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Estimation of Mortar Compressive Strength at Different Curing Temperatures using the Maturity Method

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ABSTRACT: Image inpainting is the process of restoring the lost or damaged regions or modifying the image contents imperceptibly. It refers to the process of filling-in missing data in a designated region of the visual input. In this paper, the technique presented is for detection and removal of text from images. The system detects text using morphological operations, connected component labelling and a set of selection criteria which helps to filter out non text regions. So, the resultant image is the image with only texts. Text Inpainting is done in two steps. The first step detects the text region automatically, without user interaction and in the second step; the text is removed from the image using exemplar based Inpainting algorithm.

KEYWORDS: Mortar compressive strength, Maturity method, Cement mortar, Curing temperature, Nurse-Saul maturity function, Early-age strength prediction

I. INTRODUCTION

The compressive strength of mortar is a critical parameter for assessing its performance in construction applications. Traditionally, mortar strength is evaluated through curing at a standard temperature, typically 20°C, but in real-world conditions, the temperature at the curing site may vary significantly. This project explores the estimation of mortar compressive strength at various curing temperatures using the maturity method, a proven technique that relates the strength development of concrete or mortar to the cumulative time-temperature history during curing. The goal is to predict mortar strength more accurately under varying thermal conditions, providing valuable insights for construction practices in different climates. The main parameter in the calculation is the internal temperature of concrete that accumulates during the chemical reaction of concrete curing, while external factors such as ambient temperature and relative humidity are fallaciously omitted. The laboratory testing to measure the concrete strength by compression method and non-destructive were performed on concrete samples.

II. LITERATURE SURVEY

1. TEMPERATURE EFFECT ON THE COMPRESSIVE BEHAVIOR AND CONSTITUTIVE MODEL OF PLAIN HARDENED CONCRETE

Following papers are related to Concrete is one of the most common and versatile construction materials and has been used under a wide range of environmental conditions. Temperature is one of them, which significantly affects the performance of concrete, and therefore, a careful evaluation of the effect of temperature on concrete cannot be overemphasized. In this study, an overview of the temperature effect on the compressive behavior of plain hardened concrete is experimentally provided. Concrete cylinders were prepared, cured, and stored under different temperature conditions to be tested under compression.

2. THE EFFECT OF HIGH TEMPERATURE ON THE COMPRESSIVE STRENGTH OF MORTARS.

Semsi Yazici, Gozde Inan Sezer, Hakan Sengul

In this study, the effect of elevated temperature on the compressive strength of mortars containing fly ash, silica fume and pumice was investigated. Thirteen mortar mixtures were produced by replacing ash, silica fume and

pumice was investigated. Thirteen mortar mixtures were produced by replacing 0%, 5%, 10%, 15% and 20% of cement with a fly ash, silica fume and pumice. After standard curing period, specimens were dried in a room temperature for 7 days and then exposed to temperature of 20, 150, 300, 450, 600 and 750 °C for 1 h in ceramic furnace. Afterwards, the compressive strengths of the specimens were determined. It was concluded that, compressive strengths of mortars containing pozzolan were less affected high temperature than that of control mortars.

3.Estimation of mortars compressive strength at different curing temperature by the maturity method

Toufik Boubekeur, Karim Ezziane, El-Hadj Kadri

Two set of mortars were made with three mineral additions to verify the relationship between compressive strength and maturity at later age. One cured in steam room at constant temperature of 20, 30, 40 and 50 °C and the second cured under variable temperature history. It was found that a limited maturity index of 350 °C days exists beyond which the relationship between strength and maturity is not unique. The newly proposed maturity index allows a better correlation between strength and maturity at later age and takes into consideration the deterioration of microstructure with temperature rise. Later age strength can be predicted using the relationship strength-maturity at early age with a correlation coefficient ranging from 0.89 to 0.98.

III. METHODOLOGY

➤ Materials

- **Cement: Ordinary Portland Cement (OPC), conforming to ASTM C150.**

Ordinary Portland cement (OPC) is the basic Portland cement and is best suited for use in general concrete construction. It is of three, 33 grade, 43 grade, 53 grade. One of the important benefits is the faster rate of development of strength. Portland slag cement is obtained by mixing Portland cement clinker, gypsum and granulated blast furnace slag in suitable proportion and grinding the mixture to get a through and intimate mixture to get a through and intimate mixture between the constituents. This type of cement can be used for all purposes just like OPC. It has lower heat of evaluation and is more durable and can be used in mass concrete production.

- **Fine Aggregate: Standard sand conforming to ASTM C778.**

Aggregate Properties greatly influence the behavior of cement mortar, since they occupy about 80% of the total volume of cement mortar. Fine aggregate are material passing through an IS sieve that less than 4.75mm gauge beyond which they are known as fine aggregate. The fine Aggregate according to IS 383:1970 the fine aggregate is being classified in to four different zone, that is Zone- I, Zone-II, Zone-III, Zone-IV.

- **Water**

It should be free from injurious amount of oil, acids, alkalis or other organic or inorganic impurities. It should be free from iron, vegetable matter or other any type of substances which likely to have adverse effect on concrete or reinforcement. It should be quite satisfactory for drinking purpose which is used in mixing of cement mortar.

➤ Preparation of Cement Mortar Cubes

The 28 day compressive strength of a 70.6mm side cube of cement mortar depends on the grade of cement used and the proportion of cement, fine aggregate, and the water- cement ratio (IS 4031- Part6).

- **The nominal mix Design**

- a) Cement: 200 gm
- b) Standard sand: 600 gm
- c) Water = $((p/4) + 3)$ percent of combined mass of cement and sand P is the percentage of water required to produce a paste (85gm).
- d) Standard sand is 600 gm.
- e) Water is (85 gm)

- **Sample Preparation**

Prepare mortar mixes with the desired water-cement ratio. Cast mortar cubes 70.6X70.6X70.6

First of all, we have to prepare a mixture of cement and sand having ratio of 1:3. That is one part of the cement and three parts sand. We take the weight of cement equal to 200 grams and therefore the weight of sand equal to 300 grams. This will make a 1:3 mortar. Then we have to calculate the amount of water for this ratio according to the ASTM standards. After calculation of weights make a homogenous mixture of dry ingredients, and then add water

carefully to make a paste. Now take the 70.6X70.6X70.6mm cube mould and clean them thoroughly from inside and if possible also apply some oil to the inner surface. So that during removal of mould the cubes are not damaged.

- **Compacting**

The test cube specimen is made as soon as possible after mixing and in such a way as to produce full compaction of the cement mortar with neither segregation nor excessive laitance. The cement mortar is filled into the mould in layers approximately 5cm deep. In placing each scoopful of cement mortar in order to ensure a symmetrical distribution of the cement mortar within the mould. Each layer is compacted by either hand or by vibration. After the top of the layer been compacted the surface of the cement mortar is brought to the finished level with top of the mould, using a trowel, the top is covered with a glass or a metal plate to prevent evaporation. After preparation cement mortar cubes those are kept in the open air for one day. After one day the cubes are placed in different types of curing.

- **Curing Regimes**

Mortar specimens will be cast and cured at various temperatures, e.g., 5°C, 10°C, 20°C, 30°C, and 40°C. - Curing temperatures will be controlled bath. The hydration of cement continues for about days and even weeks, therefore curing is undertaken for a reasonable period of time if cement mortar is to achieve its potential strength and durability. Curing may also encompass the control of temperature since this affects the rate at which cement hydrates. Adequate curing of cement mortar cubes are essential for the proper strength development, imperviousness and durability of cement mortar cubes. Thus, purpose of curing is to ensure that the cement mortar cubes does not dry out prematurely, but retains moisture so that it will build up strength and gain durability and resistance to wear.

- **Curing Periods and Temperature**

The period of time that cement mortar cubes should be protected from freezing, abnormally high cementing materials used: mixture proportions required strength, size and shape of the cement mortar members, ambient weather and future exposure conditions. The curing period may be three weeks or longer for lean cement mortar cube mixtures used in massive structures such as the length of the curing period for ambient temperatures dams, conversely it may be only a few days for rich mixes, especially if type III cement is used above 5 degree centigrade should be minimum of 7 days, additional time may be needed to attain 70% of the spec centigrade or lower a higher curing temperature provides earlier strength gain in cementified compressive or flexural strength. When the daily mean ambient temperature is 5 degrees mortar cubes than a lower temperature but it may decrease 28 days strength. strength tests are made to establish the time when curing can cease or forms can be removed, representative cement mortar test cylinders or beams should be fabricated in the field, kept adjacent to the structure or pavement they represent, and cured by the same methods. During cold weather, additional heat is often required to maintain favourable curing temperatures of 10 degree centigrade to 20 degrees centigrade.

IV. TEST

1. Compression test

Compression test is the most common test conducted on hardened concrete, partly because most of the desirable characteristic properties of concrete are quantitatively related to its compressive strength. The compression test is carried out on specimens cubical or cylindrical shape. Prism also sometimes used, but it is not common in our country. Sometimes, the compression strength of cement mortar is determined using parts of the beam tested in flexure. The end parts of the beam are left intact after failure in flexure and, because the beam is usually of square cross section, thin part of the beam could be used to find out the compressive strength. The cube specimen is of the size 70.6mm x 70.6mm x 70.6mm. After curing of the cubes take them out of the mould carefully and then bring them for test by UTM.

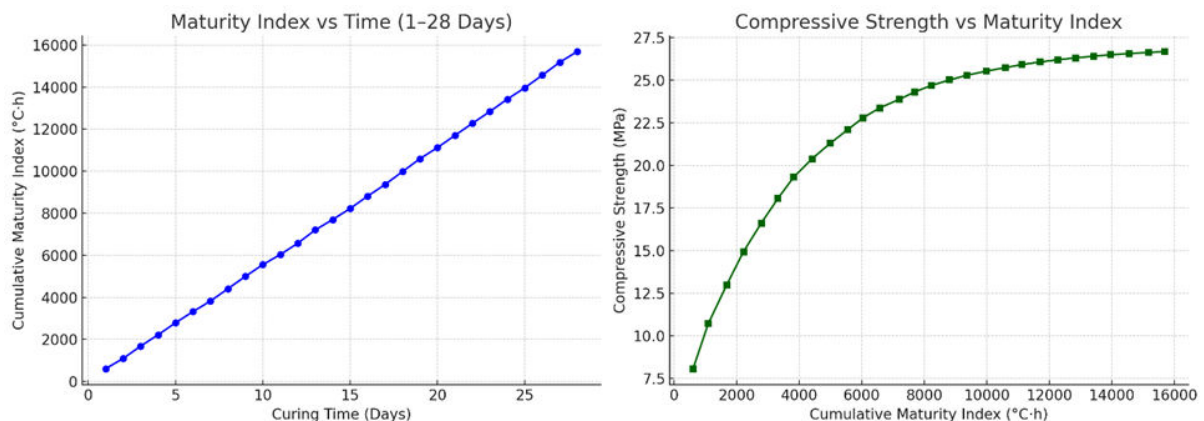
V. EXPERIMENTAL RESULTS

Day	Avg. Temp (°C)	$(T-T_0) \times \Delta t$ (°C·h)	Cumulative Maturity Index (°C·h)	Compressive Strength (MPa)
1	25.3	607.2	607.2	8.06
2	20.2	484.8	1092.0	10.70
3	24.5	588.0	1680.0	12.97
4	22.4	537.6	2217.6	14.93
5	23.8	571.2	2788.8	16.61
6	22.2	532.8	3321.6	18.06
7	20.9	501.6	3823.2	19.30
8	24.4	585.6	4408.8	20.37
9	24.5	588.0	4996.8	21.30
10	23.3	559.2	5556.0	22.09
11	19.9	477.6	6033.6	22.77
12	22.4	537.6	6571.2	23.36
13	26.4	633.6	7204.8	23.87
14	20.5	492.0	7696.8	24.31
15	22.0	528.0	8224.8	24.68
16	24.3	583.2	8808.0	25.00
17	23.2	556.8	9364.8	25.28
18	25.6	614.4	9979.2	25.52
19	25.5	612.0	10591.2	25.73
20	22.0	528.0	11119.2	25.90
21	24.2	580.8	11700.0	26.06
22	23.8	571.2	12271.2	26.19
23	23.4	561.6	12832.8	26.30
24	24.6	590.4	13423.2	26.40
25	22.4	537.6	13960.8	26.48
26	25.0	600.0	14560.8	26.55
27	25.6	614.4	15175.2	26.62
28	21.2	508.8	15684.0	26.67

The maturity index of mortar and estimating its compressive strength Mortar, like concrete, develops strength over time, and the maturity index method can be applied to estimate its strength based on curing time and temperature. The **Nurse-Saul equation** is: $M(t) = \sum (T_a - T_0) \cdot \Delta t$

Where:

- $M(t)$ = maturity index ($^{\circ}\text{C}$ hours or $^{\circ}\text{C}$ days)
- T_a = average concrete temperature during time interval ($^{\circ}\text{C}$)
- T_0 = datum temperature (typically 0°C for mortar)
- Δt = time interval (hours or days)



1. Expected Outcomes:-

- A comprehensive understanding of how curing temperature impacts the rate of strength development in mortar.
- A validated maturity function for predicting mortar compressive strength at different curing temperatures.
- different curing temperatures. strength based on maturity.

2. Improved Construction Scheduling

- Allows for real-time strength monitoring based on temperature history, enabling more accurate construction timelines.
- Helps reduce downtime and increases efficiency.

VI. CONCLUSION

1. The present study demonstrates that the maturity method, particularly the Nurse-Saul approach, provides a reliable means for estimating the compressive strength development of cement mortar under varying curing temperatures.
2. Results indicate a strong correlation between **maturity index** and **compressive strength**, confirming that maturity is an effective indicator of early-age strength gain.
3. It was observed that **higher curing temperatures** accelerate the rate of strength development at early ages, resulting in higher maturity values in a shorter time.
4. By establishing strength-maturity relationships, this study enables more accurate **prediction of in-situ strength**, especially in field conditions where curing temperatures fluctuate.

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