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Early age evolution and Prediction of compressive strength of concrete

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Abstract. Concrete's Compressive Strength and quality of concrete are important parameters to make effective decisions on a construction site, such as removal of formwork, stressing of tendons in a post-tensioned structure, opening of roads to traffic, optimizing curing schedules, etc. The Hydration process, time, and method of curing, and ambient temperatures are the vital parameters on which the concrete strength development is based on. This research emphasizes the application of the Concrete Maturity Technique for determination of in-situ concrete strength and mark the specific concrete signature to monitor quality on High performance mix being used for Precast segments. Maturity sensors valued on-site due to its ability to provide real-time data than can be accessed through Mobile or Computer device. Thus, the results are provided at a faster rate with more accuracy which helps Project Engineer to make well-informed and quick decisions on-site. The maturity technique is a most reliable Non-Destructive test method however, barely used in India. As this technology holds a smart and Non-Destructive approach the results are not awaited which considerably reduces the costs associated with labour, material, and testing of concrete cube specimens. In this research M50 mix is calibrated with 8-day calibration cycle and strength is predicted for 14 and 28 days with validation by using cube tests.

Keywords: Prediction, Maturity Method, Quality, Optimization, Strength

1 INTRODUCTION

Concrete is the most widely used construction material in the world, and its compressive strength is one of the most important properties that engineers and architects need to consider when designing and constructing buildings, bridges, roads, and other infrastructure. The compressive strength of concrete refers to the ability of the material to resist deformation under compression, and it is typically measured in megapascals (MPa). Traditionally, the compressive strength of concrete is determined by conducting destructive tests on samples taken from the actual construction site. However, this method can be time-consuming, expensive, and may not provide accurate results in real-time, which can lead to delays in construction schedules. To address these issues, the maturity method has been developed as a non-destructive technique for predicting the compressive strength of concrete based on its temperature history. The maturity method is a non-destructive technique that estimates the compressive strength of concrete based on its temperature history over time. It takes advantage of the principle that the rate of concrete strength development is directly related to the temperature-time profile experienced during curing. By monitoring and analyzing the temperature history of concrete, engineers can calculate its maturity index, which represents the cumulative effect of time and temperature on strength development. This method involves measuring the temperature of the concrete during curing and then using a mathematical model to estimate its strength based on the relationship between temperature and strength development. The maturity method has become increasingly popular in the construction industry due to its many advantages, including its accuracy, speed, and cost-effectiveness. By using this method, engineers and contractors can obtain reliable predictions of concrete strength in real-time, allowing them to make informed decisions about the timing of construction activities, such as formwork removal and post-tensioning, without compromising the quality and safety of the project.

The use of the maturity method for predicting concrete compressive strength has several advantages, including the ability to make accurate predictions of strength at any time during the curing period, allowing for better scheduling of construction activities. Additionally, it is a non-destructive testing method, which means that the concrete can be left undisturbed during the testing process.

The maturity method for concrete compressive strength prediction is based on the concept of cumulative temperature-time factor, commonly known as the maturity index. This index is determined by continuously monitoring the temperature history of the concrete from the time of casting until the desired age is reached. By correlating the maturity index with the corresponding compressive strength values obtained from laboratory testing, it becomes possible to establish a reliable predictive relationship between the two parameters.

In this context, the present study aims to predict the compressive strength of M50 grade concrete using the maturity method. M50 grade concrete is a high-strength concrete mix commonly used in the construction of heavy-duty structures, such as high-rise buildings and bridges. The study will investigate the relationship between temperature and time to maturity for M50 grade concrete and develop a mathematical model to predict its compressive strength. The results of this study can provide valuable insights for the design and construction of high-strength concrete structures.[1-6]

2 METHODOLOGY

Methodology followed:

1. Determine the Maturity Function:

- The temperature-maturity relationship for M50 grade concrete from laboratory testing was obtained. This relationship expresses the maturity of concrete as a function of temperature and time.
- The maturity function can be represented as M(t), where M is the maturity index and t is the age of the concrete in time units (hours or days).

2. Collect Temperature Data:

- The temperature sensors were placed in two cubes to monitor temperature and TTF.
- The temperature was recorded at regular interval of 10 min throughout the calibration cycle.

3. Calculate the Cumulative Maturity:

- Using the recorded temperature data, the cumulative maturity (CM) was calculated at each time interval using the maturity function.

$$CM(t) = \Sigma[M(ti) * \Delta t], \quad (1)$$

where ti is the temperature at each interval and Δt is the time duration between intervals.

4. Establish Maturity-Strength Relationship:

- Laboratory tests (Compressive strength test) were performed to determine the compressive strength of concrete specimens at 1,2,3,5,7,8 days respectively.
- A graph was plotted between compressive strength versus maturity to establish the maturity-strength relationship specific to M50 grade concrete.

5. Determine the Time-Temperature Factor (F):

- The Time-Temperature Factor (F) was calculated based on the temperature history of the concrete elements or structures.

$$F(t) = \Sigma[(T(ti) - T0) * \Delta t], \quad (2)$$

where T(ti) is the temperature at each interval, T0 is the reference temperature, and Δt is the time duration between intervals.[7]

- The reference temperature T0 is usually taken as the temperature at which the concrete achieves a defined strength (O ^{O}C considered in this study).

6. Calculate the Maturity Index (M) for Desired Strength:

- Determine the desired compressive strength of the M50 grade concrete.
- Use the maturity-strength relationship established in Step 4 to find the corresponding maturity index (M) for the desired strength.

7. Estimate the Compressive Strength:

- Calculate the estimated compressive strength (fck) of the M50 grade concrete at a given age (t) using the maturity index (M) and the Time-Temperature Factor (F).[8]

$$fck(t) = fck(M, F) \quad (3)$$

8. Validate the Predicted Strength:

Compare the predicted 28 day compressive strength from 8 day compressive strength with the actual compressive strength measured from field-cured specimens or in situ testing.

3 EXPERIMENTAL PROGRAM

The experimental program consists of casting 23- concrete specimens of size 150mm x 150mm x 150mm. The concrete specimens are cured under standard conditions. The temperature of the concrete is continuously monitored using temperature sensors embedded in the concrete specimens. The maturity index is calculated using the equivalent age concept, which is defined as the time-temperature integral of the concrete. The 18 cubes were tested at 6 intervals namely 1,2,3,5,7,8 days respectively. And remaining 3 were tested at 28 days to validated the predicted results.

Fig. 1. Temperature sensors inserted in 2 cubes for TTF Monitoring

Table 1. Calibration Results

Sr. No	Age (days)	Measured Compressive Strength (MPa)	TTF (^{O}C-hr)
1	1	14.79	646.77
2	2	25.98	1193.00
3	3	32.67	1745.53
4	5	40.49	2838.82
5	7	48.13	3909.11
6	8	49.85	4459.41

4 RESULTS AND DISCUSSION

4.1 CALIBRATION RESULTS:

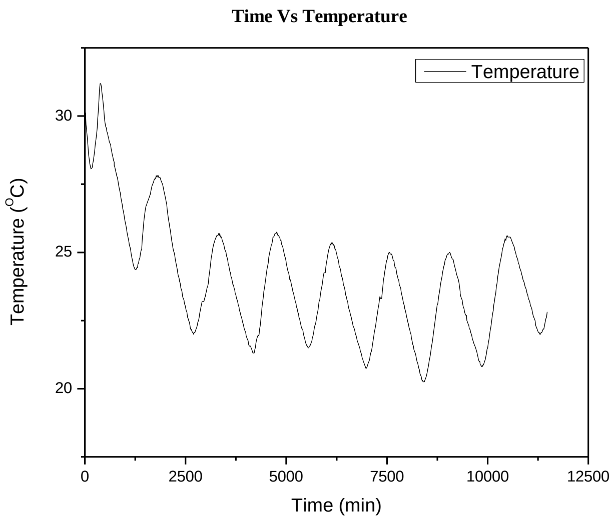

Fig. 2. Temperature profile of M5o mix during 8-day calibration cycle

From above figure it can be concluded that the behavior of M50 mix concrete is normal resembling normal concrete behavior

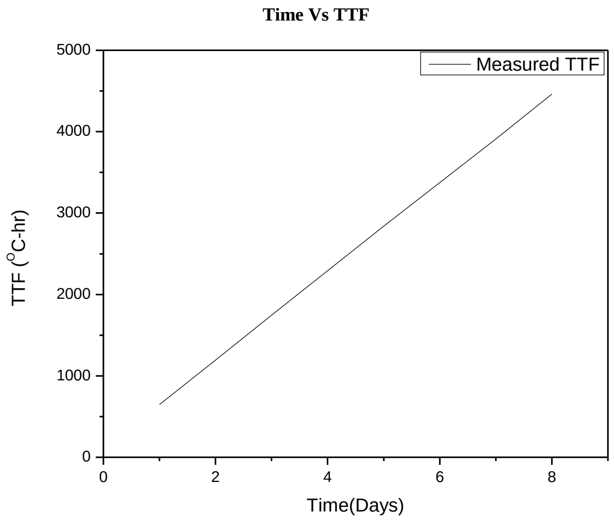

Fig. 3. Time Vs TTF

Above figure shows that the gain of TTF with time is almost linear.

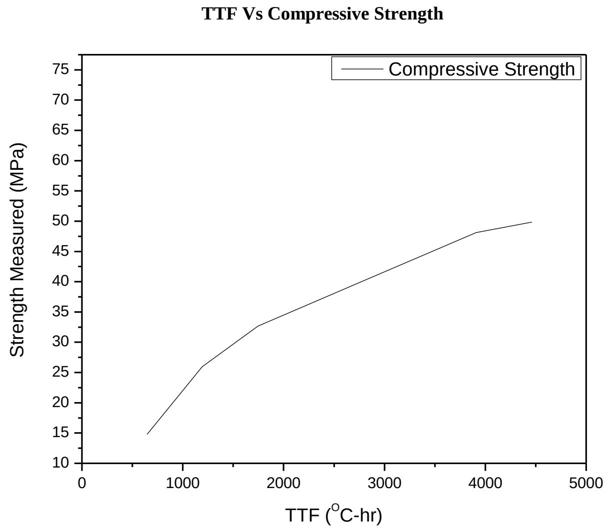

Fig. 4. TTF Vs Compressive Strength

4.2 PREDICTION OF 28 DAY STRENGTH:

Table 2. Prediction of 28-day strength

Age (days)	Measured Compressive Strength (MPa)	Predicted Compressive Strength (MPa)	%Difference
1	14.79	-	-
2	25.98	-	-
3	32.67	-	-
5	40.49	-	-
7	48.13	-	-
8	49.85	-	-
28	71.50	74.27	-3.87%

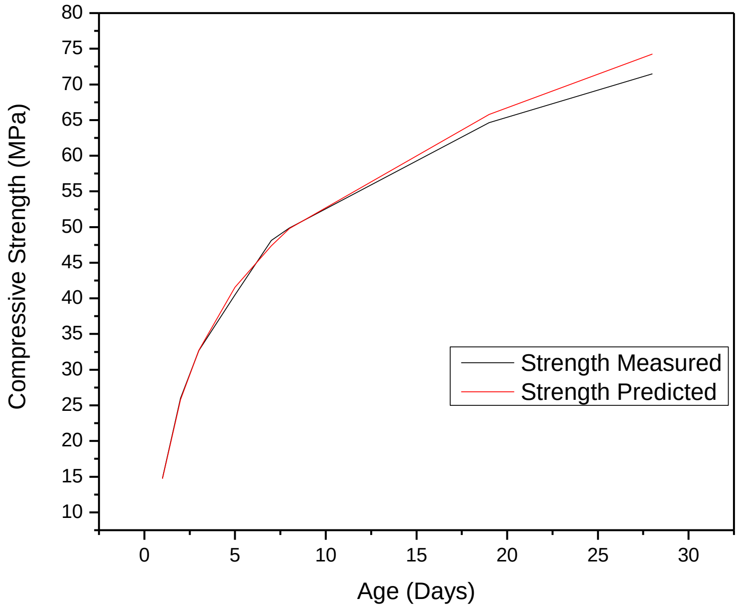

Fig. 5. Strength measured and strength predicted comparison.

5 CONCLUSION

Based on the results and the analysis conducted, it is clear that the maturity method can be applied to estimate the compressive strength development in high performance concrete if special considerations are taken into account. In addition to proposing a methodology to apply the method, the following conclusions are drawn from the findings of this study.

- The M50 high performance mix was successfully calibrated during 8-day calibration cycle.
- The strength predicted found out to be accurate with -3.87% difference between measured and predicted strength.
- The quality control of concrete is good.
- The maturity curves are affected by the type of accelerator, the dose of accelerator and the type of cement. Therefore, a maturity curve has to be defined for each mix design.

References:

1. ACI Committee 228,1995, "In-Place Methods to Estimate Concrete Strength," ACI 228.1R-03 (2003), American Concrete Institute, Farmington Hills, MI.
2. ASTM (2019). "Standard practice for estimating concrete strength by the maturity method." ASTM C1074, Manual of Aggregate and Concrete Testing, Annual Book of ASTM Standards, Vol 04.02.
3. BIS (2009). Indian Standard "Concrete Mix Proportioning" IS 10262:2009
4. Carino N. J. and Lew H. S. (2001). "The Maturity Method: From Theory to Application." Reprinted from the Proceedings of the 2001 Structures Congress & Exposition, May 21-23, 2001, Washington, D.C., American Society of Civil Engineers, Reston, Virginia, Peter C. Chang, Editor, 2001, 19 p
5. Carino, N. J. and Malhotra, V. M. (1991). "The Maturity Method." Handbook on Non-destructive Testing of Concrete, 2nd Ed., CRC Press: Boca Raton, FL., 101- 146.
6. Plowman, J. M., 1956, "Maturity and the Strength of Concrete," Magazine of Concrete Research, Vol. 8, No. 22, March, pp. 13-22
7. Plowman, J. M., 1956, "Maturity and the Strength of Concrete," Magazine of Concrete Research, Vol. 8, No. 22, March, pp. 13-22
8. Kaszyñska M. Early age properties of high-strength/high-performance concrete. Cem Concr Compos 2002;22.