EVALUATION OF CONCRETE STRENGTH BY MONITORING CONCRETE TEMPERATURE USING SENSOR

R. Magesh[1], R. Parthiban[2], P.V. Pravin Kumar[3], R. Rajesh Kumar[4], S.S. Manu[5]

[1,2,3,4]UG Student, Department of Civil Engineering, Valliammai Engineering College, Tamil Nadu, India
[5]Assistant Professor (S.G), Department of Civil Engineering, Valliammai Engineering College, Tamil Nadu, India

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Abstract - *In recent times, a new technology has been introduced to determine the strength of the concrete using sensors. The existing method depends purely based on the time period to determine the concrete strength during the hydration process. Generally the concrete strength depends on both time and temperature, so the maturity method is adopted in our project. This method helps to correlate the time and temperature as a factor with the concrete strength. So by using ASTM C 1074, the time and temperature are related , Time-temperature factor (TTF) is found out. Using this TTF the concrete strength will be predicted and it is compared with in place concrete strength. Thus the evaluation of concrete strength by monitoring concrete temperature using sensor is found to be approximate. In a massive concrete structure to achieve the strength the structure has to be properly monitored in order to advantage the temperature effect due to hydration process of the concrete.*

Key Words: **Time-temperature factor (TTF), Strength, Hydration , Concrete, Sensor.**

1. INTRODUCTION

A mass concrete mixture will generate heat as a result of the hydration process. This will create that is required for concrete to develop its strength. In general, concrete temperature attains at 48 hours and remains constant for seven days. This is a thermocouple temperature sensor that helps you track the temperature of concrete. The temperature history can then be used to calculate the time and temperature factor of concrete, enabling the user to predict its early-age compressive strength. The larger the concrete structure, the more heat it will likely generate. Differential temperature, air temperature and concrete mix temperature are all important factors considered in monitoring the temperature of concrete during the hydration process. evaluate the concrete strength due to hydration process at different temperature.The of study the performance and temperature of the concrete specimen is made clear.

1.1 SCOPE

- To ensure the quality and durability of massive concrete structure.
- High accurate data collection and report analysis using sensor technology

1.2 OBJECTIVE

- To evaluate the concrete strength due to hydration process at different temperature.
- To study the performance and temperature of the concrete.
- To study the time and temperature factor of the concrete.

2. LITERATURE REVIEW

TITLE : THE MATURITY METHOD , FROM THEORY TO APPLICATION

YEAR : 2001

AUTHOR : N.J. Carino and H.S. Lew

INFERENCE : The maturity method is a technique to account for the combined effects of time and temperature on the strength development of concrete.

ABSTRACT : The NBS research laid the foundation for the development of first standard in the world on the application of the maturity method [ASTM C 1074]. To develop the strength-maturity relationship, cylindrical concrete specimens are prepared using the mixture proportions and constituents. These specimens are prepared according to the usual procedures for making and curing test specimens in the laboratory.

3. METHODOLOGY

The literature review is studied thoroughly and clearly stated above. Material is collected according to the requirement of the concrete specimen. The application and properties of thermocouple temperature sensor is researched thoroughly .Casting of concrete specimens cube and beam with same mix proportion, preliminary test on cubes (compression test) is practiced. Secondary test on beam (flexural test) is also practiced on the in place concrete specimen. The result is attained by comparing strength.

4. MATERIALS TO BE USED

1. Arduino UNO
2 .Temperature sensor
3. Cement
4. Fine aggregate
5. Coarse aggregate

1. ARDUINO UNO

Arduino is a tool for making computers that can sense and control more of the physical world than your desktop computer. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board. Arduino can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs. Arduino projects can be stand-alone, or they can communicate with software running on your computer (e.g. Flash, Processing, max MSP.) The boards can be assembled by hand or purchased preassembled; the open-source IDE can be downloaded for free.

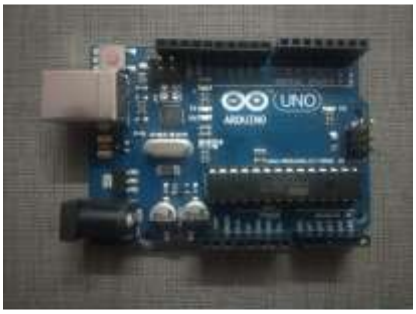

Figure-1 Arduino UNO

2. TEMPERATURE SENSOR

Thermocouple temperature sensor are used to accurately monitor and record concrete temperature . The type K is the most common type of thermocouple. It's inexpensive, accurate, reliable, and has a wide temperature range. The type K is commonly found in nuclear applications because of its relative radiation hardness. Maximum continuous temperature is around 1,100C.

Figure 2- Thermocouple sensor with ardunio

3. CEMENT

Although the terms cement and concrete often are used interchangeably, cement is actually an ingredient of concrete. Portland cement concrete, is a composite material composed of fine and coarse aggregate bonded together with a fluid cement (cement paste) that hardens over time most frequently a lime-based cement binder A cement, most commonly Portland cement, is the most prevalent kind of concrete binder. For cementitious binders, water is mixed with the dry powder and aggregate, which produces a semi-liquid slurry that can be shaped, typically by pouring it into a form. The concrete solidifies and hardens through a chemical process called hydration the water reacts with the cement.

4. FINE AGGREGATE

Fine aggregate is the essential ingredient in concrete that consists of natural sand or crushed stone. The quality and fine aggregate density strongly influence the hardened properties of the concrete. Fine aggregate are soil particles that pass through a 4.25 mm sieve, the soil or aggregate retained on this sieve is classified as coarse aggregates. Fine aggregates are usually river Sand or Machine sand.

5 .COARSE AGGREGATE

Coarse aggregates are any particles greater than 0.19 inch, but generally range between 3/8 and 1.5 inches in diameter. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder. Aggregates are generally thought of as inert filler within a concrete mix. But a closer look reveals the major role and influence aggregate plays in the properties of both fresh and hardened concrete. Changes in gradation, maximum size, unit weight, and moisture content can all alter the character and performance of your concrete mix.

Figure- 3 Coarse aggregate

5. PROCEDURE

- Prepare at least 12 cube and 3 beam concrete specimen .The M30 mix proportions shall be similar to all concrete specimens whose strength will be estimated using this practice .
- Embed temperature sensor at the centre of the specimen. Connect sensor to the ARDUINO UNO microcontroller.
- Perform compressive test at the age of 3, 7 ,21 and 28 days. Test three cube at each age and compute the average strength.
- Perform flexural test at the age of 28 day.
- At each test age calculate the average maturity index for instrumented specimens

Figure -4 Casting of beam

Figure- 5 Casting of beam

Figure – 6 Sensor embedded in beam

6. FORMULA USED

1. TIME TEMPERATURE FACTOR

The common expression used for maturity Is the maturity temperature-time factor.

$$TTF = \sum (T_a - T_0)\,\Delta t$$

(Reference ASTM C1074)

Where,

TTF - temperature-time factor, degree hours
T_a - average concrete temperature during each time interval, °C
T_0 - datum temperature,-10°C
Δt - time interval, hours

2. EXPRESSION FOR STRENGTH

Expression for calculating strength

$$MR = S_u e^{-(\tau / TTF)^{\alpha}}$$

(Reference ASTM C1074

Where,

MR - flexural strength or compressive strength
Su - ultimate expected flexural strength,
τ - time coefficient
α - shape parameter

7. DATA COLLECTED

The concrete specimen is casted on 19/2/2019 and the intial temperature was 24.7 °C ,and for every 24 hours the reading is recored.

DATE	DAY	TEMPERATURE (°C)	DATE	DAY	TEMPERATURE (°C)
20-02-2019	1	34.5	06-03-2019	15	38.9
21-02-2019	2	30.6	07-03-2019	16	39.2
22-02-2019	3	27.2	08-03-2019	17	40.5
23-02-2019	4	32.4	09-03-2019	18	40.9
24-02-2019	5	35.7	10-03-2019	19	41
25-02-2019	6	36.9	11-03-2019	20	41.9
26-02-2019	7	38	12-03-2019	21	42.5
27-02-2019	8	37.1	13-03-2019	22	39
28-02-2019	9	39.2	14-03-2019	23	37
01-03-2019	10	36.8	15-03-2019	24	39.5
02-03-2019	11	32.3	16-03-2019	25	40.3
03-03-2019	12	34.9	17-03-2019	26	41.2
04-03-2019	13	36.5	18-03-2019	27	40.2
05-03-2019	14	38.2	19-03-2019	28	39.8

TABLE – 1 Temperature of concrete

8. TEST TO BE PERFORMED

1. COMPRESSIVE STRENGTH TEST

The concrete specimen cubes after curing in water the specimen is placed in compression testing machine with 6 mm plywood on top and bottom of it to get uniform load on the specimen. The load is applied axially at a rate of 14 N/mm^2.The crushing load is noted. Then the crushing strength is the ratio of crushing load to the area of brick loaded. Average of three specimens is taken as the crushing strength .The test is conducted at age of 3, 7, 21, and 28 days, after complete curing for the respective ages the specimen will attain the strength.

2. FLEXURAL STRENGTH

Flexural test evaluates the tensile strength of concrete indirectly. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending. The results of flexural test on concrete expressed as a modulus of rupture which denotes as (MR) in MPa or psi. The test should be conducted on the specimen immediately after taken out of the curing condition so as to prevent surface drying which decline flexural strength.

9. TEST RESULT

A. FLEXURAL TEST ON BEAM

BEAM NO	AGE OF TESTING (days)	ULTIMATE TEST LOAD(KN)	Avg TTF (degree hours)
1	28	468	720
2		512	
3		537	

TABLE- 4 Average TTF for beam with load

B. COMPRESSION TEST ON CUBES

CUBE NO	AGE OF TESTING (days)	ULTIMATE TEST LOAD(KN)	Avg TTF (degree hours)
1	3	127	487.2
2		148	
3		142	
4	7	420	610
5		388	
6		435	
7	21	470	697
8		529	
9		512	
10	28	530	720
11		540	
12		490	

TABLE-3 Average TTF for cubes with load

10. CONCLUSIONS

Based on the above experimental procedure and test, we conclude as;

1.Using the thermocouple temperature sensor the variation in the temperature of concrete specimen due to hydration process is monitored properly.

2.The compressive strength predicted using TTF is 3.8 N/mm^2, 13.9 N/mm^2, 15.5 N/mm2,18.9 N/mm^2 for the age of concrete specimen at 3, 7, 21 and 28 .

3.The evaluation of concrete strength by monitoring its temperature is found to be approximate.

4.This study helps in considering time-temperature factor for evaluation of concrete strength.

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