An Experimental Research on Prognosis of Compressive Strength of Concrete by using Sensor

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Abstract: now a days there are many methods available to monitor the health condition of the structures. The need of monitoring of health of structures also serves as important factor because of lower quality of materials availability now a days. In this project the temperature sensor is embedded inside the concrete specimen to monitor the variation in temperature of the concrete due to process of hydration. Temperature is one of the major factor that determines the compression strength of concrete structures. The maturity in the temperature data can be monitored by applying this concept in real time application in field. The Internet of Things (IOT) technique is used to send and store the temperature data in the cloud server. With help of the data that stored in the cloud server maturity index formula is used to calculate the temperature time factor with help of which the strength of the structure is indirectly correlated and can be found. In case of the large scale projects there are various methods being adopted to find the strength attained in the concrete element in site such that by doing the cube destructive testing, this concept can also been adopted to ensure the strength attainment in concrete. Hence more than one method was been adopted to ensure the strength which allows the engineers to take the decision without any confusion

Index Terms: Sensor, IoT (Internet of Things), Cloud server, Compression strength.

I. INTRODUCTION

Structural Health Monitoring (SHM) serves as important tool for improving the safety and serviceability of critical structures such as bridges, buildings and formwork. SHM also provides us a real-time and accurate information on the health condition of structure. The concept of monitoring the compression strength of concrete using the sensor and IoT Technique can be used in many engineering cases.

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For example in case of formwork removal the formwork should only been removed only after ensuring that the strength of concrete inside the formwork is enough to withstand the further load that is to be added while the structure is developed vertically.

In present days the formwork is removed by simply notifying the days after pouring the concrete, this can cause the deflection in the concrete structural elements. In this case our project concept is used to find the compression strength of concrete inside the formwork. Hence the high risk activities can be avoided by implementing this concept. Another example where this concept can be adopted is prestressing concrete. Before doing the prestressing in concrete elements it is necessary that the concrete elements must attain the minimum required strength as per design considerations. This was ensured by doing the cube test on each days after pouring the concrete into the formwork. As discussed earlier this concept was adopted to ensure the strength in more than one ways which helps the engineer to do prestressing in concrete without any confusion. This this serve as the smart technique to find the compression strength of the concrete.

The idea of using this technique is obtained with studying on many literatures as discussed below. ASTM C 1074 [1] discusses the maturity method that can be applied in concrete structures. The simpler approach is by calculating the temperature time factor which we used in our project, other method involves calculation of equivalent age factor. The concept used is also a non-destructive method of testing to evaluate the strength of the concrete structure with the help of data extracted through statistical model developed in the project and also it can be done without any special specimen such as casting of cubes. This type of technique will also reduce the laboratory test that are to be performed to evaluate the real time strength of the structures. Maneesh K et al [2] uses the concept of activation energy along with the equivalent age concept as per ASTM C 1074 discussed earlier This paper provides an introduction to the maturity method for estimating in-place strength development of cement mortar or concrete during construction. They have concluded that the maturity method is more reliable in estimating relative strength development rather than absolute strength. They used Arrhenius equation can be used to represent the variation of the rate constant with curing temperature. A plot was made of the average compressive strength as a function of the average maturity index. A best-fit smooth curve is drawn through the data, or regression analysis may be used to determine the best-fit curve for an appropriate strength-maturity relationship.

The resulting curve would be used to estimate the in-place strength of that concrete mixture. D.S.Kumbhar et al [3] uses the wireless monitoring technique to find the temperature of the concrete they used the transmitter and receiver section separately to accurately monitor the data. Arduino UNO board and zigbee was been used in transmitter section and the receiver section was provided with the Raspberry pi, Micro SD card and zigbee.

Here in our project work we move forward towards IoT technique along with the conventional procedures that where been followed now a days. IoT was been used for monitoring, and to manage cloud data services. The program is done in such a way to step-up the module and activate the cloud service. The data can be also monitored through the application in mobile called things view and this it can be viewed from anywhere in the world which serves as main advantage of our project.

II. EXPERIMENTAL SETUP

A. *Casting of concrete cubes*

The concrete cubes of dimension 150mm x 150mm x 150mm is casted for grade M20. The mix ratio for M20grade concrete used is given in below Table 1.

TABLE I
Mix ratio for grade M20

Water	Cement	Fine Aggregate	Coarse Aggregate
197	438	622	1188
0.5	1	1.5	3

The cube casted was tested for 3rd, 7th, 14th and 28th day's strength of concrete during curing of specimen. The compression test was done with the help of compression testing machine to find the maximum compression stress capacity of concrete cube casted.

B. *Temperature sensing module*

The temperature sensor LM35 is choosen for measuring the temperature inside the concrete. This type of temperature sensor can withstand the temperature up to 150 degree Celsius. Even the fresh concrete which will have maximum temperature due to initial higher rate of hydration, may not exceed this maximum temperature capacity of sensor. The temperature sensor may stop working while reaction with the water during power supply. Hence protective coating as shown in figure is provided. Temperature sensor is soldered with the ribbon wires to bring the connection of sensor outside the concrete specimen. Hence the sensing module prepared works immediately after the connection is made with micro-controller. The connection was made immediately after mixing and pouring i.e., while it is fresh concrete.

Fig 1: LM35 Temperature sensor

C. *Circuit connection for sensing module*

The micro controller used in our project is Node MCU which is shown in figure. The Node MCU acts as an intermediate between the temperature sensor and the input data sent to the microcontroller, which is done using arduino coding. Arduino ide is the open source programming software. Coding is the only way through which the working of Arduino microcontroller can be controlled. Formula is used to convert the input data from the temperature sensor to the required temperature value, it was been included in the coding done to control the micro controller. Coding was done also in such a way that micro-controller will able to get into access of cloud server to monitor the temperature. The advantage of using Node MCU is that it control the working of sensing module along with the advantage of Wi-Fi connection through which the data is sent to the online cloud server.

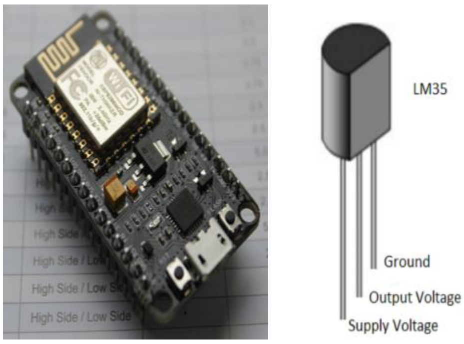

Fig 2: Node MCU and sensing module

The operating voltage of 3.3v is given to temperature sensor to start its work. The temperature sensor LM35 has 3 pins on it as shown in figure. The work of three pins are to supply voltage to sensor, to ground the sensor and to take the output from the sensor.

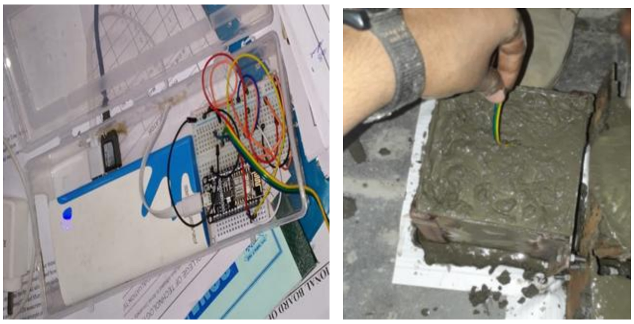

Fig 3: Circuit connection & cube casted with sensor

D. *Testing procedure*

Cubes were been casted for the 3rd, 7th, 14th, 21st, and 28th day strength. Three number of trial specimens for each day test were been casted to check the variation in compression strength and take average strength value. Separate cube was casted for monitoring the temperature values.

The same testing procedure was been adopted and two batches of cubes were been prepared to do a comparative study on the project to estimate the accuracy of calculating the compression strength of concrete using temperature sensor and IoT technique.

Batch 1 cubes: To draw the graph between the Temperature Time Factor obtained in cloud server versus the compression strength of concrete calculated for cubes casted using Compression testing machine.
Batch 2 cubes: To indirectly find the compression strength of cube using the temperature data of batch 2 cubes. The strength is found by correlating the temperature data of batch 2 with the compression strength in the graph drawn for batch 1 cubes.
The temperate data for all 28days was taken into account and with the help of ASTM C 1074 TTF is found and maturity curve has been drawn using the formula specified in that code. ASTM C 1074 – 98 is the Standard practice for estimating concrete strength by the maturity curve.

III. RESULT AND DISCUSSION

A. *Maturity in Concrete*

The below formula is used to calculate the temperature time factor or maturity index value as per ASTM C 1074 code. The datum temperature was choosen as zero degree Celsius. As per ASTM C 1074 if the datum temperature was unknown are cannot be found using available facilities it recommends to take value as zero degree Celsius.

$M(t) = \sum (Ta - T0).\ \Delta t$

Where,

M (t) is the maturity index at age t,
Ta is the average temperature during time interval,
Δt is cumulative time period,
and T0 is the datum temperature.

B. *Maturity Graph for BATCH 1 cubes*

For the batch 1 cubes the compression stress values where been calculated, and with the help of Temperature time factor found using the temperature data a maturity graph is drawn as shown in the below figure 4. American Society for Testing Materials ASTM C 1074 provides Standard procedures to be followed to draw the maturity graph. The batch 1 cube results were noted for 28 days and after UTM test based on its temperature, a maturity graph has been plotted as shown in above Fig 4

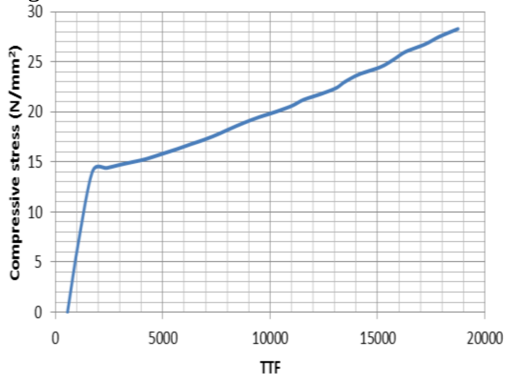

Fig 4: Maturity Graph for BATCH 1 cubes

C. *Maturity for BATCH 2 cubes*

The compression strength was then similarly found for batch 2 cubes. Following table shows the stress values for batch 2 cubes.

TABLE II
Compressive Stress of Batch 2 Cube

SPECIMEN SIZE (mm)	DAY	LOAD (KN)	STRESS (N/mm^2)
150X150X150	3	327	14.5
150X150X150	7	341	15.1
150X150X150	14	367	18.6
150X150X150	21	445	22.8
150X150X150	28	549	27.4

Table III shows the compression stress value that was found with the help of TTF value for batch 2 cubes and the Maturity graph for batch 1 cubes. Correlation technique was used to obtain the stress for batch 2 from maturity graph of batch 1.

TABLE III
Batch 2 Cube Comparison of TTF and Stress

Days	Temperature Time Factor (TTF)	Stress (N/mm^2)
1	374.4	0
2	913.1	7
3	1417.3	14.5
4	2076.1	14.56
5	2365.3	14.8
6	2937.3	14.99
7	3282.2	15.15
8	3731.9	15.2
9	4244.5	15.3
10	4623.2	15.4
11	5140.0	15.6
12	5819.6	15.8
13	6146.0	16
14	6456.2	16.3
15	6936.3	16.8
16	7452.5	17.3
17	7785.1	17.8
18	8244.9	18.3
19	8623.8	18.8
20	9140.4	19.3
21	9894.8	19.8
22	10423	20.45
23	10731	21.1
24	11244	21.75
25	11623	22.4
26	12140	23.05
27	12819	23.7
28	13146	24.4

D. *Comparing batch 2 cube compression strength with the maturity graph of batch 1 and NDT*

The following chart shows the variation in stress for 3, 7, 14, 28 days.

For each mentioned day the compression stress variation is seen for strength obtained with use of conventional destructive method using UTM, strength obtained with help of maturity graph of batch 1, and strength obtained from non-destructive testing method.

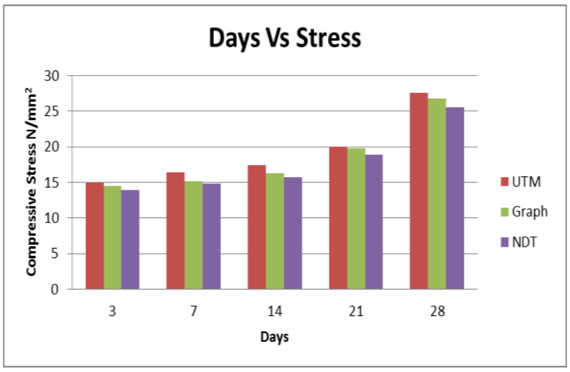

Fig 5: Comparison of Strength

With the help of Figure 4 we can say that the maturity curve with help of which the compressive strength for M20 grade concrete has been identified for its mix ratio. By using this maturity graph the compressive strength of concrete can be calculated at any time if the same mix ratio been preferred to be use in construction projects.

IV. CONCLUSION

Temperature of concrete or rate of hydration in concrete is one of the main factor which determines the strength of concrete. In this project work we kept temperature as an only factor to determine the concrete strength. With the help of research made it is concluded that the variation in compression strength of cube found using compression testing machine and the maturity graph drawn between stresses versus temperature time factor is found to have only little variation in compression stress value. So it is better to say that drawing the maturity graph and finding the strength is most reliable method rather than to say it as accurate method.

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