Available online at www.scholarsresearchlibrary.com

Scholars Research Library

European Journal of Applied Engineering and Scientific Research, 2015, 4 (2):35-43
(http://scholarsresearchlibrary.com/archive.html)

ISSN: 2278 – 0041
CODEN(USA): EJAEAJ

Study of temperature differential in different concrete slabs of varying slab thickness in different regions

Vineethraj B. Math[1,2], Akshatha Sheregar[2] and G. Kavitha[2]

[1]*Department of Civil Engineering, K.L.E.I.T, Hubli, Karnataka, India*
[2]*Department of Civil Engineering, RASTA-Centre for Road Technology VTU-Extension Centre, Bangalore, Karnataka, India*

ABSTRACT

In this paper the curling behaviour of rigid pavements are observed due to variation of slab thickness in different regions with two different mix proportions of M40concrete slabs at different layers. Top layer of slab will have high temperature compared to bottom layer at day time which will be vice versa at night. To sustain these stresses, IRC: 58-2011 specifies different temperature differentials, 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 within the state, 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. In the present study the temperature differentials for varying slab thickness at moderate and high temperature regions viz., Bangalore and Gulbarga have been considered. The study indicated that the actual temperature differentials measured even for Gulbarga (where temperature is high 41 degrees) was only 12.1 degrees maximum while the recommended temperature differential in IRC is 21 degrees which is about 73.5% high which leads to overestimate the slab thickness.

Keywords: Temperature differential, curling behavior, Thermocouples.

INTRODUCTION

Temperature differential is the important parameter considered for design of rigid pavements. IRC 58-2011 has specified some temperature differentials for different states. Rigid pavements are those which posses flexural strength & flexural rigidity. It is observed that, stresses are not transmitted from grain to grain to the lower layer as in flexible pavement layers. The rigid pavements are of Portland cement concrete plain, reinforced or pre-stressed concrete. In this study the temperature differential for high temperature region Gulbarga is selected and the behaviour of temperature gradient for different thickness at different layers of concrete are studied and comparison is done with the temperature differential measured at Bangalore Region. The temperature differential for all the regions in the state may not be same so to compare the temperature differential at Bangalore region [13] with the temperature differential observed at Gulbarga will indicate the behaviour of temperature differentials. 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 the bottom region of the concrete slab, hence the stresses in concrete also various with change in temperature differential.

Temperature is an important environmental factor that influences the performance of concrete pavements. Warping, which results from the temperature gradient between the concrete pavement top and bottom surfaces, induces stresses in the pavement, as the pavement is restrained by its weight. The thermally induced stress caused by such interaction may result in early pavement cracking [11]. This also results in a loss of support along the slab edges or at the slab interior. The effect of the loss of support results in higher stresses as the sub-base becomes stiffer. This may become critical, particularly within a few hours after slab placement, since hydration of concrete at early stage may not have sufficient strength to prevent cracking. Temperature increase due to hydration does not immediately produce thermal stresses because of the process of stress relaxation or creep in the concrete. Thermal stresses arise when the temperature drops after its peak value and the concrete has set.

Temperature stresses in Portland cement concrete (PCC) pavement can be classified into two types- curling stress and thermal expansion stresses. Curling stresses result observed from temperature differential between the top and bottom of a Pavement Quality concrete pavement. This tendency to curl induces stress in the pavement as the pavement is restrained by its weight and support pressure from the sub-grade layer. Depending on the external position of applied load and the time, curling stresses may be sufficiently high causing failure of the slab. Temperature stresses can also occur in PCC pavements as a result of uniform temperature changes that cause's the slab to contract or expand.

Field observation quotes that the maximum difference in the temperature between the top surface mid width is about twice the difference between the mid depth and the bottom of slabs and the peak temperature differential (PTD) during the night hours is about half of the daytime PTD.

LITERATURE REVIEW

The primitive approach used for temperature stress is that given by Westergaard. Westergaard's equation is based on assumption of linear temperature gradient supported on Winkler foundation and concrete slab being linear, isotropic. Based on Westergaard's solution, Bradbury arrived at a solution for a slab with finite dimension. Teller and Sutherland reported the results conducted on concrete pavements to study the effect of temperature variations on pavement stresses. There results showed that temperature distribution throughout the pavement thickness is highly non-linear. An analytical solution for the effect of temperature stresses was also introduced by different researchers. Based on Westergaard's solution other analytical solutions were introduced to solve for pavement stresses.

Sandeep M [13] through his thesis work "*study of thermal gradient in concrete slabs through experimental approach - 2012*" Studied the thermal properties of PQC and High volume fly ash concrete at Bangalore region, Concrete slabs of size 500X500 mm and of different thickness were instrumented with thermocouples to record the temperature differential between top, middle and bottom layers of the slabs. It was observed that the temperature was more predominant at the top of the slab when compared to bottom of concrete slabs during day time and also observed that the temperature was more at the bottom of the slab when compared to top of concrete slabs during night time. The temperature gradient in concrete slabs achieved equilibrium two times a day i.e. during morning hours and also during evening hours. The observed maximum positive and negative temperature differentials for different thickness of slabs are quoted in Table I **Puttappa C G [11]** "Experimental studies in the high performance concrete" studied the properties of HPC with the thermal properties and their investigation revealed that the temperature differential in HPC is lower than the values suggested by IRC 58:2011 and the temperature differential varies with the slab thickness. The values suggested for Karnataka region is high to the extent of 6°C .It also suggests that the thickness of the slab can be reduced to considerable extent for the same design condition which is proved by taking a case study on normal and high performance concrete.

Siddique [9], have studied that curling generally results from the temperature differential across the concrete slab thickness. Curling induces stresses in the pavement slab that may contribute to early-age concrete cracking. This study deals with the field measurement of temperature and curling on a newly built jointed plain concrete pavement. The pavement section consisted of a 12-inch concrete slab, 4' bound drainable base, and 6' lime treated subgrade. Temperature data was collected at five depth locations across the thickness of the concrete slab with the digital data loggers embedded in the slabs. Curling was measured on five different days in the summer and fall with a simple setup. The results show that both upward and downward curling increase as the temperature differential increases. The magnitude of curling deflection resulting from a particular positive temperature differential is slightly higher than that resulting from the same negative temperature differential value. The in situ curling can be simulated with a properly built finite model. Since the temperature differential has a significant influence on curling, the effect of curling can be mitigated at an early age of pavement concrete with perfect measures, such as enhanced curing.

Tien [14] have studied that pavement temperature differential causes thermal stresses in concrete pavements. This paper works with a closed-form model to analyze the effect of nonlinear temperature distribution on thermal warping stresses in concrete pavements. This model was developed at the National University of Singapore for a single rectangular slab with four free edges resting on a Pasternak foundation. It takes into consideration the exact slab dimensions, the effect of subgrade inter-locking action and the effect of transverse shear deformation. The effects of the following factors on warping stresses in concrete pavement were analyzed: (1) horizontal slab dimensions, (2 slab thickness, (3) slab elastic modulus, (4) modulus of subgrade reaction, and (4) temperature profile across slab thickness. For each of the factors analyzed, the variation between stresses computed based on linear and nonlinear temperature profiles respectively are computed and the need for considering nonlinear temperature distribution is assessed.

Table I: Temperature differential

Sl No	Slab thickness(mm)	Temperature differential	Bangalore Region(°C)	
			PQC	HVFC
1	150	max positive temperature differential	7.4	5.9
		max negative temperature differential	-2.8	-1.8
2	200	max positive temperature differential	8.8	7.8
		max negative temperature differential	-3.3	-4.0
3	250	max positive temperature differential	9.9	10.6
		max negative temperature differential	-4.1	-4.0
4	300	max positive temperature differential	11	11.0
		max negative temperature differential	-4.7	-4.2

Michael Edward Robbins [1] studied the Development of temperature differential prediction models for different types of HPC pavements" suggests that environmental parameters are to be considered to get realistic temperature differentials in HPC pavements & temperature differential is different on different grade of concrete. Temperature differential in PQC is more compared to silica fume concrete & high volume fly ash concrete.

K.Eswaramma and K.Rajasekhar [12] studied on concrete properties by silica as a replacement. Silica fume is a highly reactive pozzolanic material primarily composed of silicon dioxide (SiO2) in noncrystalline form. It is a thin dark gray or bluish green-gray powder produced by an electric arc furnace during the manufacture of silicon or ferrosilicon alloy. It has a spherical like fly ash, but it is hundred times smaller, with an average dia size of 0.1 µm. Its specific surface area is very large compared to Portland cement.

PRESENT STUDY

Conventional Pavement Quality and Concrete with silica fume as an admixture are designed to M40 compression strength (per IS 10262:2009.). These concrete slabs with varying thickness are used in this study to evaluate the temperature differentials in Concrete pavement slabs in high temperature region. The high temperature region selected is Gulbarga and the studies are carried out at PDA College Gulbarga (with their approval).

The physical properties of the materials used in this study were determined in the laboratory. Tests were carried out on fine aggregates, coarse aggregates, cement and silica fume and samples confirming to IS standards were selected.

Silica fume is a by-product from electric arc furnaces used in the manufacture of silicon metal of silicon alloys. The material, which contains more than 80% silica in no crystalline state and in the form of extremely fine particles (0.1 um average diameter), is highly pozzolanic. This product is excellent for use as a Portland cement supplement In addition to economic and energy saving potential, the use of pozzolanic admixtures in concrete leads to several technical advantages, such as reduction in thermal cracking caused by heat of cement hydration, improved durability to attack by sulphate and acidic waters, and high ultimate strength. Unlike other by- product pozzolans such as fly ashes, a unique feature of CSF is that it has a better faster pozzolonic action. It is especially good for high temperature conditions as per ACI 234R-06.

Mix design is done as per IS 10262: 2009 using the material satisfying IS Standard. Two types of mix for 40 MPa is designed one without any admixture and other with silica-fume.

The obtained mix proportion for normal M40 concrete is 1: 1.68: 2.4 and for M40 silica fume concrete is 1: 1.86: 2.7: 0.08.

Cube specimen of PQC and Silica fume concrete are prepared as per mix proportion and tested in a compressive testing machine for cube compressive strength at 3,7 and 28 days of curing. The flexure strength of PQC &Silica fume concrete beam specimens were determined using third point loading method. Loading is done continuously without any shock. Reaction shall be parallel to the direction of the applied force at all times during the test and the ratio of distance between the point of load application and nearest reaction to the depth of the beam shall not be less than one. The test has been done for 7 and 28 days of curing. Slabs of size 500mmx500mm with thickness 150, 200, 250, and 300 mm are casted on site at Gulbarga. The site has been selected such that it is exposed to sun light. The slabs are directly casted on earth surface. Total eight numbers of slabs are casted, in which four slabs are of normal PQC and rest are of Silica fume concrete. The form works of slabs to be casted and placing of thermocouples are presented in Fig. 1. Thermocouples are fixed to a wooden strip at calculated heights to reach top, bottom and middle layer of slab. The thermocouples arrangement are placed at the time of casting.

Fig.1 Form work and placing of Thermocouple

Fig.2. Concrete slabs with thermocouple

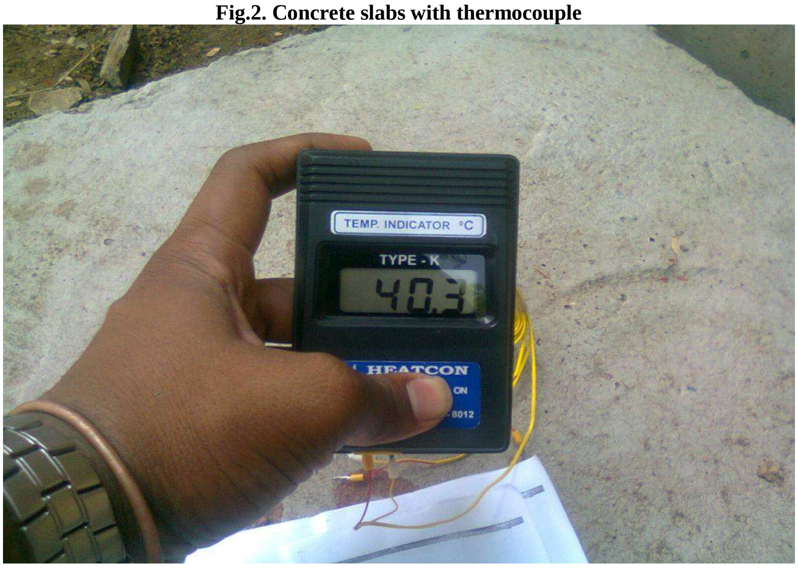

Fig.3 Temperature reading using Thermocouple

Thermocouples are provided with two open ends which can be connected to the digital temperature reader to get the display of temperature at the corresponding junction, which is embedded in concrete. A thermocouple is a sensor for measuring temperature. It consists of two different metals, combined together at one end, which produce a small unique voltage at a given temperature. This voltage is measured and interpreted by thermometer. Thermocouple generates the voltage which intern the voltage is converted to temperature reading which can be read in Digital temperature indicator. Temperatures are recorded after 28 days of curing. As shown in Fig. 2 and Fig. 3.

I. DATA COLLECTION AND ANALYSIS

Using hand held digital temperature indicator the temperature readings of different layers of slab has been taken, as the thermocouple has been placed at three layers top, middle and bottom layer of slab. Temperatures are recorded after 28 days of curing for both the plain concrete as well as Silica fume concrete. The temperature readings are recorded for top, middle & bottom layer of the normal concrete and Silica Fume concrete slabs, every hour for a period of two days and the corresponding air temperature is noted down. M40 Normal concrete at Gulbarga Region and readings of M40 Silica Fume concrete are noted. Graphical Representation of the Temperature readings are presented in Fig 4 to Fig 7 for Normal M40 Concrete and from Fig 8 to 11 represents the Temperatures of M40 Silica Fume Concrete for varying thickness.

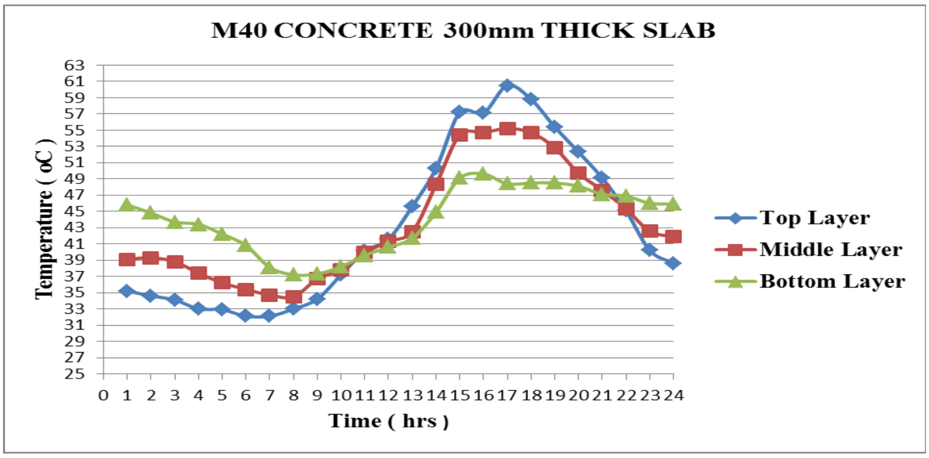

Fig.4 Temperature differential graph for normal M40 of 300mm thick

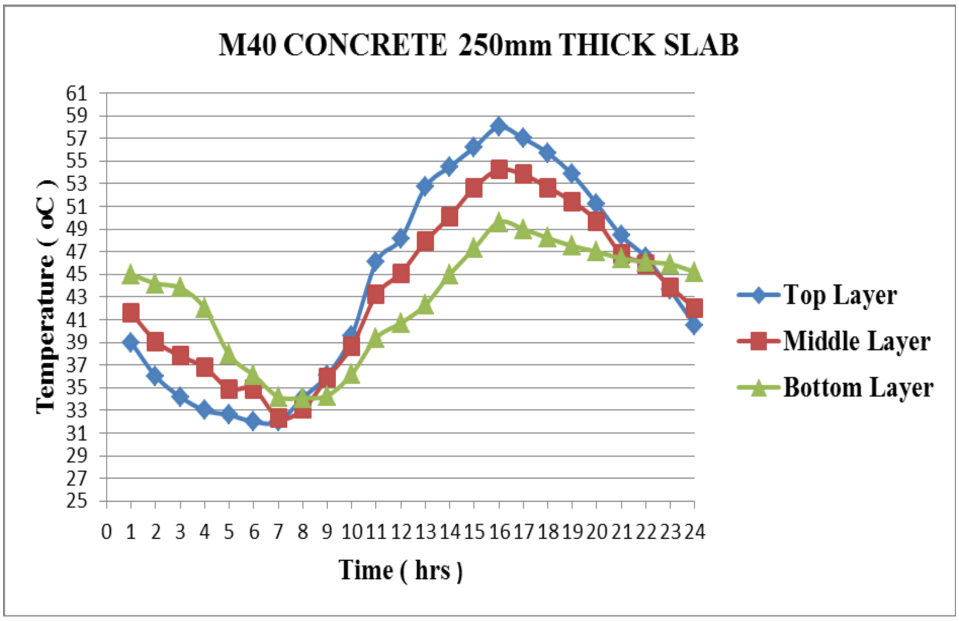

Fig. 5 Temperature differential graph for normal M40 of 250mm thick

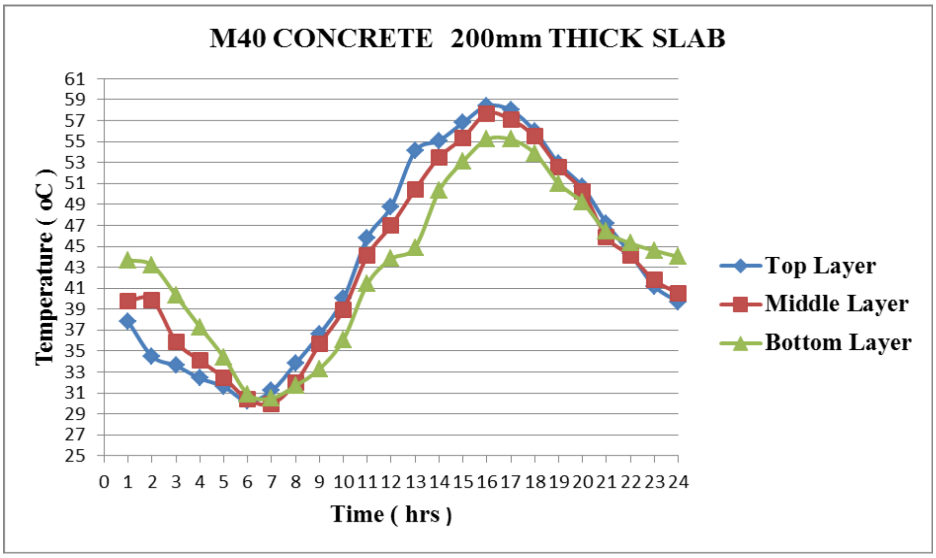

Fig. 6 Temperature differential graph for normal M40 of 200mm thick

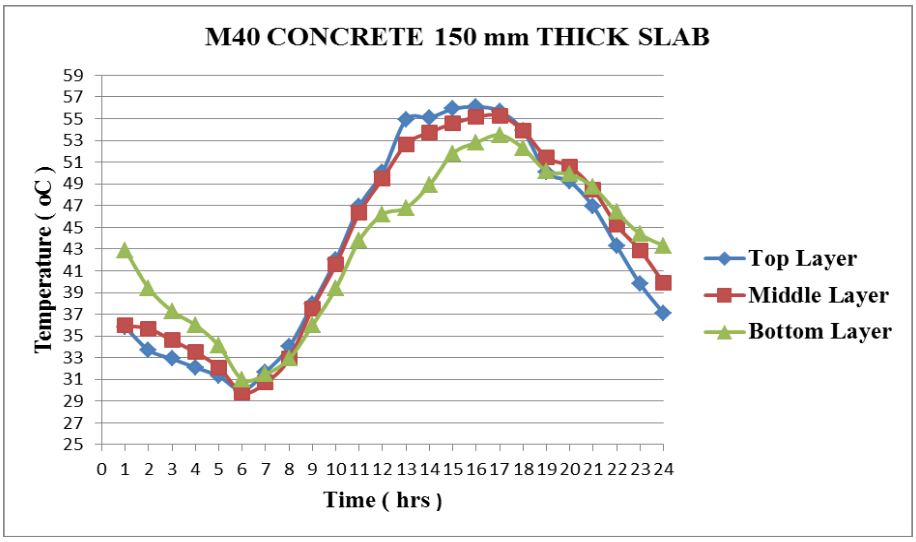

Fig. 7 Temperature differential graph for normal M40 of 150mm thick

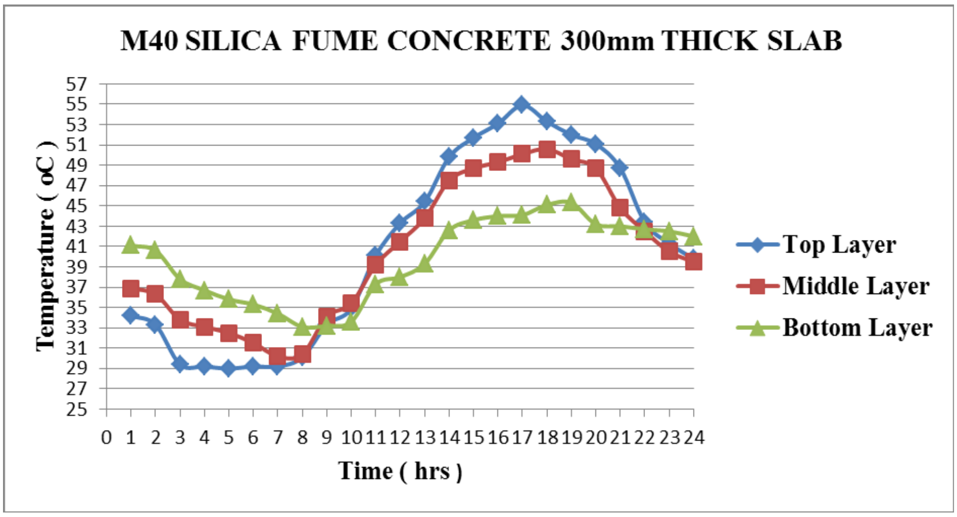

Fig. 8 Temperature differential graph for M40 silicafume of 300mm thick

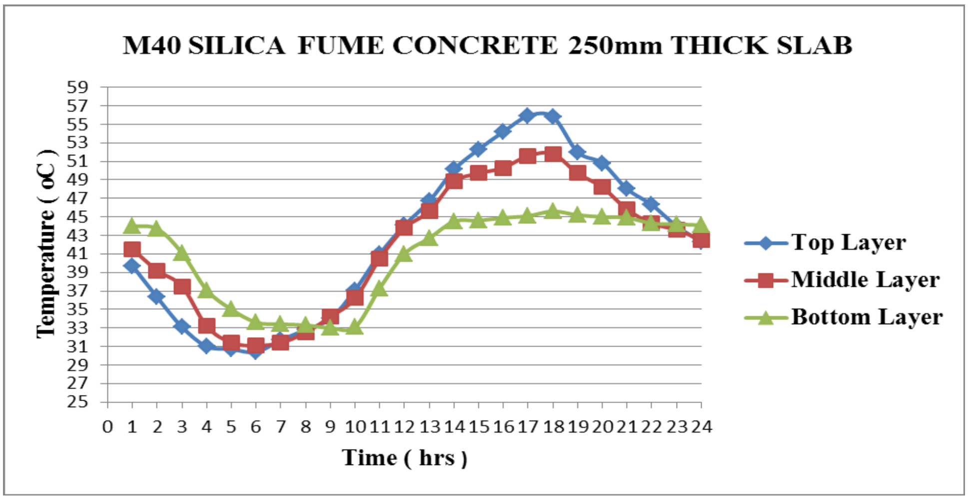

Fig. 9 Temperature differential graph for M40 silicafume of 250mm thick

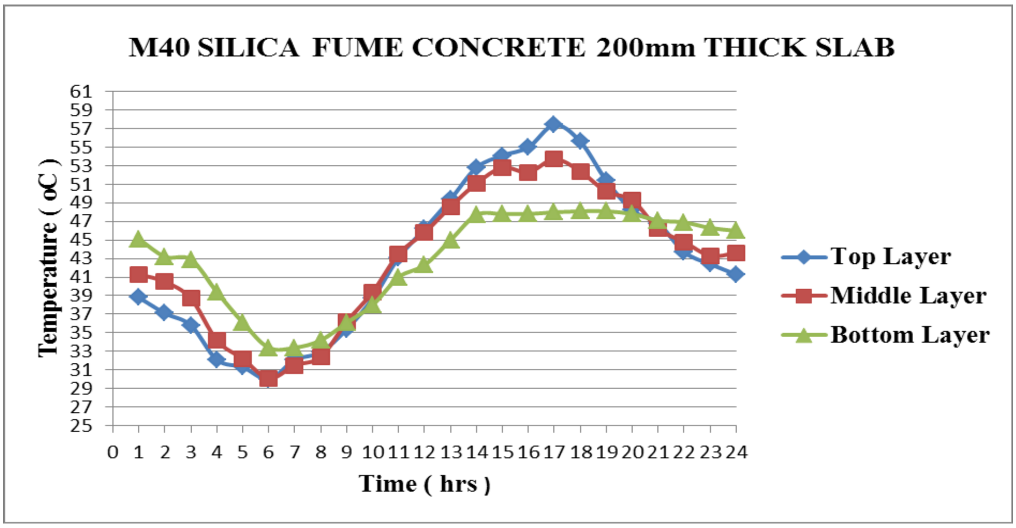

Fig. 10 Temperature differential graph for M40 silicafume of 200mm thick

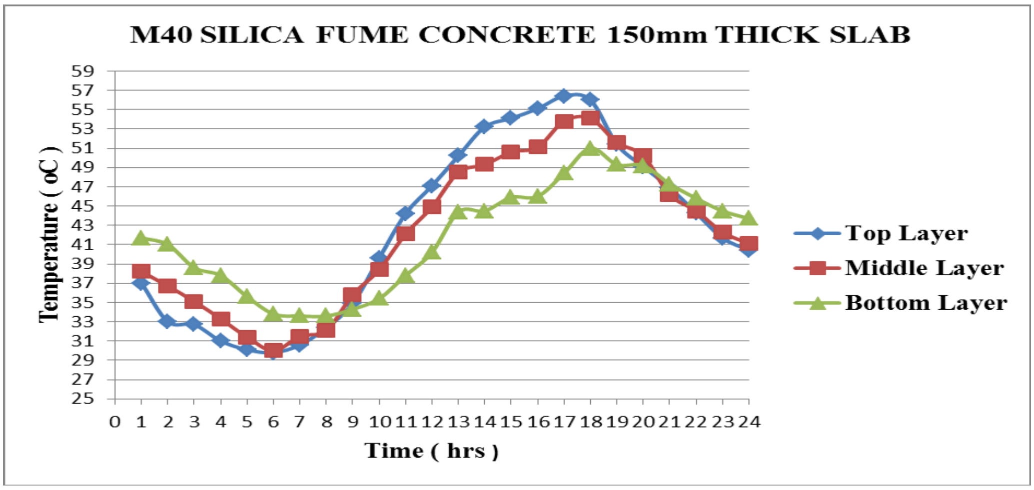

Fig. 11 Temperature differential graph for M40 silicafume of 150mm thick

Table II: Temperature differential variation

Sl No	Slab thickness (mm)	% variation from IRC specification with Gulbarga region	% variation from IRC specification with Bangalore region
1	150	53.18	57.23
2	200	51.58	53.68
3	250	48.77	51.23
4	300	42.38	47.62

The maximum positive and negative temperature differentials observed in Gulbarga are higher than the temperature differentials of Bangalore region. The percentage variations of this variation are quoted in the Table II.

RESULTS AND DISCUSSION

The results obtained from the present investigation conducted on normal M40 concrete slabs and M40 Silica fume 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. The variations of maximum positive and negative temperature differentials of Gulbarga region are higher than that of Bangalore Region. Design a cement concrete pavement thickness constructing over a granular sub base of modulus of reaction 15 kg/ cm^2. The spacing between transverse joint is 4.5 m and between long joints 3.5 m. The design wheel load is 12000 kg. E value = 3 x 10^5 kg/cm2, Poisson's ratio = 0.15, Co- efficient of thermal expansion =10 x 10^{-6} per, Maximum sustainable stress =45 kg/cm^2.

Table III: Pavement thickness Variation

Particular	Design slab thickness (mm)	Percentage variation (%)
Design as per IRC 58-2002 Specification	320	28
As per temp diff at Gulbarga region	250	

At the identical conditions of parameters with varying Temperature differential, the thicknesses are designed and the cost comparison for the same thicknesses with the width of 3.5m pavement for a stretch of 1km is represented in Table III.

1. The maximum positive and negative temperature differentials in normal pavement quality concrete slab is 12.1 and -10.6 respectively.
2. The maximum positive and negative temperature differentials in Silica fume concrete slab is 11 and -9.8 respectively
3. The temperature differentials in silica fume concrete observed are less than the normal concrete.
4. The variation of maximum **Positive** temperature differentials obtained in Gulbarga
Region with the Temperature differentials in Bangalore region is less about 4 to 9 %.
5. The variation of maximum **Negative** temperature differentials obtained in Gulbarga
Region with the Temperature differentials in Bangalore region is high about 50 to 60%.
6. The temperature differentials observed even in High temperature region are much higher than the IRC 58: 2011 Specifications for the Design of Plain jointed concrete pavements
7. Percentage variations of temperature differentials observed in this study with the IRC standards is about 42 to 53 % less.
8. Design of plain jointed concrete pavements for temperature differentials observed in Gulbarga region and specified by IRC results in 28% reduction in Observed temperature differential.
9. The cost of construction with higher thickness obviously increases the cost of construction for the same requirement of sustainability.

CONCLUSION

As the main objective is to, Study the behaviour of the temperature variation in different concrete slabs of varying slab thickness in different regions. The maximum positive and negative temperature differentials in high temperature region and comparatively low temperature are varying from 9.8 to 12.1^{o}C and this is even less for Silica fume concrete mix of M40 each.

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 congress standards and similarly it is less for remaining slab thickness less than 300mm. Design thickness of Rigid pavements are reduced by 20 to 30% for different loading conditions. This will have a major impact on total cost of construction. There is a need to modify the Temperature differentials specified by IRC 58 with reference to regions but not referring the States as a whole area. The temperature differential cannot be considered common for all regions within a given state.

Acknowledgments
One of the authors Prof. Vineet B.Math gratefully acknowledges Prof. G. Kavitha and Dr. Krishnamurthy for the kind sustainable support and fruitful discussions, during the project.

REFERENCES

[1] Michael Edward Robbins, "Predicting Temperature Rise and Thermal Cracking in Concrete"- © Thesis, portland cement association (Skokie, Illinois, **2007)**.
[2] Federal Highway Administration (FHWA),"Silica Fume User Manual"-**2003**.
[3] IRC: 58, "Guidelines For The Design Of Plain Joint Rigid Pavements For Highway", *Indian Road Congress, New Delhi* – **2002**.
[4] IS: 10262, "Recommended guidelines for Concrete Mix Design" *Bureau of Indian Standards, New Delhi*-**2009.**
[5] IS: 2386, Methods of Test for Aggregates for Concrete", *Bureau of Indian Standards, New Delhi*. – **1963**.
[6] IS: 456, Code of Practice for Plain and Reinforce Concrete", *Bureau of Indian Standards, New Delhi.* – **2000**.
[7] M.S.SHETTY, Concrete Technology, Theory and practice, S.chand &co.ltd, New Delhi **2003** 4th edition.
[8] Mallikarjuna, "Evaluation of Temperature Stress in High Performance Concrete Pavement Admixed with Silica Fume" ME Thesis Report (Unpublished) Submitted to Highway Engineering Section of Department of Civil Engineering Bangalore University (Bangalore, India).
[9] Tarun R. Naik, Bruce W. Ramme, Rudolph N. Kraus, and RafatSiddique., *ACI Material Journal*, , **2003**, Vol.100, Issue:2 pp.150- 155.
[10] Punith B, "Studies on Temperature stresses in Concrete Pavements using Ansys"- Thesis Report (Unpublished) Submitted to Department of Civil Engineering PDA Gulbarga, Visvesvaraya Technological University (Gulbarga, India, **2011)**.
[11] Puttappa, C.G, Experimental Studies on the High Performance Concrete, Thesis Report Early View Study of Thermal Gradient in Concrete Slabs through Experimental Approach © 2014 Global Journals Inc. (US) Global Journal of Researches in Engineering ( ) Volume XIV Issue V Version I 15Year 2014 E Submitted to Highway Engineering Section of Department of Civil Engineering Bangalore University (Bangalore, India, **2005)**.
[12] K.Eswaramma, K.Rajasekhar *International Journal of Advanced Technology in Engineering and Science*, May **2015**, Volume No.03, Issue No. 05.
[13] Sandeep M, Study of thermal gradient in concrete slabs through experimental approach – Thesis Report (Unpublished) Submitted to Department of Highway Technology IR RASTA Bangalore, Visvesvaraya Technological University (Bangalore, India, **2012).**
[14] Tien Fang, *Journal of the Eastern Asia Society for Transportation Studies*, October **2003**, Vol.5.
[15] Yoder, E.J. and Witczak, M.W, Principles of pavement Design", Second Edition, *John Wiley and Sons*- **1975**.