Temperature Distribution in a Cement Concrete Slab using Thermocouples & an Experimental Study on Replacement of Fine Aggregate by Manufactured Sand

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Abstract— Concrete is one of the most widely used construction material throughout the world. Usage of concrete is next to the water. Concrete is man-made material produced by the proper mixing of cement, coarse aggregate, fine aggregate (N-sand or M-sand) and an adequate and controlled amount of water, with or without super plasticizers. In this project two slabs were cast with different material properties like one slab cast with N-sand and another slab cast with M-sand. Slab design is largely based on past experience and empirical data. Temperature differential across the depth or thickness of the concrete slab causes the slab to warping and deform resulting in the bending and temperature stresses. The analysis is based on the assumption that the temperature distribution is linear throughout the depth of the slab. This is an approximation because studies have shown that the actual temperature distribution is non-linear. Various researchers have proved that the assumption of linear temperature differential is un- conservative. Therefore, it is necessary to consider non- linear temperature differential instead of linear temperature differential to evaluate the temperature stresses and in the design of slabs when exposed to temperatures. Therefore, an attempt has been made in this study to evaluate the stresses due to the actual temperature distribution across the thickness of the slab. Two slabs of different material properties are cast, instrumented with K-type thermocouples at different levels viz., top, middle and bottom and the actual temperature in the slabs are recorded every hour (8:00 AM - 5:00 PM) for 28 days using a digital temperature recorder. The result obtained from the study clearly shows that the actual temperature differentials are Non-linear. The finding confirmed the importance and the need to account the nonlinear temperature differential in the design of concrete slabs.

Key words: Concrete, Thermocouple, Thermometer

I. Introduction

Concrete is most popularly used construction material all over the world. Concrete is an artificial material can be obtained by uniform mixing of cement, coarse aggregate, Manufactured sand and sufficient and controlled amount of water, with or without super plasticizers. Due to the Scarcity of good quality natural sand has made concrete manufacturers to look for suitable alternatives of ‘fine aggregates’. One of the suitable alternatives is “Manufactured sand”.

Slab of similar material properties are cast, instrumented with thermocouples at different levels viz., top, middle and bottom to calculate stresses at interior edge and corner regions and the actual temperature in the slab are recorded every hour for 28 days (8:00 AM-5:00 PM) using a digital temperature recorder. Hence it is necessary to analyze the slab for thermal and structural loadings. The main aim of placing the thermocouples at Centre for deflection, at edge for bending and at corner for torsion. These are calculated in this study, we have carried experimental studies on the slab which was under construction.

We have adapted M30 grade concrete using OPC43 grade cement, using natural sand, manufactured sand and coarse aggregate. The result obtained from the study clearly shows that the actual temperature differentials are Non-linear.

The finding tells that the importance and need of nonlinear temperature differential in the design of slab. Theory states that, thermal (temperature) stresses and load stresses at mid, edge and corner regions of slab are calculated by different methods. Temperature gradient across the thickness of slab causes, slab to curl and deform resulting in the bending stresses. The result obtained from the study clearly shows that the actual temperature differentials are non-linear.

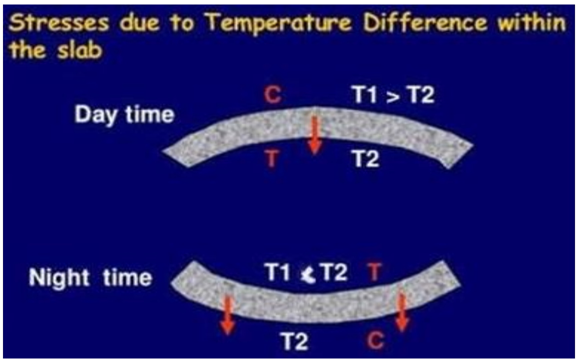

Fig. 1:

A. *Thermocouples*

Thermocouples are most popular temperature sensors used for measuring temperature. They are cheap, interchangeable, have standard connectors and can measure a wide range of temperatures. Thomas See beck was the name of the Inventor discovered the junction between two metals creates a voltage which is a function of temperature. Thermocouples works on this principle.

The working of thermocouple is shown in Figure 1.1.

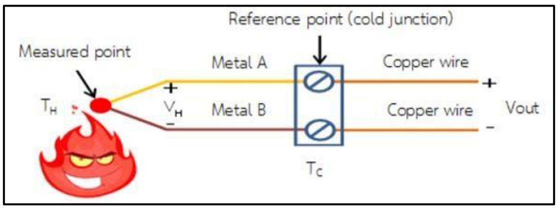

Fig. 1.1: Working of Thermocouple

1) Type K

Type K should not be used in sulphurous atmospheric condition, in vacuum or low oxygen environments.

B. Scope of the Present Study

The study focuses on computing the nonlinear temperature variations across the thickness of slab. Temperature recorded across the thickness of the slab are divided in to three components viz., axial, linear and nonlinear. Therefore, an attempt has been made in this study to estimate and compare the temperature differentials in the slab subjected to effect of recorded temperature and also to evaluate the concrete properties when the natural sand is replaced by manufactured sand.

C. Objectives

- To determine the actual Non-linear temperature differential by slab instrumentation at edge, corner and interior regions of the concrete slab.
- To determine peak positive and peak negative temperature in the slab due to the recorded temperature data.
- To determine which among two slabs is subjected to more temperature variation.
- To arrive at the Mix proportions for good quality concrete.
- To determine the fresh and hardened properties of concrete when the natural sand is replaced with manufactured sand.

D. Cement

Ultratech 43 grade cement confirming to IS 4031:1968 was used.

Sl No	Test	Results	Requirements as per IS 12269:1987
1	Consistency	34%	------
2	Initial setting time	40 min	Not less than 30 min
3	Final setting time	600 min	Not greater than 600 min
4	Specific gravity	3.10	2.99 – 3.15
5	Fineness(sieve analysis)	8.3%	Should be less than 10% of its weight
6	Compressive strength(MPa)		
	3 days	26.05	16 (minimum)
	7 days	41.14	22 (minimum)
	28 days	53.68	43 (minimum)

E. Fine Aggregate (Natural sand)

Locally available natural river sand is used in the present project. Properties of natural sand are determined by various tests as per IS: 2386-Part3. Fine aggregate (natural sand) confirms to Zone-I of IS 383:1970.

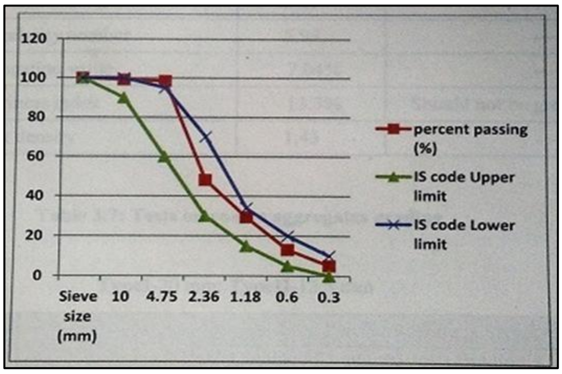

Fig. 1.2: Natural Sand Confirming to zone I

F. Tests Results of Natural Sand

Tests conducted	Results
Fineness modulus	3.03
Bulk density, g/cc	1.57
Specific gravity	2.67

G. Fine Aggregate (Manufactured Sand)

Manufactured sand nearby available is used in the present investigation. The properties of the manufactured sand are determined by various tests as per IS: 2386-Part3. The test results are shown in table and figure. The results show that the manufactured sand selected conforms to Zone-II.

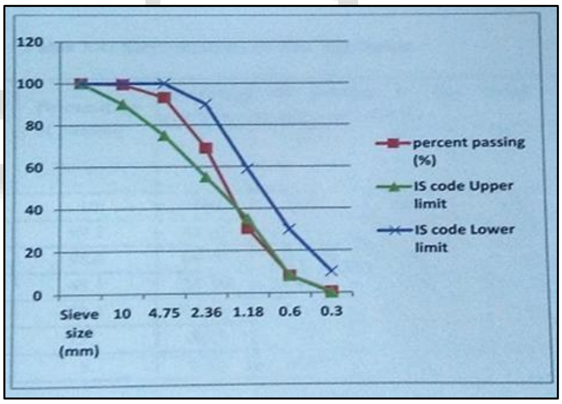

Fig. 1.3: Manufactured Sand Confirming to Zone-II

H. Test Results of Manufactured Sand

Tests conducted	Results
Fineness modulus	3.06
Bulk density, g/cc	1.60
Specific gravity	2.94

I. Coarse Aggregate

Aggregates are retained on IS sieve size 4.75mm are called course aggregates. Locally available crushed granite coarse aggregates are used in this study. The tests for physical properties on these are conducted as per IS: 383-1970 and the test results shown in Table 1.

Properties	Results
Aggregate impact value, %	18.59
Water absorption, %	0.4
Aggregate crushing value, %	27.80
Specific gravity	2.65

Angularity number	16.22
Elongation value	11.54 %
Flakiness index	19.9 %
Bulk density	2.65

Table 1: Test results on coarse aggregate

J. Water

Water is a very essential ingredient in the concrete. As it is necessary for hydration process. Potable water free from impurities and other substances is used for mixing and curing purpose. Water should meet the requirements stipulated in IS456:2000.

K. Mix Proportions

In the present study, IS: 10262-2009 method of mix design is used for arriving at the mix proportions.

L. Mix Proportions for Natural Sand

Description	M30
Water-cement ratio	0.45
Cement, kg/m^3	427
Fine aggregate (natural sand), kg/m^3	728.82
Coarse aggregate, kg/m^3, Type I (20 down) Type II (12 down)	649.8 433.2
Water, kg/m^3	192

M. Mix Proportions for Manufactured Sand

Description	M30
Water-cement ratio	0.45
Cement, kg/m^3	427
Fine aggregate (natural sand), kg/m^3	728.82
Coarse aggregate, kg/m^3, Type I (20 down)	671.14
Type II (12 down)	447.42
Water, kg/m3	192

N. Compressive Strength Test Results for Natural Sand

Specimen	7 days, N/mm^2	14 days, N/mm^2	28 days, N/mm^2
1	24.86	30.98	35.95
2	25.25	31.37	36.34
3	26.01	32.13	37.10
Average	25.37	31.19	36.46

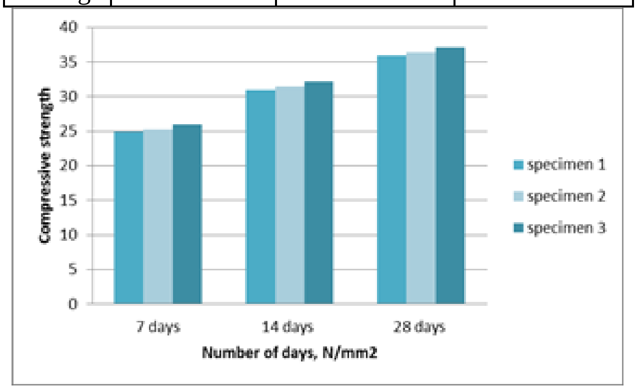

Fig. 1.4: Compressive Strength Test Result for Natural Sand

O. Compressive Strength Test Results for Manufactured Sand

Specimen	7 days, N/mm^2	14 days, N/mm^2	28 days, N/mm^2
1	25.04	31.28	36.04
2	25.38	31.86	37.86
3	26.94	32.74	37.56
Average	25.79	31.96	37.15

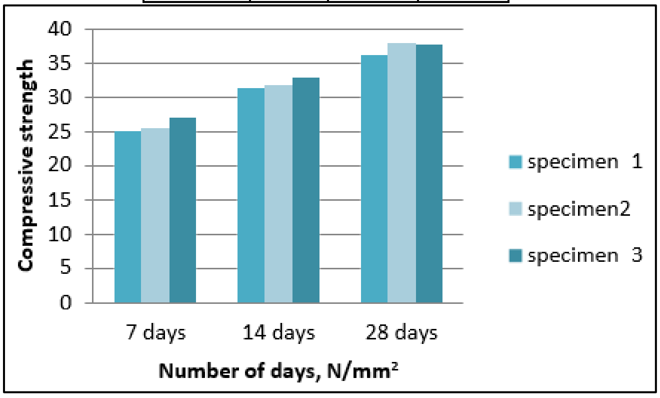

Fig. 1.5: Compressive Strength Test Result for Manufactured Sand

P. Splitting Tensile Test for Natural Sand

Split tensile strength is used to find concrete tensile capacity. Cylinders were prepared for testing. The loading test is conducted as per IS: 516-1959 on Cylinder specimens cured for 7days 14days and 28days to evaluate Tensile strength of concrete. The results are shown in the table

Specimen	7 days, N/mm2	14 days, N/mm2	28 days, N/mm2
1	2.19	2.68	3.32
2	2.25	2.71	3.26
3	2.31	2.81	3.35
Average	2.25	2.73	3.31

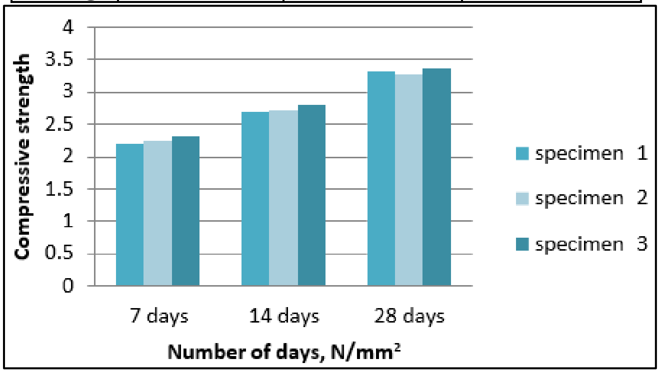

Fig. 1.6: Split Tensile Strength Test Result for Natural Sand

Q. Split Tensile Strength Test Result for Manufactured Sand

Specimen	7 days, N/mm^2	14 days, N/mm^2	28 days, N/mm^2
1	1.99	2.48	3.06
2	2.14	2.65	3.19
3	2.18	2.74	3.22
Average	2.10	2.62	3.15

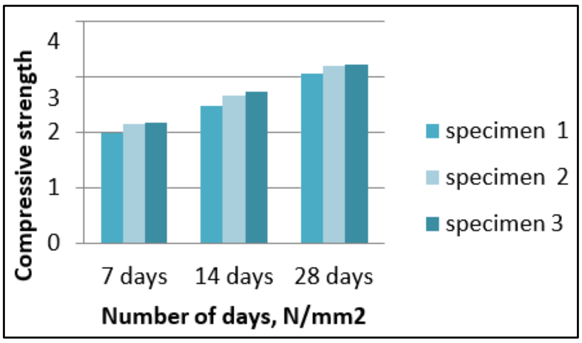

Fig 1.7: Split Tensile Strength Test Result for Manufactured Sand

R. *Slab Instrumentation*

Two concrete slabs are of size 1000mm x 600mm x 170mm (Natural sand) and 1000mm x 600mm x 170mm (Manufactured sand) are casted directly on soil and sand layer after excavating the earth surface to the required dimensions such that the slabs are confined on all sides.

"K-type" Thermocouples are fixed to a wooden bead using adhesive tape at three different levels depending on the thickness of the slab. The thermocouples are fixed at 50mm, 100mm, and 150mm from bottom as shown in Figure 3.12.The wooden beads are then placed at three regions of the excavated earth surface viz., interior, edge and corner. The concrete is first poured around the bead and then in remaining portions of the excavated pit. Precaution is taken not to damage or disturb the thermocouples during the compaction.

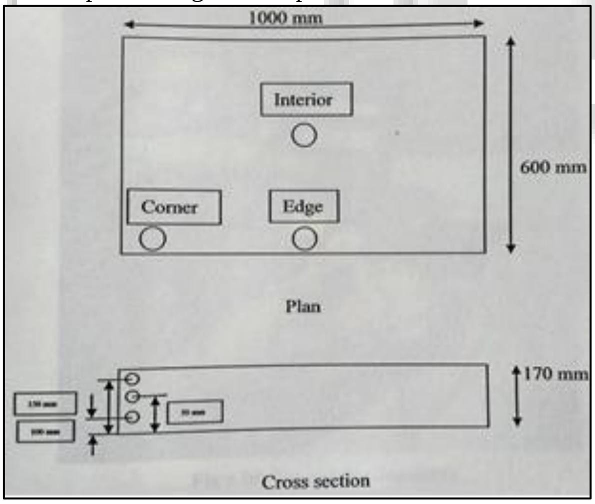

Fig. 1.8: Diagram Showing the Location of Thermocouples in the Slab

Fig. 1.9: Excavated Ground Surface

Fig. 1.10: Placing Of Thermocouples at Interior, Edge and Corner

Fig. 1.11: Finished Surface of Slabs

Fig. 1.12: Curing of Slabs

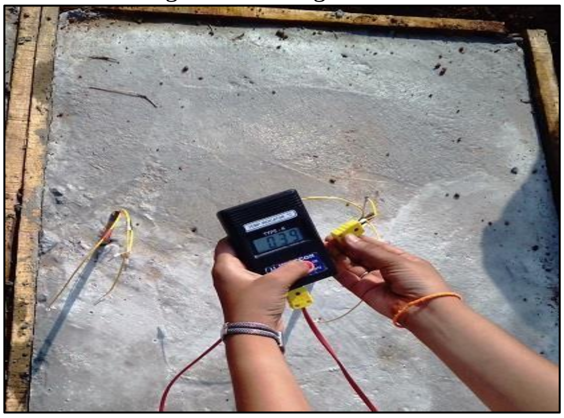

Fig. 1.13: Reading the Temperature

II. RESULTS & DISCUSSIONS

Table shows the peak positive temperature differentials (PPTD) and peak negative temperature differential (PNTD) values for all the interior, edge and corner region.

Slab	PPTD, ^{0}C	PNTD, ^{0}C
Natural sand	13	-11
Manufactured sand	7	-12

Table 2: Peak Temperature Differential in Slab

Slabs	Location	Temperature
Natural sand	Interior	8
	Edge	13
	Corner	6
Manufactured sand	Interior	6
	Edge	3
	Corner	7

Table 3: Peak Positive Temperature Differential in Slab

Slabs	Location	Temperature
Natural sand	Interior	-8
	Edge	-11
	Corner	-10
Manufactured sand	Interior	-9
	Edge	-12
	Corner	-9

Table 4: Peak Negative Temperature Differential in Slab

III. CONCLUSION

- Compressive strength of concrete is 1.89% more when it is cast with manufactured sand.
- Split tensile strength of concrete is 4.83% less when it is cast with manufactured sand.
- Temperature distribution throughout the thickness of slab is non-linear.
- Initial cost of construction or maintenance for concrete overlays is more compared to bituminous overlays. But over a period of time concrete overlays prove more economical.
- As a deflection increases strength of the slab decreases.
- Due to the scarcity of the natural sand, manufactured sand is widely used due to easy accessibility and low cost.
- Replacement of natural sand by manufactured sand does not affect the compressive strength of the concrete.

IV. SCOPE FOR FURTHER STUDY

- Different geographical location
- Different type and grade of concrete
- Varying slab dimension
- Varying material properties
- Different loading pattern
- Location of thermocouples at different region of the slab
- Different temperature sensors other than thermocouple
- Replacement of different materials in concrete
- Thermocouples can be used in reinforced cement concrete slabs or pavement

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