A Study On Evaluation Of Temperature Stresses In Fiber Reinforced Concrete Slabs

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Abstract - Temperature is an important parameter which affects the design and performance of both flexible and rigid pavements. Temperature variations within the rigid pavement structure induces many distresses. Knowledge of temperature effects is essential for the design and maintenance requirement. The temperature differential depends mainly on the thickness of slab and the grade of concrete. In this study an effort is made to design M-40 grade concrete mix as per IRC:44-2008 and to determine realistic temperature differential and temperature stresses in pavement quality concrete, fiber reinforced concrete slabs of different thickness i.e., 150 mm and 200 mm. The optimum dosages of the fibers are fixed based on the mechanical and durability properties of the concrete. The Concrete slabs of size 500X500 mm are cast by adding optimum dosages of crimped steel and polypropelyne fibers and placed on the prepared subgrade and instrumented with thermocouples to record the temperature differential in the slabs. The temperature is recorded every hour for a period of seven days during summer and monsoon season of the year to study the variation of temperature. It is 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. A rigid pavement is designed for an assumed traffic as per IRC:58-2011 by doing bottom-up and top-down cracking analysis. It is observed that thickness requirement for steel fibre and polypropelyne fiber reinforced concrete pavement is lesser as compared to the conventional concrete for the same traffic. Among steel and polypropelyne fibers, steel fibers will give satisfactory results and hence preferred.

Keywords: Fibers, Cracking, Crimped steel fiber, Polypropelyne, Temperature variation, Thermocouple, Traffic.

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1 INTRODUCTION

Construction of a highway involves huge outlay of investment. A precise engineering design may save considerable investment and reliable performance of the in-service highway can be achieved. Two important things are considered in flexible pavement, pavement design and the mix design. A good design is expected to result in a mix which is adequately (i) Strong (ii) durable (iii) resistive to fatigue and permanent deformation (iv) environment friendly (v) economical and so on. A mix designer tries to achieve these requirements through anumber of tests on the mix with varied proportions and finalizes with the best one.

Rigid pavements possess high compressive strength and transmits the wheel loads mainly by slab action. Minor imperfections and localized weak spots in the material below the slab can be taken care by the slab itself and this type of pavement surface can be selected on weak soils also. Rigid pavement is more precise to structural analysis than the flexible pavement. This is because flexural strength is the main basis for design. On the other hand design of flexible pavement is based on empirical method. The initial cost of concrete pavement is high but they require least maintenance and lasts for a longer period. As petroleum products are exhausting day by day, it is necessary to adopt rigid pavements than the flexible pavements.

Concrete pavement design has so far become a more important part of concrete roads. A high investing cost has to be motivated, and the benefits of a pavement with less maintenance over a longer design life have to be proved already before construction. Efforts to avoid premature performance failing of concrete roads are, at a larger degree, considered than for other pavement alternatives since rehabilitation techniques are expensive. A modern design methodology has to take into account all sorts of environmental conditions as well as future estimations on, for example traffic growth or environmental changes. The optimization of materials in the pavement system, demands for long-term fatigue resistance at the lowest cost and ecologically sound choices must be considered. The understanding of the behaviour of a concrete road is vital for the design and the performance prediction.

1.1 Components Of A Rigid Pavement

The rigid pavement structure typically consists of the following layers:

(a) prepared soil subgrade
(b) granular sub-base course as drainage layer
(c) base course (Dry lean concrete)
(d) Pavement quality concrete

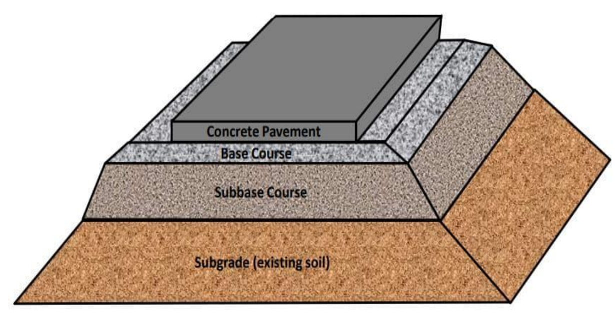


Figure 1. Typical layers in rigid pavement

Soil Subgrade

The soil subgrade is prepared by naturally available soil or borrowed from approved soil pits. The stability of pavement surface depends upon the stability of its subgrade soil. It governs the performance, life span and effectiveness of the pavement. The entire load coming over the pavement is ultimately transferred to the subgrade. The soils of subgrade are subjected to lower stresses than the surface and subbase courses. These stresses decrease on increasing with depth. Unusual conditions, such as a layered subgrade or sharply varying water content or densities, may change the locations of the controlling stress. The soils investigation should check for these conditions. Since subgrade soils vary considerably, the interrelationship of texture, density, moisture content, and strength of subgrade material is complex. The capacity of a particular soil to resist shear and deformation will vary with its density and moisture content. In this regard, the soil profile of the subgrade requires careful examination. The soil profile is the vertical arrangement of layers of soils, each of which may possess different properties and conditions.

Granular Sub-Base

GSB is the layer between the base course and subgrade. It functions primarily as structural support but it can also minimize the intrusion of fines from the subgrade into the pavement structure and improve drainage. Presence of excess moisture in subgrade soils will cause early failures of concrete pavement due to mud pumping. The subbase also serves to control frost action, provide subsurface drainage, control swelling of subgrade soils, provide a stable construction platform for rigid pavement construction, and prevent mud pumping of fine-grained soils. Rigid pavements generally require a minimum subbase thickness of 4 inches (100 mm).

Base Course

Base course lies below the surface course and constructed by using crushed aggregate, soil-aggregate mixture, cement treated granular materials etc. However, on roads carrying heavy to very heavy traffic loads, high quality base course material such as lean cement concrete or dry lean concrete are preferred. A separation layer consisting of a suitable type of membrane is laid over the DLC base course before laying PQC slab with a sensor paver.

Surface Course Or Wearing Course

M-40 grade cement concrete mix with a minimum flexural strength of 45 kg/cm^2 is recommended by the IRC for use in the CC pavements of highways which carry heavy to very heavy traffic loads. It is expected to withstand the flexural stresses caused by traffic and warping effects in the cc slabs.

1.2 Necessity Of Fiber Reinforced Concrete

- It increases the tensile strength of the concrete.
- It reduces the air voids and water voids the inherent porosity of gel.
- It increases the durability of the concrete.
- Fibers such as graphite and glass have excellent resistance to creep, while the same is not true for most resins. Therefore, the orientation and volume of fibers have a significant influence on the creep performance.

1.3 Effects Of Temperature In The Concrete Pavement

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. 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.

1.4 Temperature Stresses In The Rigid Pavement

Temperature stresses in a cement concrete pavement can be classified into two types – curling stresses or warping stress and thermal- expansion stresses. Curling stresses results when there is a temperature differential between the top and bottom of 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. Depending on the position of the externally applied load and the time of the day, curling stresses can be sufficiently high causing the failure of slab. Temperature stresses can also occur in rigid pavements as a result of uniform temperature changes that cause the slab to contract or expand.

Whenever the top & bottom surface of a concrete pavement simultaneously possess different temperature, the slab tends to warp down ward or upward inducing warping 9stress. Due to uniform temp rise & fall in the cement concrete slab, there is an overall expansion & contraction of the slab. Since the slab is in contact with soil sub grade or the sub- base, the slab movements are restrained due to the friction between the bottom layer of the pavement & the soil layer. The frictional resistance therefore tends to prevent the movement thereby inducing the frictional stress in the bottom fiber of the cement concrete pavement. Stress in slabs resulting due to this phenomenon vary with slab length. Temperature tends to produce two types of stress in a concrete pavement these are,

- Warping stress (curling stresses)
- Frictional stresses

Warping Stress (Curling Stresses):

Whenever the top & bottom surface of a concrete pavement simultaneously possess different temperature, the slab tends to warp downward or upward inducing warping stress. By the time the top temperature increases to t1 degree, the bottom temperature may be only t2 degree the difference between the top & bottom of the slab would be (t1-t2) = t °C.

Frictional stresses:

Due to uniform temperature rise and fall in the concrete slab, there is an overall expansion and contraction of the slab.

1.5 Thermocouples

Thermocouple is a type of temperature measuring device. Mainly it is used for measuring the temperature at one particular point. In other words, it is type of sensor used for measuring the temperature in the form of an EMF or the electric current. It usually consists of two wires of different metals and they are welded together at ends. The welded portion was creating the junction where the temperature is used to be measured. Variation in the temperature of wire induces the voltage. In the present study K-type thermocouples are used.

K-type Thermocouple:

Type K-thermocouples usually work in most applications as they are mainly nickel based and exhibit good resistance to corrosion. It is the most common sensor calibration type providing the widest operating temperature range. Due to its reliability and accuracy the Type K thermocouple is used extensively at temperatures up to 2300°F (1260°C). This type of thermocouple should be safely protected with a suitable metal or ceramic protection tube, especially in reducing atmospheres. K-type thermocouple is as shown in figure 2.

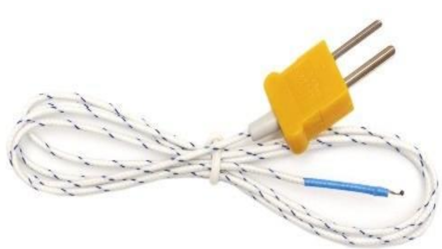


Fig 2. K-type Thermocouple

2 OBJECTIVES OF THE STUDY

- To find the difference in temperature differential between the conventional and fiber reinforced concrete slabs.
- To study the daily variation of temperature differential of cast concrete slabs.
- To evaluate the temperature stresses developed in the conventional and fiber reinforced concrete slabs.
- To design a rigid pavement for an assumed traffic conditions as per code IRC:58.

3 LITERATURE REVIEW

Dhananjay M et al (2014) In this paper an effort is made to determine realistic temperature differential and temperature stresses in pavement quality concrete, high volume fly ash concrete slab and high-volume marble powder concrete slab of different thickness. It was concluded that High volume fly ash concrete slabs are found to gain compressive strength in gradual way at higher curing stages as compared to PQC. The obtained temperature differential of HVFAC and HVMPC are lower than suggested value by IRC 58:2002 for the design of concrete pavement. Lesser the temperature difference in HVFAC and HVMPC shows that warping stresses in HVFAC and HVMPC pavement will be lesser than normal PQC. Due to the reduction in the total stresses in the pavements, hence the thickness will be less than the conventional concrete pavement.

Vineethraj B. Math et al (2015) In this paper the warping behaviour of rigid pavement is observed due to variation of slab thickness in different regions with two different mix proportions of M-40 grade concrete. Thermocouples are fixed to a wooden strip at calculated heights to reach top, bottom and middle layer of slab. The temperature reading for every hour for a period of two days were recorded. Finally, it was concluded that the temperature differential cannot be considered common for all regions within a given state.

Vijay kumar C S et al (2017) In the present study, three different mix proportion models of (S1) cast with N-sand, (S2) cast with M-sand and (S3) cast with equal proportion of M-sand and N-sand were prepared. The analysis is based on the temperature variation is linear throughput the depth of the models. There modules of different materials properties are cast, instrumented with K-type thermocouple at different levels top, middle and bottom and the actual temperature in the models are recorded every hour for 28 days using a digital temperature recorded. the result obtained from the study clearly shows that the actual temperature variations are non-linear.

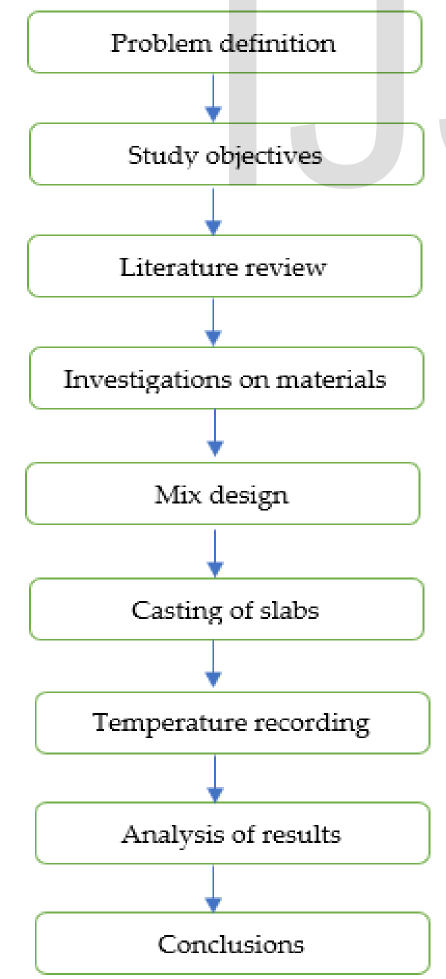
Renuka R et al (2018) In this paper, an attempt is made to evaluate the stresses due to the actual temperature distribution across the thickness of the slab. Two slabs of different material properties are cast instrumented with K-type thermocouple at different level viz., top, middle and bottom and the actual temperature in the slabs are recorded every hour for 28 days using a digital temperature recorder. The result obtained from the study clearly shows that the actual temperature differentials are Non-linear.

Kamalakara G. K et al (2018), "Study of temperature differential in different types of concrete slabs" The purpose of this study is to measure the temperature changes in concrete slabs. From the studies it was found out that 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.

Sathish P et al (2017) "Effects of Warping Stresses on Rigid Pavements – An experimental investigation" To minimize the construction cost of rigid pavements, alternative materials are sought for and therefore fly-ash is used as a blending material for cement in rigid pavements. The objective of the project is to reduce the cost of rigid pavement by replacing certain quantity of cement with fly-ash thereby reducing the effect of warping stresses in rigid pavement. From the observations, temperature differentials are more in normal concrete pavement when compared to fly-ash blend concrete pavement. Due to the replacement of 30% of cement with the fly-ash, the reduction in the pavement thickness is 4.6cm when warping stresses are alone considered. From the rate analysis, the percentage of reduction in the cost due the replacement of fly-ash is about 13.7%.

4 METHODOLOGY

In the present study crimped steel and polypropylene fibersare selected. The methdology adopted is as shown in figure.



5 EXPERIMENTAL INVESTIGATIONS ON MATERIALS

In the present study materials such as cement, fine aggregate, coarse aggregate, superplasticizers (Sika fluid) and water are used.

5.1 Cement

In the present study OPC 53 grade cement conforming to IS: 12269-1987 is used. The quantity of cement required for the experiments is collected from single source and stored in a nearly airtight container. The tests are conducted on cement to obtain Specific gravity, Normal consistency, Initial setting time and Compressive strength.

Table 1. Physical properties of cement

Physical properties of cement			
Sl. No.	**Details of test**	**Test Results**	**Requirements as per IS: 12269-1987**
1	Specific Gravity	3.12	2.9-3.15
2	Soundness	1.23	Less than 10 mm
3	Fineness of cement	3.10	Less than 10%
4	Standard Consistency	28%	Not Specified
5	Setting time (in minutes)		
	Initial Setting time	135	Shall not be less than 30 minutes
	Final Setting Time	235	Shall not be more than 600 minutes

5.2 Fine Aggregate

Locally available M-Sand obtained from Quarry near to Bangalore city is used. The Physical properties of M-Sand are determined by conducting tests as per IS: 2386-part3 and IS: 383-2016. The test results are shown in the Table 2. The Fine aggregate satisfies the requirement of grading Zone-II as per IS: 383-2016.

Table 2. Sieve Analysis of Fine Aggregate

Sieve Size	**Percentage passing**	**As per IS: 383 – 2016 (% passing)**			
		Zone I	**Zone II**	**Zone III**	**Zone IV**
10 mm	100	100	100	100	100
4.75 mm	95.40	90-100	90-100	90-100	95-100
2.36 mm	79.60	60-95	75-100	85-100	95-100
1.18 mm	71.00	30-75	55-90	75-100	90-100
600µm	47.70	15-34	35-59	60-79	80-100

300µm	21.90	5-20	8-30	12-40	15-50
150µm	6.20	0-10	0-10	0-10	0-20

5.3 Coarse Aggregate

Locally available crushed granite coarse aggregates are used in the present study. The tests for physical properties on coarse aggregates are conducted as per IS: 383-2016 and the test results are shown in Table 3.

Table 3. Test results of Coarse Aggregates

SI. NO.	Property	Test results	Requirement as per MORT&H (V revision) 2013
1.	Aggregate impact value, %	24.02	30% max
2.	Water absorption, %	0.40	2.0% max
3.	Abrasion value, %	25.14	30% max
4.	Aggregate crushing value, %	25.84	30% max
5.	Specific gravity	2.74	---
6.	Combined Flakiness and Elongation Index (%)	28.28	35% max

5.4 Water

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. In the present investigations potable water free from all salts and other impurities is used for mixing and curing of concrete as per IS: 456-2000.

5.5 Chemical Admixture

Admixture is defined as a material, other than cement, water and aggregates that is used as an ingredient of concrete and is added to the batch immediately before or during mixing. Additive is a material which is added at the time of grinding cement clinker at the cement factory.

Superplasticizers (High Range Water Reducers):

Superplasticizers mainly constitute a relatively new category and improved version of plasticizers, the use of which was developed in Japan and Germany during 1960 and 1970 respectively. They are chemically different from that of normal plasticizers. Use of superplasticizers permit a reduction in water content to the extent upto 30 per cent without reducing workability of concrete. In the present investigation Sika is used as superplasticizer. The superplasticizer used in the present study is collected from "Durgamba Build Solutions" near RR Nagara in Bengaluru and the properties are as shown in Table 4.

Table 4. Properties of superplasticizer (Sika fluid)

Property	Description
Form	Liquid
Color	Yellow
Relative density	1.080
pH value	4.3
Chloride content	<0.1
Alkali content	0.6
Dosage	0.6

*The properties are tabulated as provided by the manufacturer.

5.6 Fibers

Fiber is a small piece of reinforcing material possessing certain characteristic properties. They can be circular or flat. The fiber is often described by a convenient parameter called "aspect ratio". The aspect ratio of the fiber is the ratio of its length to its diameter. Typical aspect ratio ranges from 30 to 150. In the present studies crimped steel and polypropylene fibers are used. Polypropylene fibers and steel fibers used in this study are collected from Ana Enterprises near Sudhama Nagara, Bengaluru and Sanjay implex near Bilekahalli, Bengaluru respectively.

Table 5. Properties of crimped steel fiber

Property	Specifications
Density	7860kg/m^3
Ultimate strength	1500Mpa
Modulus of elasticity	2×10^5Mpa
Poisson's ratio	0.28
Length	35mm
Diameter	0.35mm
Aspect ratio	100

*The properties are tabulated as provided by the manufacturer.

Table 6. Properties of polypropylene fiber

Fiber type	Recron 3S
Tensile strength	700Mpa
Modulus of elasticity	3.5Mpa
Elongation	25%
Specific gravity	0.9
Filament diameter	0.01mm

*The properties are tabulated as provided by the manufacturer.

6 MIX PROPORTIONS OF M-40 GRADE CONCRETE

The minimum flexural strength required for cement concrete pavements to resist the load and temperature stresses under the worst exposure conditions as per IS specifications is 45Kg/cm². Keeping this point in mind proportioning of concrete mix to get the target cube strength of 40Mpa was initially aimed to satisfy the flexural requirements of the rigid pavements. Mix design was done as per IRC:44-2008. The mix proportions of different constituent materials were as given in Table 7.

Table 7. Mix proportions of M-40 grade concrete

Material	Quantity
Cement	392 kg
M-sand	706 kg
Coarse aggregate	1275 kg
Water	149 lit.
Superplasticizer	2.35 lit.
W/C ratio	0.38
Mix proportion - 1:1.80:3.25	

7 MODEL STUDIES ON CONCRETE SLABS

Considering the importance of temperature stresses in cement concrete pavement design, an attempt was made to study the temperature variations in the pavement slab of size 500 X 500mm and with thickness of 150mm and 200mm are made. In the present study two fibers namely crimped steel and polypropylene fibers are used and the slabs are reinforced with optimum fiber content. Total of six slabs are cast i.e., two conventional, two SFRC and two PFRC slabs of thickness 150 mm and 200mm. The results are compared with the conventional concrete specimens of the same dimensions. The moulds used for the present study are as shown in the below figure 3.

Figure 3. Moulds for Casting

7.1 Preparation Of Subgrade And Casting Of Slabs

A trench had dug up to a depth of 50cms, and soil is laid in the trench and well compacted up to 30cms and surface is levelled. Moulds are placed in the excavated trench. According to mix design cement, coarse aggregates, fine aggregates and water are mixed in proportion and laid and well compacted.

Conventional M-40 grade concrete slabs of size 500 mm x 500 mm of varying thickness are cast according to designed mix proportions. The slab thickness considered are 150 and 200 mm. The location for casting of the slab is identified such that it is exposed to sun light. The slab is directly cast on prepared earth surface. The thermocouple fixed to wooden beads of size 10mm x 10mm at three levels that is 25mm from top, 25mm from bottom and at the middle of the beads.

Figure 4. Subgrade preparation

Figure 5. Dry mixing of materials

Figure 6. Mixing of constituent materials

Figure 7. compaction and finishing of the mix

Figure 8. Model concrete slab

7.2 Temperature Recording Of Concrete Slabs

Temperatures are recorded after 28 days of casting by using a digital temperature indicator. The temperature indicator has two leads which are connected to the two leads of the thermo-couple. When temperature indicator is activated it displays the temperature directly in degree centigrade. The temperature is recorded every hour for a period of 7-days.

Figure 9. Temperature recording using digital indicator

8 ANALYSIS OF TEMPERATURE DATA

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. Temperature is recorded after 28 days of curing for both the plain concrete as well as fiber reinforced concrete slabs.

8.1 Variation Of Temperature With Time

By using a digital temperature indicator hourly temperature for a period of 7 days for summer and monsoon seasons are collected. Graphical representation of hourly variation and daily variation of temperature is presented in this chapter. By using this data temperature stresses are calculated.

8.2 Evaluation Of Temperature Stresses Using Westergaard's Approach

Due to variation in the temperature exapansion and contraction of the concrete takes place. This thermal variation will lead to the development of thermal stresses in pavement. Therefore, temperature stress is a very important factor to design the pavement. To determine the temperature stresses in concrete slabs the temperature differentials measured are considered. The stresses are calculated using Westergaard's equations in a pavement slab of standard size 3500 x 4500 mm.

Table 8. Temperature data collected for conventional concrete slab

Time	Air Temp.	Conventional (150mm)			Conventional (200mm)			Humidity (%)
		T	M	B	T	M	B	
1.00 AM	26	32	33	34	30	32	34	63
2.00 AM	24	32	33	34	30	32	34	69
3.00 AM	24	30	33	35	29	32	35	72
4.00 AM	23	30	31	32	29	32	34	80
5.00 AM	23	30	30	30	29	32	34	82
6.00 AM	23	29	30	30	29	31	32	83
7.00 AM	23	31	31	30	30	31	32	77
8.00 AM	25	32	31	29	32	32	31	60
9.00 AM	28	33	31	29	34	32	30	50
10.00 AM	27	33	31	29	35	33	30	55
11.00 AM	29	34	33	32	36	33	30	44
12.00 AM	35	36	34	31	37	34	30	40
1.00 PM	35	38	35	31	39	35	31	38
2.00 PM	35	42	37	32	43	37	31	39
3.00 PM	32	39	36	32	42	37	32	40
4.00 PM	33	37	36	34	38	35	32	41
5.00 PM	31	36	35	34	36	34	32	42
6.00 PM	32	35	36	36	35	34	33	44
7.00 PM	31	35	36	36	35	34	33	46
8.00 PM	26	35	36	36	34	34	34	48
9.00 PM	28	34	35	36	34	34	34	51
10.00 PM	28	34	35	35	34	35	35	51
11.00 PM	28	33	34	35	33	34	34	56
12.00 PM	26	33	34	35	33	33	33	59

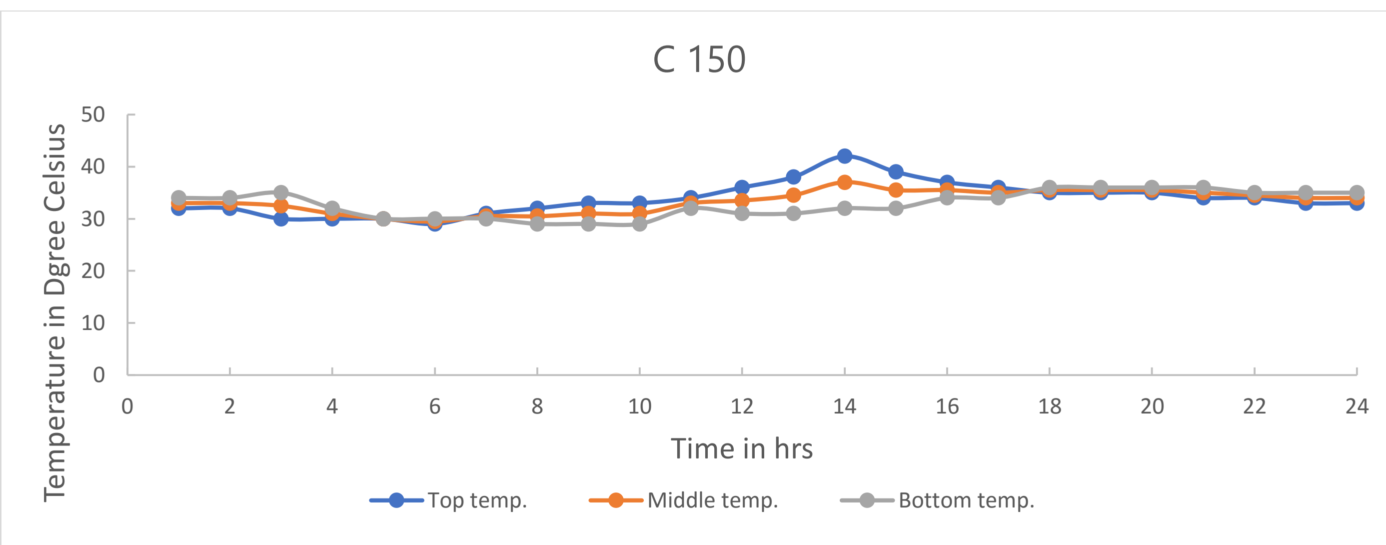


Figure 10. Variation of temperature with time for conventional concrete slab of thickness 150 mm

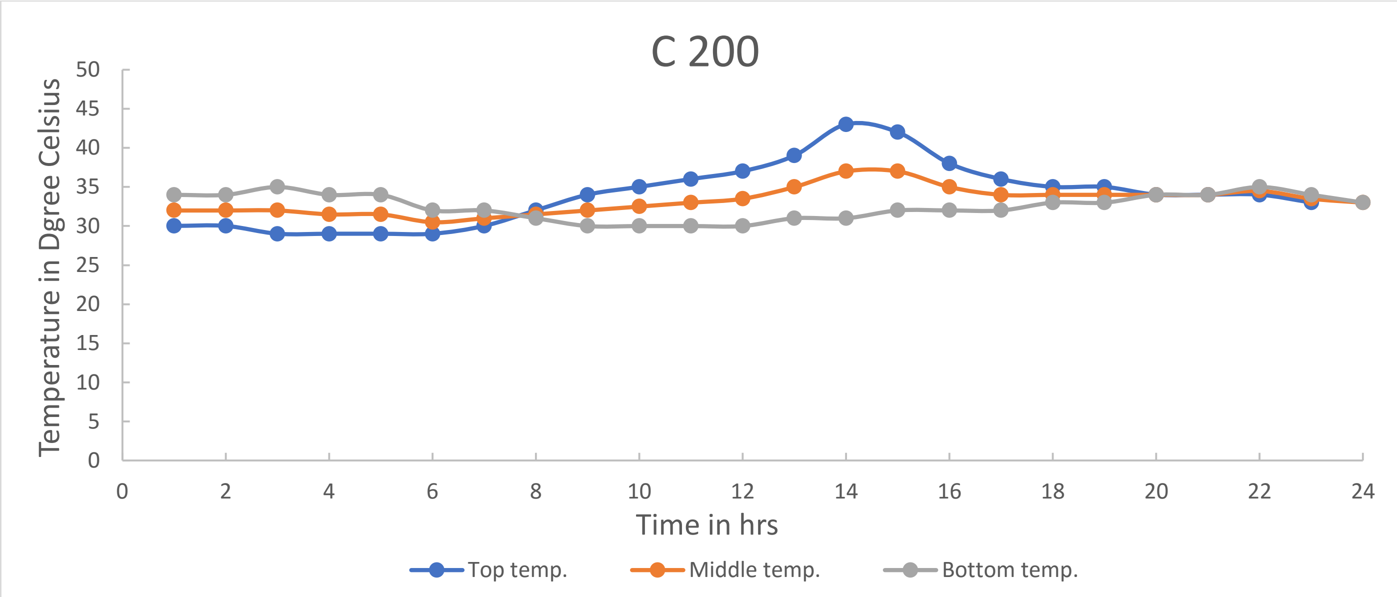


Figure 11. Variation of temperature with time for conventional concrete slab of thickness 200 mm

Table 11. Daily variation of temperature differential in Conventional concrete during summer season

Conventional concrete	150 mm		200 mm	
	Max positive	Max negative	Max positive	Max negative
Day 1	9	-5	12	-6
Day 2	8	-4	11	-6
Day 3	9	-5	11	-6
Day 4	10	-5	12	-6
Day 5	9	-4	12	-6
Day 6	9	-5	12	-6
Day 7	9	-5	12	-6

Table 12. Daily variation of temperature differential in steel fiber reinforced concrete during summer season

SFRC	150 mm		200 mm	
	Max positive	Max negative	Max positive	Max negative
Day 1	7	-3	8	-4
Day 2	6	-4	8	-4
Day 3	6	-4	8	-5
Day 4	6	-3	8	-4
Day 5	6	-4	7	-4
Day 6	6	-4	7	-4
Day 7	6	-3	8	-3

Table 13. Daily variation of temperature differential in polypropylene fiber reinforced concrete during summer season

PFRC	150 mm		200 mm	
	Max positive	Max negative	Max positive	Max negative
Day 1	6	-4	7	-5
Day 2	6	-4	8	-5
Day 3	7	-4	8	-5
Day 4	6	-4	8	-5
Day 5	6	-4	7	-5
Day 6	6	-4	8	-5
Day 7	7	-4	8	-4

Table 14. Comparison of maximum temperature differentials in the slabs

Slab type	Temperature differential	
	Max. positive	Max. Negative
SFRC 150	7	-3
SFRC 200	8	-4
PFRC 150	7	-4
PFRC 200	8	-4
C 150	9	-5
C 200	12	-6

Table 15. Comparison of maximum temperature differentials in the slabs

Slab type	Temperature stresses (kg/cm^2)	
	Max. positive	Max. Negative
SFRC 150	16.16	7.94
SFRC 200	17.18	8.54
PFRC 150	17.08	9.82
PFRC 200	17.58	10.10
C 150	18.79	10.27
C 200	20.54	10.44

9 Design Of Rigid Pavement

Rigid pavements design code IRC 58 aims at design of pavements by considering the combined flexural stresses under the simultaneous action of load and temperature gradient for different category axles. In the present study an attempt is made to design the rigid pavement for a two-way two-lane road by considering an assumed traffic of 2500 CVPD and design life of 30 years.

Input data:

Type of pavement
Design period - 30 years
Lane width - 3.5 m
Transverse joint spacing - 4.5 m
Traffic - 2500 CVPD in each direction
Modulus of subgrade reaction (K-value) - 5.5 kg/cm^3
Young's modulus of concrete:
For conventional M-40 concrete - 38115 Mpa
Steel fiber reinforced concrete - 52543 Mpa
Polypropylene fiber reinforced concrete - 48557 Mpa
Temperature differential:
For conventional M-40 concrete - 12 ^{0}C
Steel fiber reinforced concrete - 7 ^{0}C
Polypropylene fiber reinforced concrete - 8 ^{0}C
Flexural strength:
For conventional M-40 concrete - 4.64 N/mm^2
Steel fiber reinforced concrete - 6.22 N/mm^2
Polypropylene fiber reinforced concrete - 5.81 N/mm^2

Design - By adopting modulus of subgrade reaction as 55 Mpa/m and provide 150 mm thick granular sub-base and 150 mm thick DLC with a minimum 7day compressive strength of 10 Mpa. Effective modulus of subgrade reaction of combined foundation of granular sub-base and DLC (from table of IRC 58) = 285 Mpa/m. provide a debonding layer of polythene sheet of 125micron thickness between DLC and concrete slab. Bottom-up cracking and top-down cumulative fatigue analysis is carried out and thickness required for different type slabs are calculated and the thicknesses are as shown in below table 16.

Table 16. Thickness for different slabs:

Slab type	Thickness required (in cm)
Conventional M-40 concrete	22
Steel fiber reinforced concrete	15
Polypropylene fiber reinforced concrete	17

10 DISCUSSION OF RESULTS

Temperature Differential:

- Maximum positive and negative temperature differential in conventional concrete slab of thickness 150 mm is 10 ^{0}C and -5 ^{0}C respectively.
- Maximum positive and negative temperature differential in conventional concrete slab of thickness 200 mm is 12 ^{0}C and -6 ^{0}C respectively.
- Maximum positive and negative temperature differential in steel fiber reinforced concrete slab of thickness 150 mm is 7 ^{0}C and -3 ^{0}C respectively.
- Maximum positive and negative temperature differential in steel fiber reinforced concrete slab of thickness 200 mm is 8 ^{0}C and -4 ^{0}C respectively.
- Maximum positive and negative temperature differential in polypropylene fiber reinforced concrete slab of thickness 150 mm is 7 ^{0}C and -4 ^{0}C respectively.
- Maximum positive and negative temperature differential in polypropylene fiber reinforced concrete slab of thickness 200 mm is 8 ^{0}C and -4 ^{0}C respectively.
- Percentage variations of temperature differentials observed in this study with the IRC standards is about 42% to 58% less.

Temperature Stresses:

- Maximum temperature stress in conventional concrete slab of thickness 150 mm 18.79 kg/cm² and in 200 mm thick slab is 20.54 kg/cm². Temperature stress increases with increase in thickness of slab to an extent of 9.31%.
- Maximum temperature stress in steel fiber reinforced concrete slab of thickness 150 mm 16.16 kg/cm² and in 200 mm thick slab is 17.18 kg/cm². Temperature stress increases with increase in thickness of slab to an extent of 6.31%. As compared to the conventional concrete temperature stress decreases by 16.27 % and 19.55 % respectively.
- Maximum temperature stress in polypropylene fiber reinforced concrete slab of thickness 150 mm 17.08 kg/cm² and in 200 mm thick slab is 17.53 kg/cm². Temperature stress increases with increase in thickness of slab to an extent of 2.63%. As compared to the conventional concrete temperature stress decreases by 10.01% and 17.53% respectively.

11 CONCLUSIONS

- The actual temperature differentials measured are much less compared to that are specified in the code IRC-58.
- Temperature differential is more in conventional concrete slab when compared to fiber reinforced concrete slabs.
- Temperature differential and temperature stresses are high in summer season as compared to the monsoon season.
- The thickness requirement of fiber reinforced concrete for an assumed traffic is less compared to conventional concrete.
- Among the two fibers, crimped steel fibers shows better results and hence preferred.

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