STUDY OF TEMPERATURE DIFFERENTIAL IN DIFFERENT TYPES OF CONCRETE SLABS

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ABSTRACT *The purpose of this study is to measure the changes of temperature in concrete slabs. Rigid pavements are observed due to variation of slab thickness with different mix proportions of M40concrete slabs at different layers.Temperature is an important factor, which influences stress and deflection in concrete slab. The temperature is recorded every hour for a period of seven days. It was observed that the temperature is more predominate at the top of the slab during day time when compared to bottom of concrete slabs and also observed that the temperature is more at the bottom of the slab during night time when compared to top of concrete slabs.Temperature data was collected at three different depth locations across the thickness of the concrete slab with the thermocouples which are embedded in the slabs through digital thermometer. The daily and seasonal variation in temperature is an important factor influencing cement concrete pavements. The temperature differential depends on the thickness of slab and the grade of concrete. In this study an effort is made to determine realistic temperature differential in pavement quality concrete andternary blend of GGBS and FLY ASHconcrete slab of different thickness. The Concrete slabs of size 500X500 mm of different 300, 250 and 200mm thickness are instrumented with thermocouples to record the temperature differential between top to bottom of the slabs. IRC: 58-2015 specifies a different temperature differential, which is considered to design the slab thickness. The temperature differential specified in IRC is recommended state wise, but the air temperature varies for different Regions, hence the temperature differentials are also likely to vary for different locations within the different regions and this will have major impact on design thickness of pavements. The study indicates the actual temperature differentials measured in the different types of concrete slabs.*

Keywords*: concrete, temperature stress, temperature gradient, thermocouples and Digital thermometer.*

I. INTRODUCTION

Concrete pavements have been utilized for all types of pavement applications including roadways, highways, parking facilities, industrial facilities and airfields. Concrete pavements offer a long-life, low-maintenance alternative for all pavement applications. A road surface or pavement is the durable surface material laid down on an area intended to sustain vehicular or foot traffic, such as a road or walkway. In the past, gravel road surfaces, cobblestone and granite sets were extensively used, but these surfaces have mostly been replaced by asphalt or concrete laid on a compacted base course. At present, the cement concrete pavement occupies a large proportion in the urban road construction of high-grade highways. At the same time, the road related research has also been carried out widely. Because Cement is a sensitive material, it is affected by stress. Stresses are divided into 3 categories:

1. Frictional stress
2. Temperature stress
3. Wheel load stress

This study is to find the temperature stress in conventional concrete, ternary mixture replaced with 30% of Fly ash and GGBS in concrete.The rigid pavements are of Portland cement concrete plain, reinforced or pre-stressed concrete. In this study, the behavior of temperature gradient for different thickness at different layers of concrete are studied and comparison is done with the temperature differential measured. The stresses developed in rigid pavement include load stress, shrinkage/expansion stress and temperature stress. Temperature stresses develop due to the change in temperature from top to bottom region of the concrete slab, hence the stresses in concrete also various with change in temperature differential.

Temperature stress is one of the main factors that destroy cement concrete pavement. It is the Temperature differential between the top and bottom of the slab causes curling (warping) stress in the pavement. If the temperature of the upper surface of the slab is higher than the bottom surface then top surface tends to expand and the bottom surface tends to contract resulting in compressive stress at the top, tensile stress at bottom and vice versa.

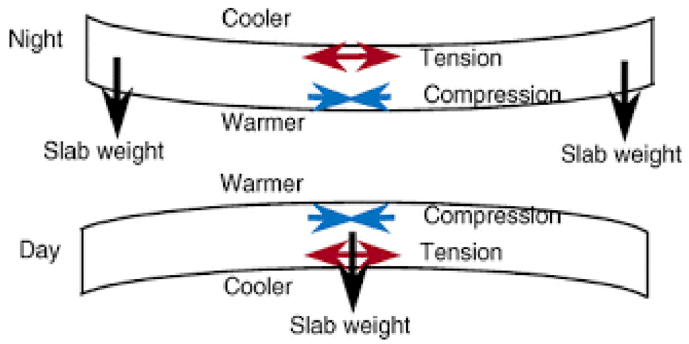

Fig: 1 Temperature stress

Temperature differentials

Maximum temperature differentials occur during the day in the spring and summer months.

•During midday of summer, the surface of the slab, which is exposed to the sun, warms faster than the subgrade which is relatively cool.

•During night time the surface of the slab becomes cool when compared to the subgrade.

•Usually, night time temperature differentials are one half the day time temperature differentials.

•The actual temperature differentials depend on the location.

•Temperature differential is expressed as temperature gradient per mm of slab thickness.

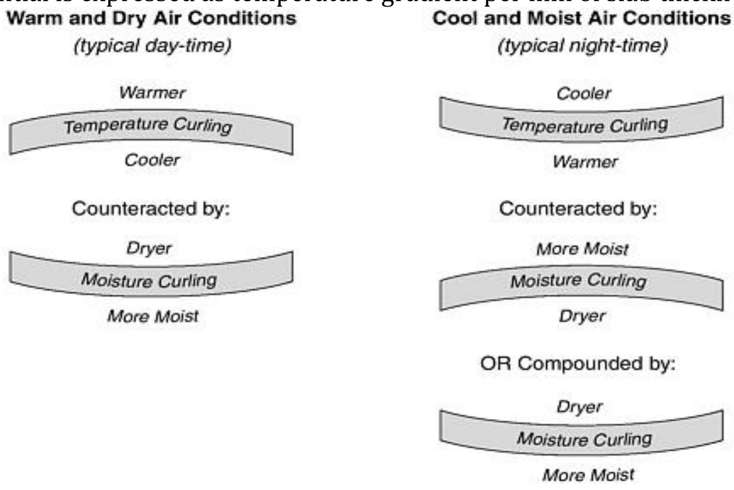

Fig: 2 Temperature stress in day-time and night time

Objective:

- ➢ The main objective is to study the behavior of the temperature variation in different concrete slabs of varying slab thickness.
- ➢ To find accurate temperature differential in pavement slabs.
- ➢ To find the properties of materials and to check Workability and properties of fresh concrete and characteristic strength of hardened concrete.

II. RESEARCH SIGNIFICANCE

The following authors have studied on the temperature stress, temperature gradient, warping stress due to changes in environmental condition and climatic condition:

Vineethraj B. Math et al[1]., studied the temperature differentials for varying slab thickness at moderate and high temperature regions viz., Bangalore and Gulbarga have been considered. The actual temperature differential measured is much less compared to that of specified by IRC: 58-2011.The temperature differential observed for 300mm thick slab is about 53% less than the Indian Road congressstandards and similarly it is less for remaining slab thickness less than 300mm. Mr.Dhananjay.M et al[2]., studied the temperature differentials depending on slab thickness and grade of concrete. Concrete is replaced by 50%

of cement by fly ash and 50% of cement by marble powder respectively, also to find compressive strength and static flexural strength at different periods of curing.Xiang-Shen et al[3]., studied cement concrete beam specimens were poured in outdoor and temperature sensor and strain sensor were buried in the cement concrete specimens to detect early-age internal temperature field and strain field, and then the study of built-in curling and Built-in construction temperature gradient were carried out.Peizhi Sun et al[4]., presented an approach that can be used to consider the effect of the quality of curing and the time of placement (collectively referred to as "curing effectiveness") on the development of the set gradient and its importance to long-term performance and also explained about laboratory and field protocol to monitor curing quality and facilitate an inspection program for concrete pavement construction and satisfy specification requirements to meet an expected design life. Dr. C.Yavuzturk et al[5]., studied accurate Knowledge of the temperature and thermal stress distribution in asphalt pavements will allow for a more sophisticated specification of asphalt binder grades for lower lifts and thus provide an economical solution to rising pavement construction cost.Tao Liu et al[6]., studiedthe main environmental factor influencing the temperature stress of cement concrete pavement are analyzed synthetically, and the calculationmethod of temperature stress of cement concretepavement isstudied by means of temperature estimation and finite element analysis. It resulted in a good effect on the calculation oftemperature stress.Fajing Pan et al[7]., studied there are alsoa lot of different considerations for temperature factors in different asphalt pavement design method and considering the experience of asphalt pavementin low temperature and high temperature.Shobha Rani Arangi et al[8]., presented a Review of models to predict high and low asphalt pavement temperatures in India and extends modelto incorporateeither the calculated daily solar radiation or latitudesuch that the model can be applied to any location in India.Mr. P. Sathish et al[9]., studiedTo reduce the cost of construction of rigid pavements, alternative materials are sought for and therefore fly-ash is used as a replacement for cement in cement concrete pavements which gives increased strength, thereby reduction in thickness of pavement is achieved. This is illustrated by designing two pavements, one: conventional and other: fly-ash replaced cement concrete pavement. The rigid pavement undergoes temperature, wheel load and frictional stresses. The temperature stresses depend upon the Temperature differential between the top and bottom of the slab, which is found out using thermocouples placed in the concrete at 2.5 centimetres from top and bottom of the concrete slab.

III. MATERIALS and METHODOLOGY

Concrete is a combination of Ordinary Portland Cement, fine aggregate, coarse aggregate and admixtures. Admixtures may be mineral or chemical admixtures. The admixtures used in this project are mineral admixture they are fly ash, GGBS and silica fume. Concrete used in this study are conventional concrete, ternary mixture in which cement is replaced with 30% of fly ash and GGBS in trial and error method as shown in table:

FLY ASH	5%	10%	15%	20%	25%
GGBS	25%	20%	15%	10%	5%

CEMENT: Cement is a binder, a substance used for construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement is used with fine aggregate to produce mortar for masonry, or with sand and gravel aggregates to produce concrete.

FINE AGGREGATE: Crushed stone sand is produced by crushing boulders. Manufactured sand is produced by rock-on-rock or rock-on-metal Vertical Shaft Impactor (VSI) in which the process that produced alluvial deposits is closely simulated. Particle size reduction and achieving equidimensional shape is critical to get desired properties. If rock is crushed in compression lot of inherent properties exhibited by natural river sand are lost. If proper technique of manufacturing is not adopted aggregates are bound to become flaky and elongated.

COARSE AGGREGATE: Coarse aggregate is a composite material that resist compressive stress and provide bulk to the composite materials but it have a wide variety of sizes.

ADMIXTURES:

FLY ASH: Fly ash is also known as pulverised fuel ash. It is also a coal combustion product but it is composed with particulates. Fly ash is generally captured by electrostatic precipitates, it includes substantial amount of silicon dioxide, aluminium oxide, calcium oxide.

GGBS: Fly ash is also known as pulverised fuel ash. It is also a coal combustion product but it is composed with particulates. Fly ash is generally captured by electrostatic precipitates, it includes substantial amount of silicon dioxide, aluminium oxide, calcium oxide.
Concrete used in this study to determine the effect of temperature in concrete pavement slabs. Concrete Mix is designed as per IS 10262:2009.

TABLE: 1Properties of materials used in the study

Sl no	Material	Properties	Results
1	Cement	Specific gravity Normal consistency	3.15 28%
2	Fine aggregate	Specific gravity	2.60
3	Coarse aggregate	Specific gravity	2.65
4 5	Fly ash GGBS	Specific gravity Specific gravity	2.2 2.8

a) CASTING OF CONCRETE SLABS
Slabs of size 50cmX50cm and thickness of 20cm, 25cm and 30cm are cast at selected site. Moulds are prepared to cast the slab.The moulds are cast directly on earth surface. The locations of slabs are exposed to sunlight. Surface is prepared before casting and thermocouples are fixed to wooden stick at three levels at top, middle and bottom of the stick

Fig: 3 Moulds for casting Fig: 4 fixing of thermocouples in wooden moulds

The wooden beads are placed in the mould and concrete is poured into the mould and compact the concrete around the thermocouples. Then all the 9 slabs are cast into similar way and kept for curing period of 3, 7 and 28 days.Temperature is recorded after curing of slabs using digital thermometer as shown in figure6.The indicator is connected to the thermocouple leads. When the indicator is connected it displays the temperature directly in degree. The temperature reading is recorded every hour for a period of 7 days.

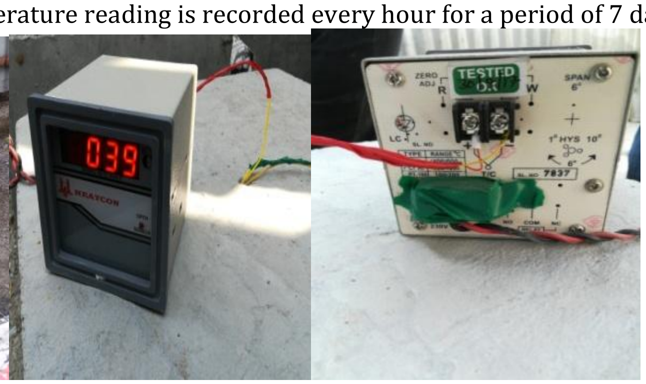

Fig: 5 curing of slab Fig: 6 Temperature recording at site

IV. STRENGTH OF CUBES
The strength investigation conducted on concrete cubes:

a) Compressive strength of concrete cube

The cube specimen of mixes is tested for compressive strength at 3, 7 and 28 days of curing.

Fig: 7 curing of cubes

Compressive strength of cubes: It is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstands loads tending to elongate.

Fig: 8 compressive strength of cube

V. RESULTS

For each concrete mix, the compressive strength is determined on three 150X150X150mm cubes at 3, 7 and 28 Days of curing.

Table: 2 Compressive strength

M40 Grade	**Conventional concrete**	**Ternary mix**
7 days	33.43N/mm^2	43.78 N/mm^2
28 days	44.58 N/mm^2	46.33 N/mm^2

The compressive strength of ternary mix concrete is higher compared to normal concrete.The results obtained from the present investigation conducted on normal M40 concrete slabs and M40 Ternary mixture of GGBS and Fly ash Concrete slabs are quoted.

The maximum positive temperature differential occurred during a day and negative differentials at night. The variations of positive temperature differentials are higher than that of negative temperature differential as show in the Table 3 and 4.

Table: 3 Positive andNegative temperature differentials for Conventional concrete

Depth of slab	30cm	25cm	20cm
Positive temperature differentials	15	12	11
	14	12	9
	13	10	12
	15	12	11
	12	13	13
	14	12	8
	14	10	10
Depth of slab	30cm	25cm	20cm
Positive temperature differentials	-6	-5	-5
	-6	-6	-4
	-6	-6	-4
	-5	-6	-5
	-6	-5	-5
	-6	-6	-5
	-5	-5	-4

Table: 4 Positive andNegative temperature differentials for Ternary mixture concrete

Depth of slab	30cm	25cm	20cm
Positive temperature differentials	10	12	10
	10	11	10
	11	12	10
	10	11	8
	11	9	8
	11	9	7
	10	9	8
Depth of slab	30cm	25cm	20cm
Positive temperature differentials	-4	-5	-5
	-6	-6	-6
	-7	-6	-6
	-6	-7	-6
	-6	-6	-7
	-6	-6	-6
	-7	-7	-7

The maximum positive and negative temperature differentials in normal pavement quality concrete slab are 15 and -6 respectively. The maximum positive and negative temperature differentials in ternary mixture concrete slab are 12 and-7 respectively. The temperature differentials in ternary mix concrete observed are less than the normal concrete.

VI. CONCLUSION

Analysis was performed on pavements, one is conventional concrete, other is ternary concrete pavements and following conclusionis drawn:

1. Compressive strength of ternary mix concrete cubes (150X150mm) increased up to 31%.
2. From the observations, temperature differential is more in normal concrete slab when compared ternary concrete slab.
3. The maximum positive and negative temperature differentials in normal pavement quality concrete slab are 15 and -6 respectively.
4. The maximum positive and negative temperature differentials in ternary mixture concrete slab are 12 and -7 respectively.

The actual temperature differential measured is much less compared to that of specified by IRC 58-.2015. Hence,ternary mixture concrete can be used for pavement construction.

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