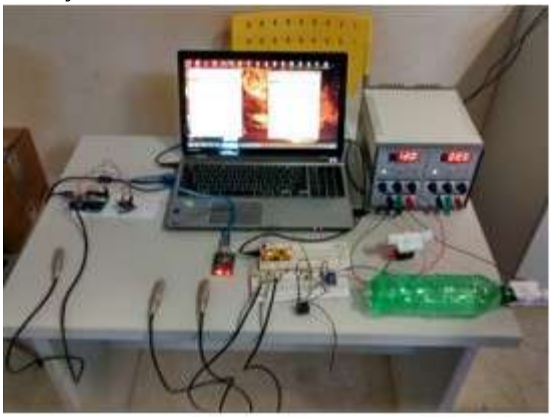

Fig. 5. Wireless acquisition system.

The whole system can be divided into 2 parts, a sensor unit and controlling unit as shown in Fig 5. Sensor unit contains the sensor and the block under test. The control unit contains the microcontroller and the solenoid valve. It is better to have a wireless medium between the 2 subsystems. Hence the lumbering wiring process is additionally disposed of. The transmitter segment of the remote module is developed in Arduino UNO board. The receiver section and the controller area is designed in Mbed board. OneXbee is configured as the coordinator and other as the end or router device.

C. Software Description

The mbed Microcontrollers are all underpinned by the mbed.org designer site, including a lightweight Online Compiler for moment access to your workplace on Windows, Linux or Mac OS X. Additionally included is a C/C++ SDK for beneficial abnormal state programming of peripherals. Joined with the abundance of libraries and code cases being distributed by the mbed group, the stage gives a beneficial environment to accomplishing things [9].

Tera Term is a free, open-source, and terminal emulator program. It imitates diverse sorts of work stations. This emulator device is utilized for perusing the soil moisture sensor values while calibrating the same. Xbee configuration is carried out with the XCTU software from Digi International.

Arduino UNO is used in transmitter section. The opensource Arduino Software (IDE) makes it easy to write code and upload it to the board.

III. ANALYSIS

As the sensor values are logged into computer the same system can also be used for various tests in concrete and their analysis can be easily plotted. An analysis on moisture and temperature dependencies on three different concrete blocks were carried. Three blocks with different admixtures were taken. One with normal cement, sand and water mix, the second one with 5% silica fume and third one with 5% silica fume and 5% SBR (Styrene Butadiene) is molded out. Fig 6 shows the three blocks under analysis.

Fig. 6. Different types of concretes.

The sensors readings are taken out for 10 hours and curing was not done at that period. The reading shows that Compound 1 containing normal mix was dehydrated at a faster rate and the temperature gets higher faster than other two. The Compound 2 containing silica fumes gets dehydrated faster than the third but was slower than first compound. Compound 3 containing SBR retains the initial moisture levels for a longer period and dehydrates at a slower rate. Still the temperature of second and third compounds were very similar with maximum change of 1 which means heat of hydration is similar but moisture content get varied.

IV. RESULTS AND DISCUSSIONS

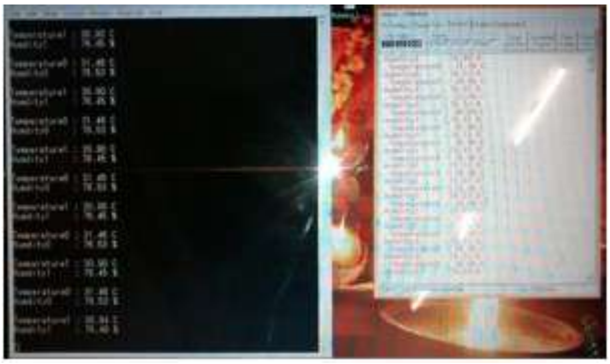

Fig. 7. Moisture and Temperature Readings.

Fig 7 shows the temperature and moisture readings of 2 concrete blocks Compound 1, Compound 2 and Compound 3. Compound 1 readings taken from log file:

Temperature2 : $30.86^{\circ}C$
Humidity2 : 96.20%
Temperature2 : $30.03^{\circ}C$
Humidity2 : 95.85%
Temperature2 : $29.82^{\circ}C$
Humidity2 : 95.49%

Compound 2 readings taken from log file:

Temperature2 : $27.86^{\circ}C$
Humidity2 : 98.60%
Temperature2 : $27.84^{\circ}C$

Humidity2 : 98.34%
Temperature2 : 27.82$^{\circ}C$
Humidity2 : 98.02%
Compound 3 readings taken from log file:
Temperature2 : 27.82$^{\circ}C$
Humidity2 : 93.8%
Temperature2 : 27.84$^{\circ}C$
Humidity2 : 93.64%
Temperature2 : 27.91$^{\circ}C$
Humidity2 : 93.38%
All the above readings were taken at same time.

V. FUTURE WORK

This system find its application mainly in manufacturing units. It starts from mixing of concrete to final delivery. So all the activities coming inside the manufacturing unit can be controlled by a web based sensor and control unit. IOT can be introduced in such manufacturing units which will reduce human effort.

VI. CONCLUSIONS

An automatic curing system was developed that allows monitoring of moisture and temperature within the concrete blocks. Since temperature and moisture levels are always maintained at the desired rate we can have strong and durable materials that have long life time .Wireless Networks allow real time monitoring and reduce the installation costs and prevents risks associated with the systems. The system is thus useful in mass production units and in large construction sites and structures installed in isolated areas. Human interaction can be avoided considerably, and since only desired water is given for curing there is perfect control on wastage of water.

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