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Validation of Concrete Maturity Meter

Yogesh M.Naik¹, Amar T. Gavhane²

M.E. - Structure Student, Department of Civil Engineering, Sinhgad College of Engineering, Pune, India¹

Lecturer, Department of Civil Engineering, Sou. Venutai Chavan Polytechnic, Pune, Maharashtra, India²

ABSTRACT: The concrete is a composite material of aggregate, cement and water. The maturity construct in concrete it's directly associated with each age and its temperature history. The strength developed in concrete it's straightforward to use for concrete strength. In current times, a replacement tool has been introduced to work out the strength of the concrete by sensors. In this research work we used concrete maturity meter for analysis of concrete temperature. Generally the concrete strength is depends on both age and its temperature. We used a thermocouple as a detector for temperature measurement. In this investigation our main objective is to calibration of the concrete maturity meter and validation of maturity meter. For experiments, we used M20 grade concrete and we created fifteen specimen cubes for testing. The testing is done as per standard procedure and we found out the compressive strength. At the end results are obtained from sensor compared with those from cube crushing test were conducted on it.

KEYWORDS: Concrete, Heat of hydration, Concrete maturity, Thermocouple Sensors.

I. INTRODUCTION

I.I General

Recently there has been increasing demand of super high rise buildings And Infrastructure. Concrete is widely used for making structures. For fulfilling these demands Concrete structure plays an important role. There is big need of large amount of Concrete structure in civil Environment. However, the Concrete structures might be susceptible to brittle Fracture if their curing process is inadequate. Therefore, to prevent this Problem, it is very essential to predict the absolute strength of the Concrete Material non-destructively. So we have decided to do the project on concrete strength measurement. The main objective of our research is to measure the strength of concrete structure without crushing it. With the help of Concrete structure properties we have come to know that strength is related to maturity, time and temperature. Hydration is the main property that we are using in our project as main part

I.II Methods to find out strength of concrete

Basically there are two ways for strength measurement of concrete

I.II.I Destructive:

In this method actual load is applied on both the sides of the concrete block and whatever is the load applied on it is known as strength of that concrete block. Which is not that much useful because we are just finding out the strength of only the block not of whole structure.



Fig 1 (a) Compressive Testing Machine. Fig (b) Sample Cube

I.II.II Non Destructive:

At early ages of concrete structures, the strength of Concrete was measured by piezoelectric material and ultrasonic waves. Strength using piezoelectric material was most popular. The strength development of Concrete structures is monitored by observing the development of harmonic response amplitude from the embedded piezoelectric sensor at early ages. From experimental results, the amplitude of the harmonic response decreases with increasing Concrete strength.



Fig 2 (a) Rebound Hammer Test. Fig 2 (b) Impact Echo Test.

I.III Hydration:

A chemical reaction called hydration takes place between the water and cement, and Concrete normally changes from a plastic to a solid state in about 2 hours. Concrete continues to gain strength as it cures.

Heat of Hydration- is the heat given off during the chemical reaction as the cement hydrates.

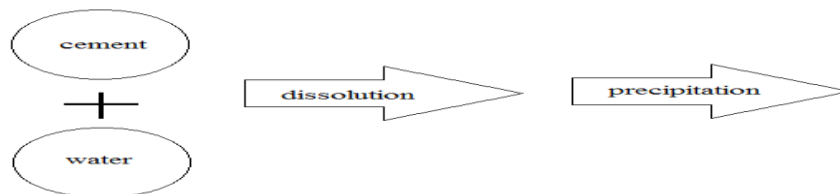


Fig 3 Hydration Process.

I.IV Concrete Maturity:

Maturity methods provide a relatively simple approach for reliably estimating the in place early age compressive strength of concrete (14 days or less) during construction. The measured maturity index of in-place Concrete, a function of temperature history and age is used to estimate its strength development based on the predetermined calibration of the time temperature- strength relationship developed from laboratory tests for that mixture. Since the degree of cement hydration depends on both time and temperature, the strength of the Concrete may be evaluate from the concept of maturity ,which is expressed as a function of the time and temperature of curing. A simple maturity function M(t) can be defined as the product between time and temperature:

$$M(t) = \sum (T_a - T_o) \Delta t \dots\dots\dots \text{Eq .1}$$

M = Maturity (a.k.a. Temperature-Time Factor) at age t
 T = Average Temperature of the concrete during time interval Δt
 T_o = Datum Temperature

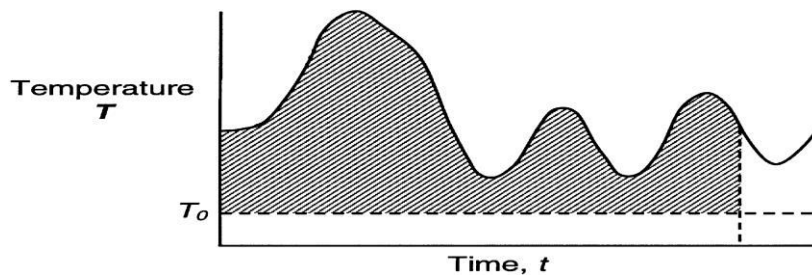


Fig. 4 Strength gain varies linearly with temperature;shaded area is the temperature-time factor(Eq .1)

The index computed by the equation is known by many different terms, such as the maturity index value; the temperature-time factor (TTF), or simply the “maturity” of the Concrete (Trost, 2006). The Nurse-Saul function is a mathematical means of calculating the area under the temperature-time curve for a given Concrete above a datum temperature. Various datum temperatures have been used, but the most common are between -10°C and -20°C with -10°C being the typical one used. The most common way of expressing the maturity index is in metric units of $^{\circ}\text{C}$ -hours (usually shown by the shorthand notation “C-Hrs”). The Arrhenius equation is the most commonly used alternative to the Nurse Saul equation (Carino, 1991). It was derived empirically from observations of homogeneous chemical systems undergoing a single reaction. Roy and Idorn (1982) note that researchers “cautioned that since cement is a multiphase material and also the process of cement hydration is not a simple reaction, homogeneous reaction kinetics cannot be applied.” The Nurse-Saul equation assumes that the chemical reaction rate of Concrete increases linearly with temperature whereas the Arrhenius equation assumes that the relationship is an exponential function. Trost, (2006) states that, “Whereas real-world chemical reactions do in fact follow an exponential rate law, the Arrhenius method is considered theoretically more “correct” than Nurse-Saul. However, the exponential nature of the Arrhenius equation can cause extreme over prediction of Concrete strength under certain unpredictable and uncontrollable conditions.” It thus is not as widely used as the Nurse-Saul equation. The datum temperature is the temperature for a given Concrete mix below which all hydration reactions cease. When the temperature of the Concrete falls below this temperature no additional strength gain occurs and no net gain in maturity is recorded. ASTM C 1074 recommends that 0°C (32°F) be used as the datum temperature for Type I cement used without admixtures when the expected curing temperature is within 0°C and 40°C (32°F and 104°F).

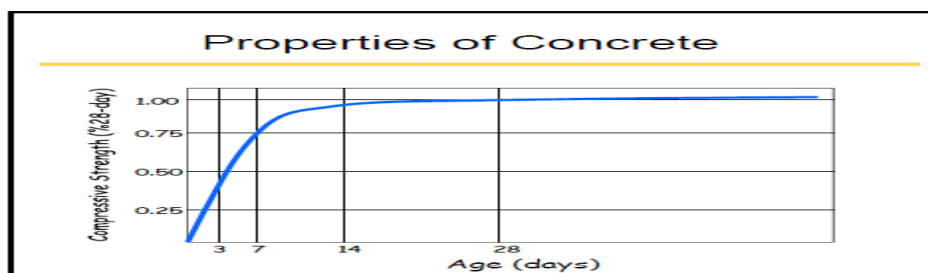


Fig. 5 Properties of Concrete.

The rate of gain of strength of concrete depends on the rate of reaction of the cement (hydration). The hydration of cement is greatly affected by both the time and the temperature of hydration. Concrete gains strength more rapidly with the temperature. Higher the temperature, higher is the strength. Thus the strength gain is controlled by these two factors i.e. age and temperature. The concept of maturity is a function of the product of curing time and temperature. The maturity concept assumes that concrete of different mixes, curing times, and curing temperatures will have about the same strength at the same level of maturity.

I.V Relation Between Strength and Maturity

If we know the maturity index then we can easily get strength of the concrete. The equation is as follows

$$\% \text{ Strength} = A + B \log_{10} \text{ maturity} / 10^3$$

The values of A and B are the coefficient depends on the strength of the concrete. At 28 days the concrete get a full maturity about 19800°

II. LITERATURE REVIEW

Nicholas J. Carino, et.al: (2001) –

1. The maturity function is related to the temperature sensitivity of initial strength Development.
2. The maturity method is more reliable in estimating relative strength development rather than absolute strength.

ASTM C1074:(1998)–

1. The temperature history of the field concrete, for which strength is to be estimated, is recorded from the time of concrete placement to the time when the strength estimation is desired.
2. Using the calculated maturity index and the strength maturity relationship, the strength of the field concrete is estimated.

Allyn Luke, et.al, (December 2002)-

1. There are three innovations the first innovation is that the strength-maturity relationship be verified.
2. The second innovation is that the predictions are made and then the predictive equation is recomputed.
3. The third innovation is a method for starting a quality assurance program with no prior laboratory testing.

SILVA, Carlos Adriano Rufinoda, et.al-

1. Steam curing is used to accelerate cement hydration reactions with the purpose to enhance mechanical strength of concrete at early ages.
2. The temperature influence can be indicated by the Apparent Activation Energy (E_a) value. The higher is the E_a value, the more energy will be necessary to start the reactions.

Keith W. Anderson, et. All, (April 2009)-

1. The study found that maturity is a useful tool for determining the strength of the pavement and allowing early opening of the roadway to traffic. The use of all of the principles of the maturity concept such as the development of the calibration curve.

Ryan J. Rohne, (Aug 2009)-

1. An implementation project was carried out on the TH-694/ TH-35E interchange (SP 6280-304) otherwise known as the Unweave the Weave project.
2. This was one of the first Mn/DOT projects to test the implementation of maturity meters in a field setting.
3. Field implementation on this project helped to show the potential benefits and weaknesses of using maturity data loggers.

III. METHODOLOGY

III.I Concrete maturity meter: (Equipment)

The equipment used to measure maturity has evolved over time from manual methods using temperature probes and meter uses a wired sensor (comprising of a temperature sensor, microprocessor, and data logger) that is embedded in the concrete. The sensor continuously records the temperature of the concrete and converts it to a maturity reading. This information can then be seen on LCD display.

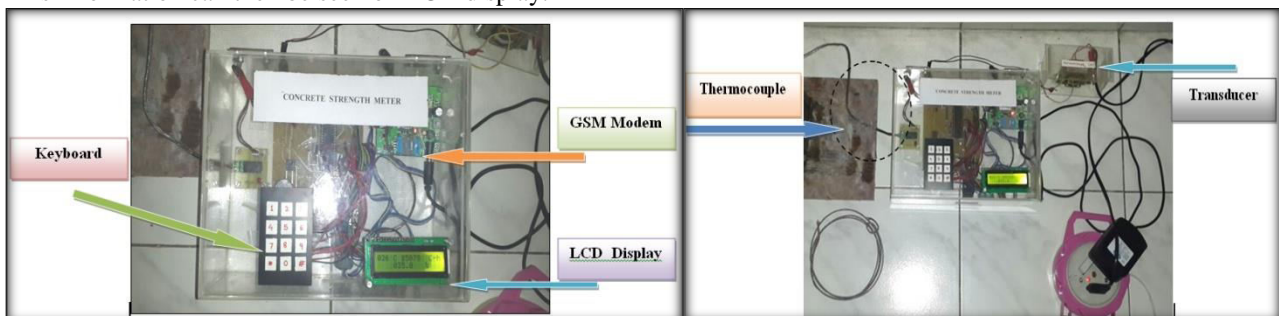


Photo-1 (a) Concrete maturity meter. Photo-1 (b) Concrete maturity meter.

III.II General Methodology

1. M20 concrete was design as per is code.
2. 15 cubes (150x150x150) were cast using proposed mix in real practice the proposed mix should be used to first calibrate the maturity curve.
3. Thermocouple are then placed at the centre of the one of the 15 specimen this thermocouple connecting to maturity meter to display and transfer through mobile temperature, time, %strength, maturity number.

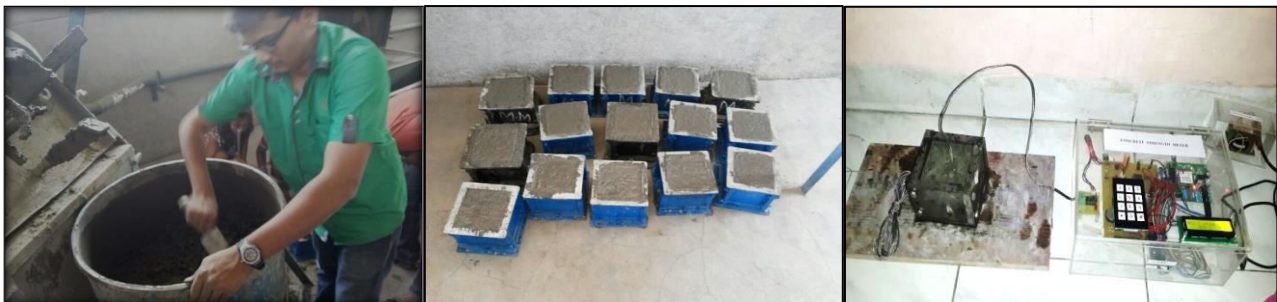


Photo-2 Mixing Process.Photo-3Concrete Cube.Photo-4Cube For CMM.

4. To in all four batches of same mix were tested two batches were used to calibrate the maturity meter while two for validate that is to check the reliability and accuracy if the maturity meter in predicting the real time compressive strength of concrete.
5. The specimen are cured using water (immersed in water) after air curing one day continuous record was maintain with regards to the temperature real time (age) of concrete and percentage strength achieved for all the tested specimen.
6. Compressive strength were perform on three specimen at 1,3,7and 14 days. The average of three test result was reported as representative compressive strength of that batch at respective age.
7. Graphs were plotted (maturity number vs strength)for all the mix. Graphical technique used to develop the “calibration curve” and “validation curve” for particular batch. Mix1A, Mix1B use as calibration curve and Mix1C,Mix1D use as a validation curve.

IV. RESULTS AND DISCUSSION

In experimentation work we made four mixes of M20 Grade of concrete were done. Two were for calibrated and another two were for validation. Results Obtained is given in terms of compressive strength.

| | Time (day) | Maturity Number in(Hrs. °C) | Compressive strength (Mpa) | | Time (day) | Maturity Number in(Hrs. °C) | Compressive strength (MPa) |
|--------------------------------|------------|------------------------------|----------------------------|-------------------------------|------------|------------------------------|----------------------------|
| Mix 1 A CALIBRATION | 0.01 | 0.01 | 0.01 | Mix 1 C VALIDATION | 0.01 | 0.01 | 0.01 |
| | 1 | 7810 | 4.89 | | 1 | 8979 | 5.21 |
| | 3 | 65609 | 9.2 | | 3 | 66612 | 9.87 |
| | 7 | 349931 | 13.8 | | 7 | 359783 | 14.1 |
| | 14 | 1393966 | 21.7 | | 14 | 1272142 | 18.9 |

Table-1 : Maturity Meter Readings of Mix 1A Calibration and Maturity Meter Readings of mix 1C validation.

| | Time (day) | Maturity Number in(Hrs. ° C) | Compressive strength (Mpa) | | Time (day) | Maturity Number in(Hrs. °C) | Compressive strength (MPa) |
|----------------------------|------------|-------------------------------|----------------------------|---------------------------|------------|------------------------------|----------------------------|
| Mix 1 B CALIBRATION | 0.01 | 0.01 | 0.01 | Mix 1 D VALIDATION | 0.01 | 0.01 | 0.01 |
| | 1 | 8218 | 5.06 | | 1 | 8743 | 5.89 |
| | 3 | 78666 | 9.8 | | 3 | 75524 | 9.5 |
| | 7 | 433290 | 17.88 | | 7 | 400046 | 20.44 |
| | 14 | 1738262 | 24.43 | | 14 | 1563562 | 25.56 |

Table-2: Maturity Meter Readings of mix 1 B calibration and Maturity Meter Readings of mix 1D validation.

The Result Is Plotted In Graphical Format

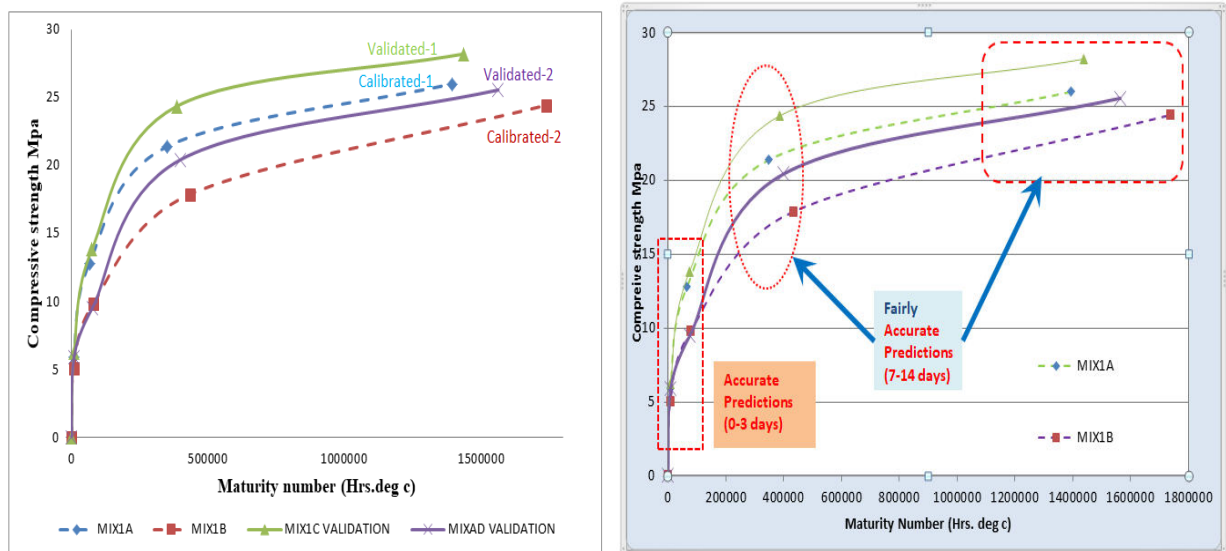


FIG 6 (a) Compressive Strength Vs Maturity Meter For M20 Grade. FIG 6 (b) Compressive Strength Vs Maturity Meter For M20 Grade.

FIG 6(a) It is observed that the maturity meter predict the compressive strength of concrete more accurately at early age that is at one day and three days. The general trend of the gain of strength in concrete as it ages typically represents normal strength concrete.

FIG 6 (b) shows the compressive strength vs age (0 – 3 days) for various mixes the graph clearly shows that the CMM predicts very accurately compressive strength of concrete this is because there is close match between the calibration curve and validation curve.

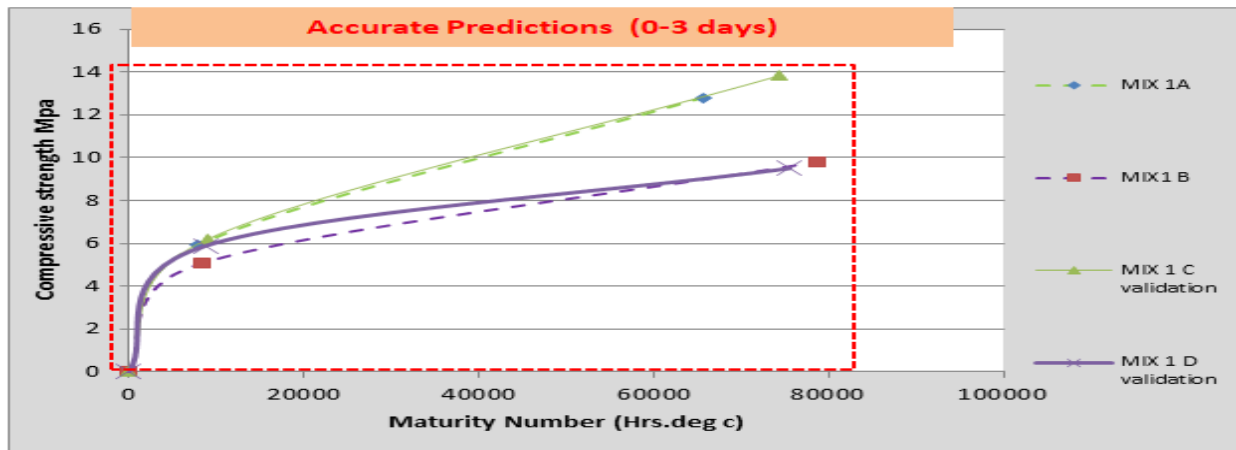


FIG 6 (c) Compressive Strength For 0-3 Days

FIG 6 (c) It indicate the compressive strength of 3 days for M20 concrete. And which is more accurate than the 7 and 14 days. So Error between the calibrated and validated is very less as per ASTM C1074

V. CONCLUSION

Based on the above experimental work and test results we found conclusions which is mentioned below,

1. According to ASTM C1074 the maximum limit of percentage error is 15 %. From result analysis we got maximum percentage error is 11% which is below 15 % as per ASTM C1074.
2. After experimentation on specimens we concentrate on the early age concrete for 0–3days maximum average percentage error is 5%, which is more accurate and suitable for early age of concrete.
3. After comparative study of concrete maturity meter with destructive testing on concrete we concluded that we can timely remove the formwork on site without affecting the strength parameter as well as avoid wastage of material (without crushing the cubes)
4. Concrete maturity meter is very useful in removal of formwork and restoring and post-tensioning of tendon which is demanding now a day.

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