

# Experimental Investigation on Temperature variation across the Thickness of Pavement Using Thermocouples

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**ABSTRACT:** The present paper is based on the assumption that the temperature distribution is linear throughout the depth of the slab. Temperature is one of the important loads for designing slab track. The characteristic of slab track temperature varies greatly with different regional climates. This is an approximation, because studies have shown that the actual distribution is nonlinear. The combined effect of load and temperature variation is responsible for the development of critical stresses. Concrete is a man-made material produced by the proper mixing of cement, coarse aggregate, fine aggregate-natural or M-sand and an adequate and controlled amount of water, with or without super plasticizers. 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 throughout the depth of the models. Three modules 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 models are recorded every hour for 28 days using a digital temperature recorder. The temperature were found using the Thermocouples. Hence it is necessary to analyze the models for Thermal and Structural loadings. The result obtained from the study clearly shows that the actual temperature variations are Non-linear. The present finding confirmed the importance and the need to account the nonlinear temperature variation in the design of concrete pavements. Hence, an attempt has been made in this study to evaluate the effect of actual temperature variation across the thickness of the models.

**KEYWORDS:** Temperature, models, natural sand, M-sand, thermocouples.

## I. INTRODUCTION

Temperature is the one of the important environmental factors, especially in pavement. This will change with the environmental temperature in the top layer of the pavement system. Due to variation in the temperature and contraction of the concrete, the thermal variation will lead to thermal stress in pavement. Therefore, temperature stress is a very important factor to design the pavement. For the continuous pavements, the expansion stress will control the design; while for the unit pavement, the warping stress can be the control factor of the design (Zhao Pingrui, *et al.*, 2014).

Temperature variation across the thickness of the pavement causes the pavement slab to warp and deform, which in turn develop the bending stresses. Which is based on the assumption that the temperature distribution is linear throughout the thickness. This is an approximation, because studies have proved that the actual distribution is nonlinear. The combined effect of load and temperature variation is responsible for the development of critical stresses. The application of loads along with temperature variation may lead to initiation of cracks at the highly stressed locations (Figure 1).

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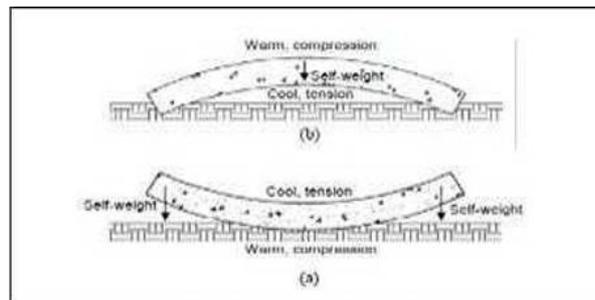


Figure 1. A pavement slab warped due to temperature variations

Temperature stresses are developed in cement concrete pavement due to variation in slab temperature i) daily variation resulting in temperature gradient across the thickness of slab resulting in curling or warping stresses ii) seasonal variation resulting in overall change in slab temperature resulting in frictional stresses.

Many investigators have conducted experiments to measure the temperature field in concrete pavement (Zhimin, *et al.*, 2013 and Haigui, *et al.*, 2007). However, because of the large area of the pavement and different heat exchange conditions of pavements, the data measured from concrete pavement cannot be used directly for design. Pavement is a structure that bears long-term temperature load and repeated load (Rostasy and Budelmann, 2007).

The maximum temperature value cannot reflect the weakness of the pavement completely. This paper will focus on the test of temperature field in different models to establish the connection between pavement temperature gradient and using thermocouples and air temperature.

## II. MATERIALS AND METHODS

### Test Plan

The tests models are prepared using concrete made of: cement, fine aggregate (Natural sand and Manufactured sand), coarse aggregate, potable water. 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 (Figure 2). The typical temperature measuring arrangements made is shown Figure 3.

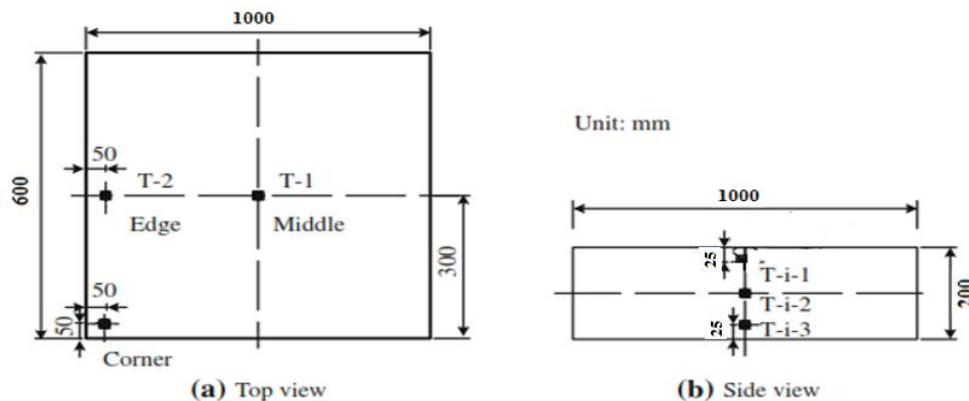


Figure 2. Schematic Arrangement of the Temperature field Test

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Thermocouples are fixed to wooden beads at top, bottom, and at middle, to record the temperature values at Interior, Corner and Edge regions of slab, during casting such that tip of the thermocouples are in contact with concrete. The purpose of placing the thermocouples at Centre is for Deflection, at Edge is for Bending and at Corner is for Torsion. The temperature differential across the thickness of the models are recorded at every hour from 8AM to 6PM.

Temperature was recorded using a digital temperature indicator as shown in the Figure 4. The temperature indicator has two leads which are connected to the two leads of the thermocouple. When temperature indicator is activated, the temperature of the slab is displayed directly in degree centigrade. The temperature indicator used for the present investigation was a “Type-K” indicator by Heatcon Instruments, Bangalore. It had a least count of 0.1°C. The temperature measuring range of the instrument was from -25°C to 400°C. The actual temperature at 25 mm, 100 mm and 175 mm of slab all the three regions are recorded for every hour for 28 days.

The casting and temperature measurement were taken at filed using Thermocouples. The tests conducted to determine the strength of materials used and quality of concrete. The mix design used in the present study confirms the IS 10262:2000. Three mix proportions (S1, S2 and S3) for conventional M30 grade concrete are arrived. A test was conducted for 28 days. Experimental Setup is given in Figure 4



**Figure 4. Experimental Setup**

### III. RESULTS AND DISCUSSIONS

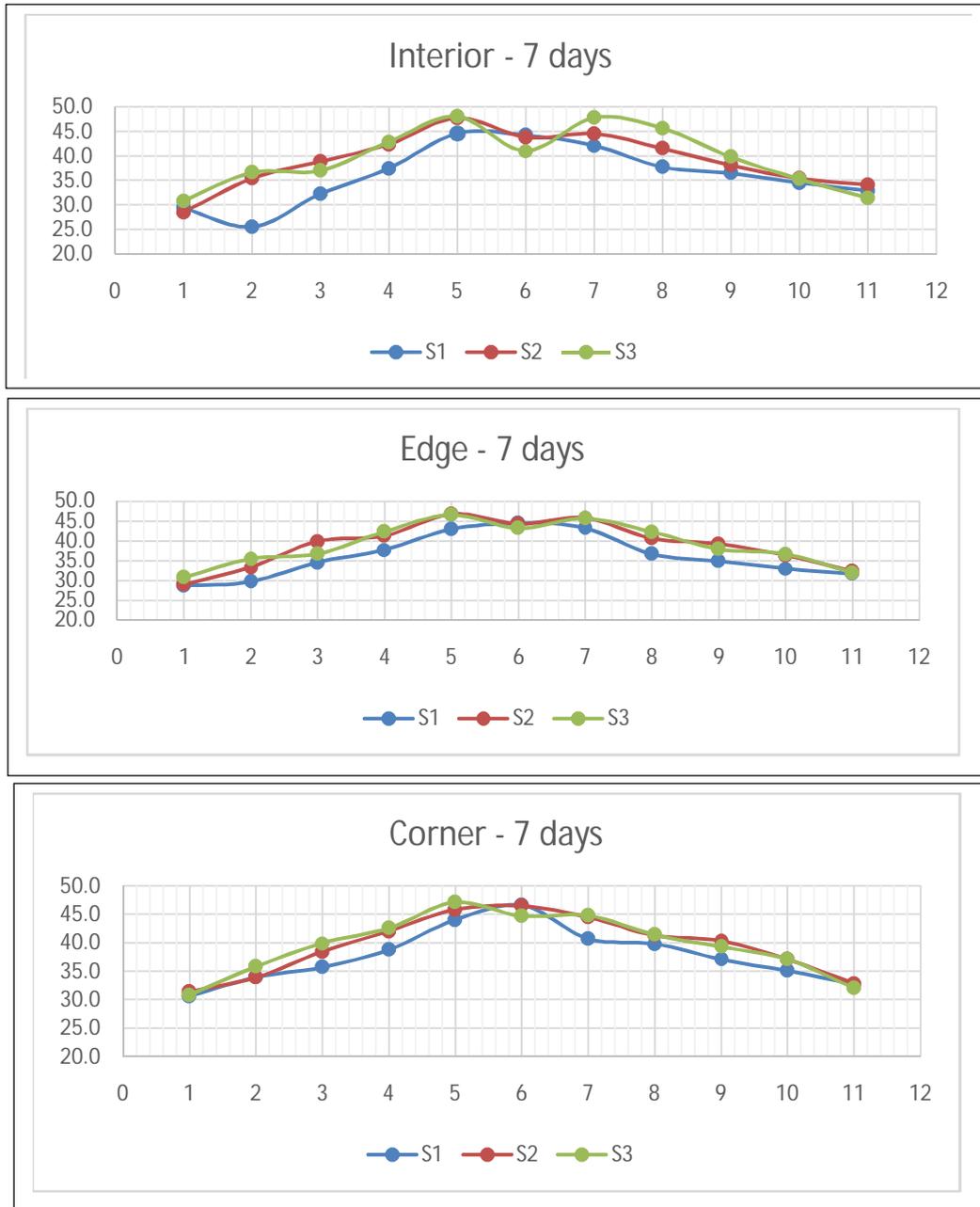
In the present study, the temperature data recorded at three different location across the depth of the pavement. The table 1 gives the average values of temperature in the entire study. The maximum positive temperature was recorded in S2 (cast with M-sand) and also the minimum negative temperature was recorded at S2. (Dhanajay and Abhilash, 2014). The maximum and minimum ambient temperatures on the day were 36.0°C and 27.0°C respectively. Slabs experienced lower bottom temperatures leading to greater temperature differentials. The peak negative temperature differentials (PNTD) were almost the half of peak positive temperature differentials (PPTD) values. Hence, it is the maximum peak positive temperature differential value which will govern the design of models.

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**Figure 5 Temperature variations at 25 mm depth: 7 Days during the study**

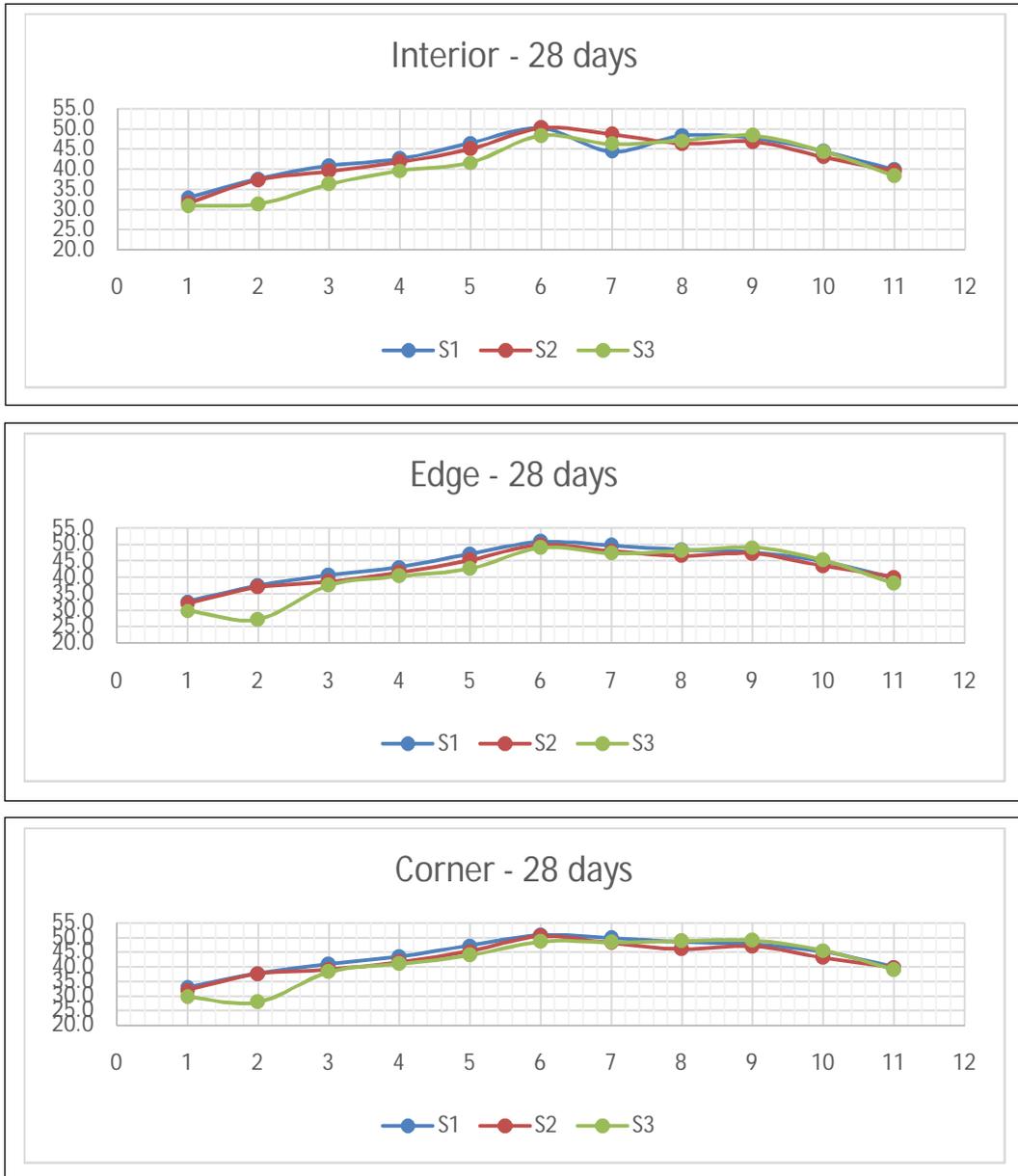
During the study period the behaviour is observed peak in later noon and S1 exhibits uniform variation at 25 mm depth for 7days in comparison to other two models S2 and S3 is given in Figure 5.

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**Figure 6 Temperature variations at 25 mm depth: 28 Days during the study**

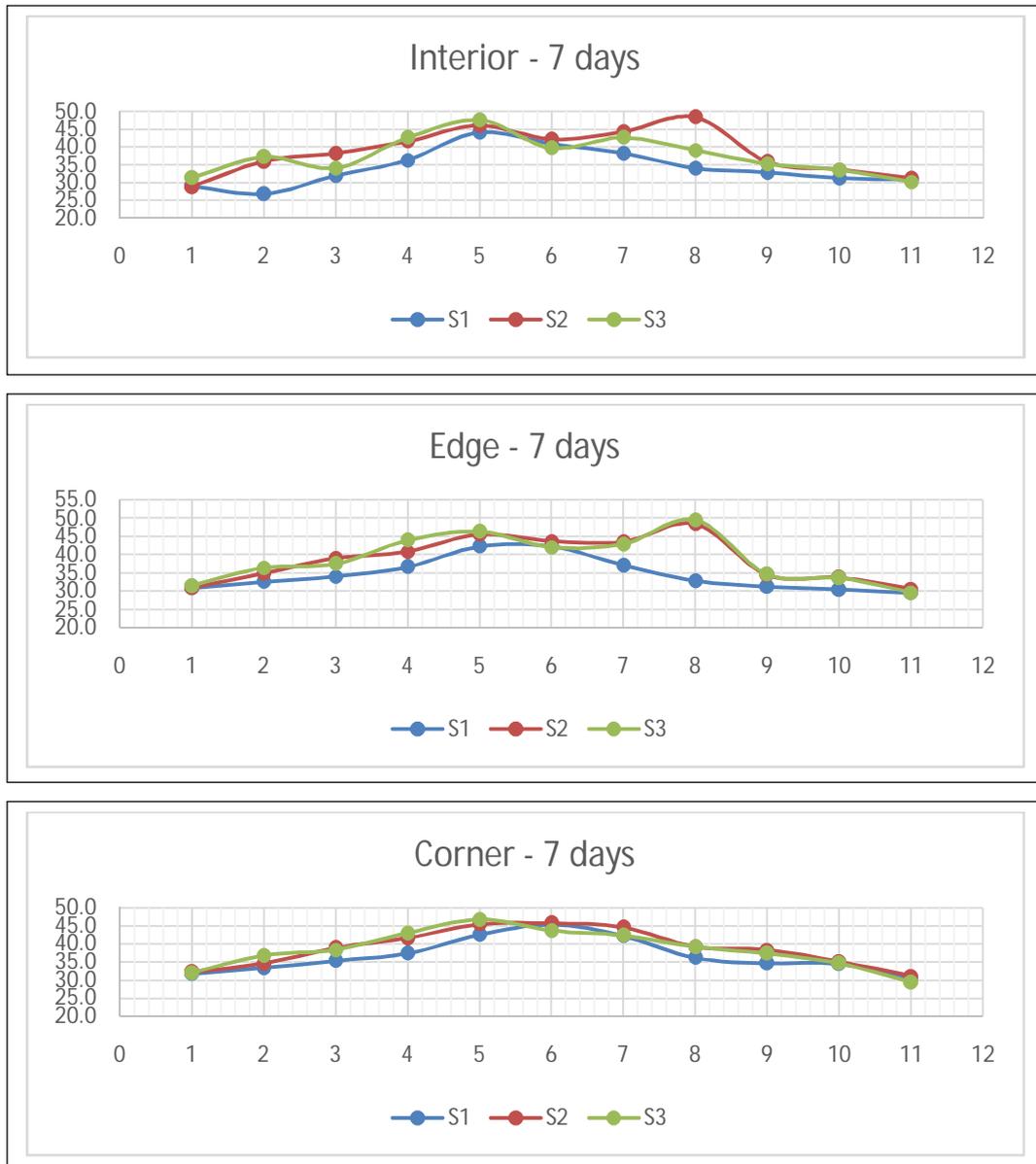
From the present study it indicates, the behaviour is observed peak in later noon and all the three models shown same trend at 25 mm depth for 28days is given in Figure 6.

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**Figure 7 Temperature variations at 100 mm depth: 7 Days during the study**

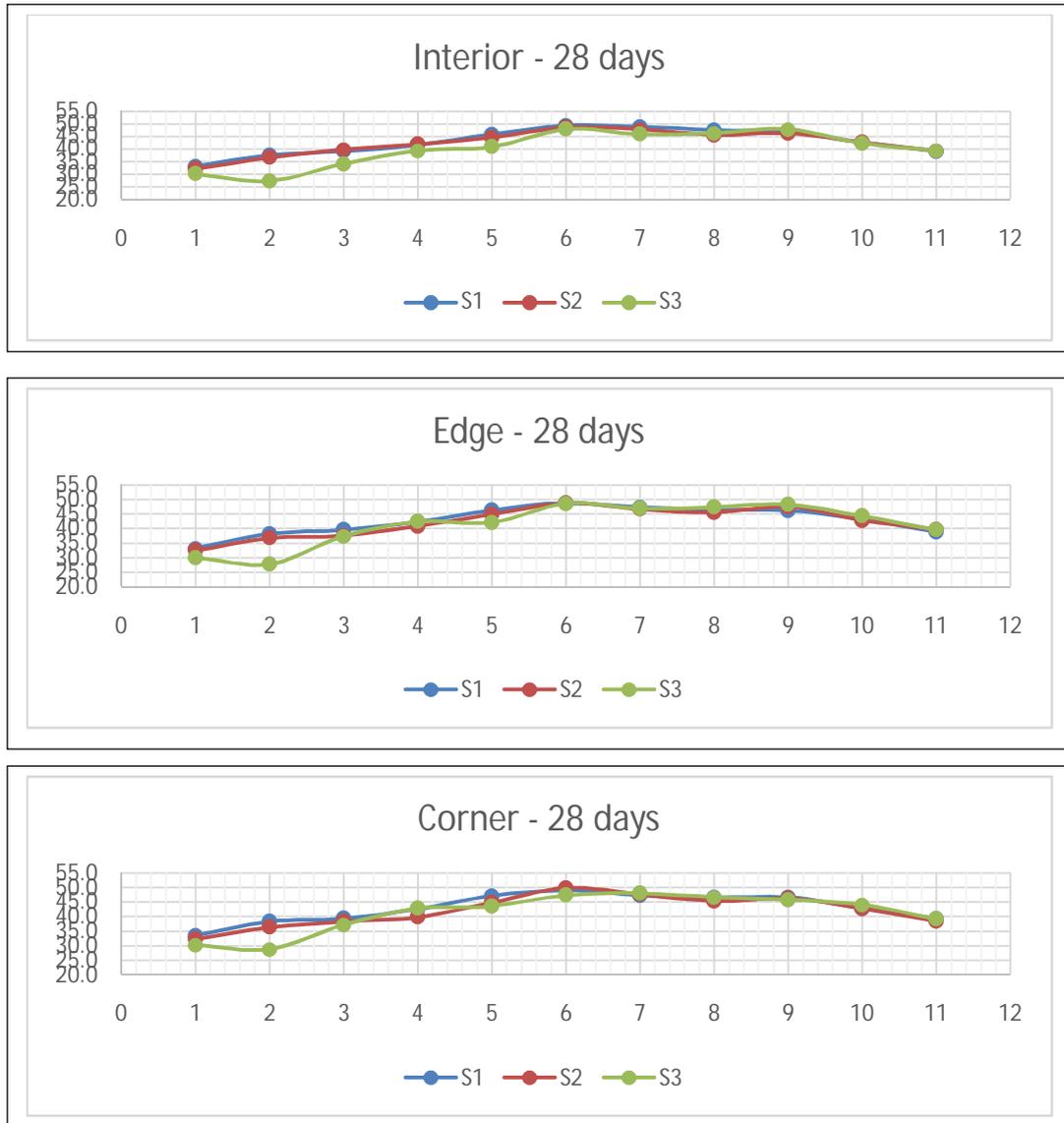
The study indicates behaviour is peak in later noon and S1 exhibits uniform variation and S2 exhibits non-uniform variation at 100 mm depth for 7days in comparison to other model S3 is given in Figure 7.

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**Figure 8 Temperature variations at 100 mm depth: 28 Days during the study**

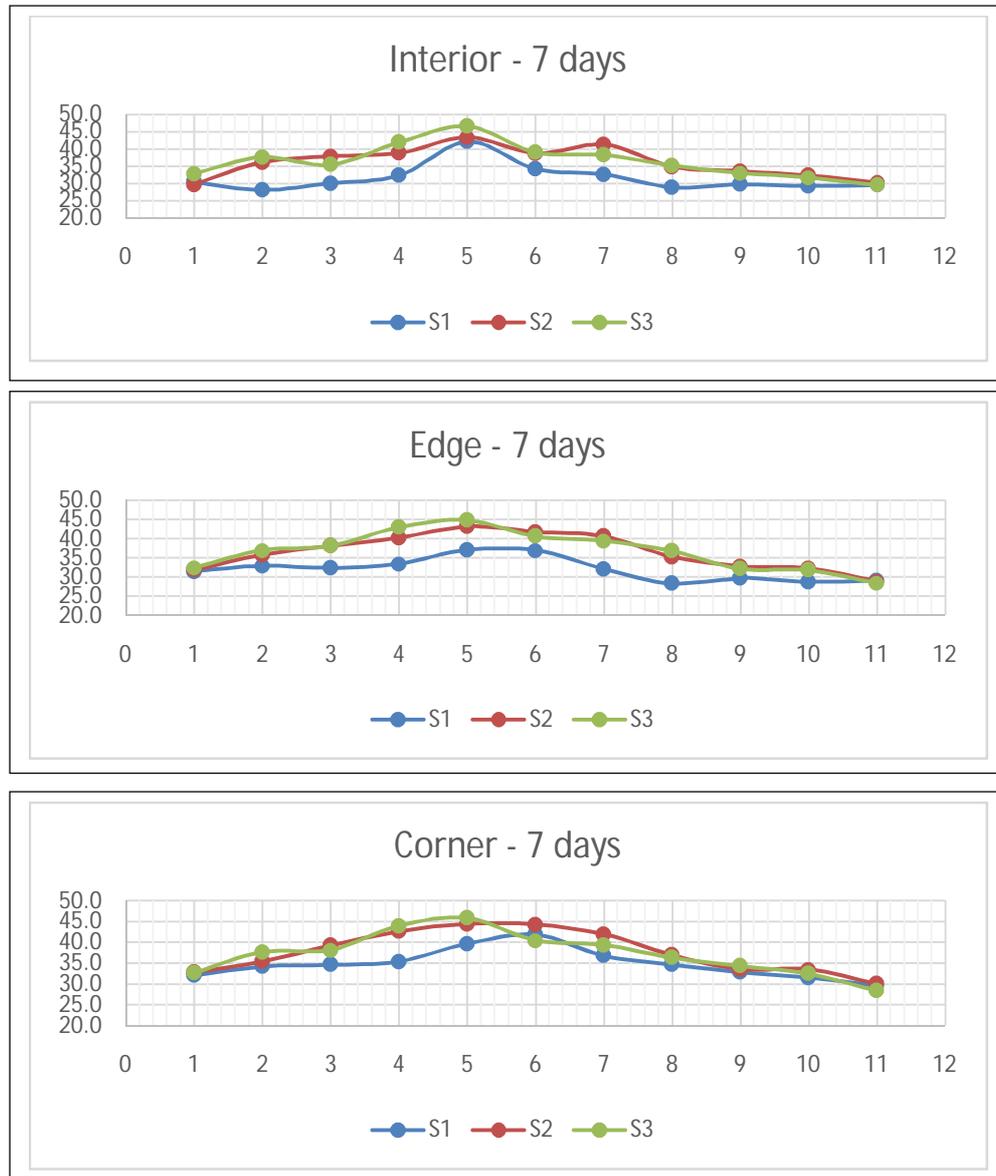
Figure 8 indicates, the behaviour is observed peak in later noon and all the three models shown same trend at 100 mm depth for 28days is given in Figure 8.

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**Figure 9 Temperature variations at 175 mm depth: 7 Days during the study**

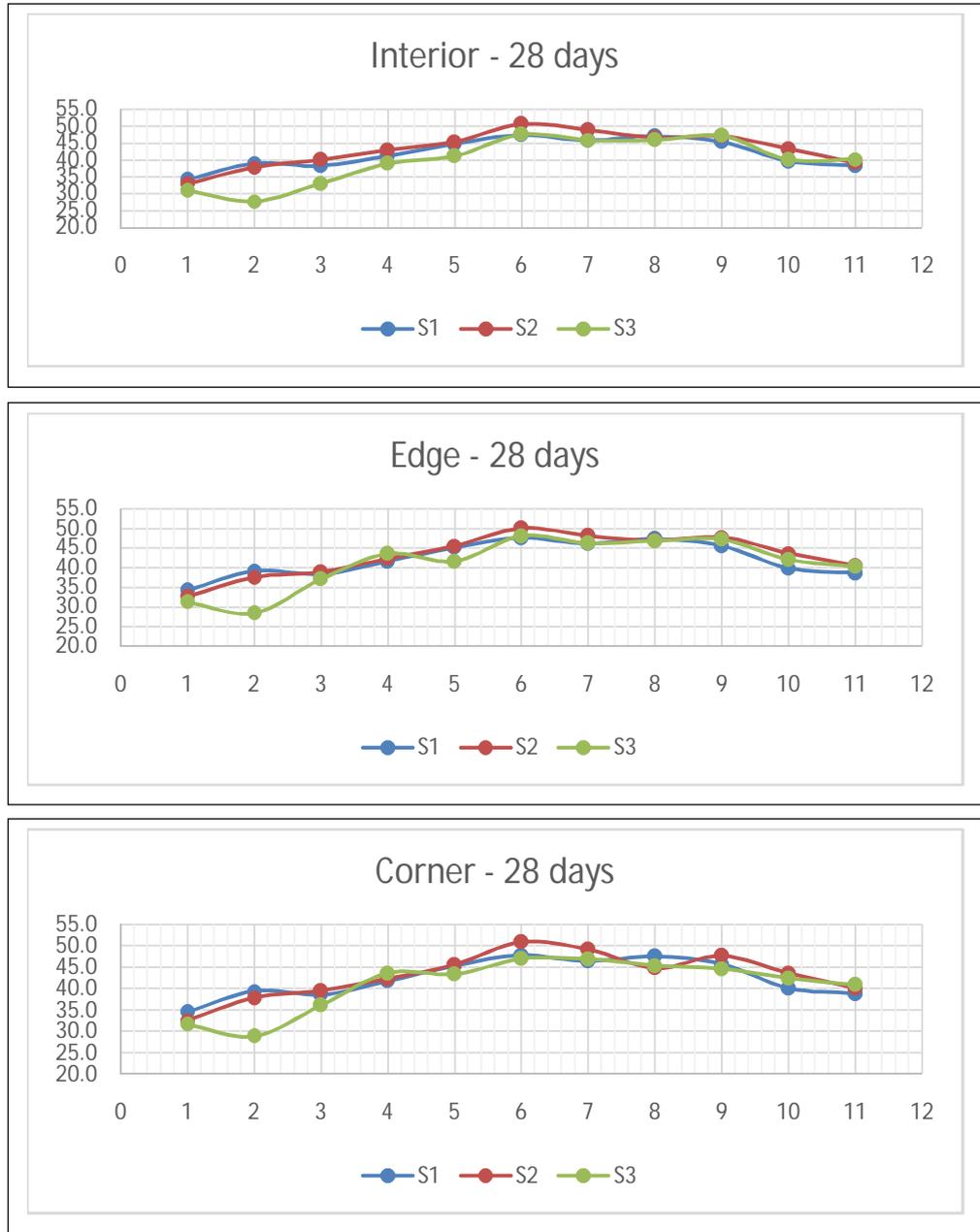
The behaviour is peak in later noon and S1 exhibits uniform variation, S2 and S3 exhibits non-uniform variation at 175 mm depth for 7days in the entire study is given in Figure 9.

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**Figure 10 Temperature variations at 175 mm depth: 28 Days during the study**

Figure 10 indicates, the behaviour is observed peak in later noon and S3 model behaviour is non-uniform compared to S1 and S2 models at 175 mm depth for 28days.

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Positive temperature variation across the depth is observed in all the three models. As the ambient temperature increase the temperature differential also increases across the thickness of the slab. PPTD and PNTD will result in warping or curling of the pavement due to the temperature changes, due to climatic or seasonal changes. The peak temperature differential, PPTD and PNTD is given in Table 1

**Table 1 Peak Temperature Differential in Pavement Slab**

Slab	PPTD, °C	PNTD, °C
S1	12.5	11.4
S2	13.2	10.9
S3	12.9	11.6

**Note:** PPTD: peak positive temperature differentials and PNTD: peak negative temperature differentials

## IV. CONCLUSIONS

From the present study the following conclusions are arrived

1. Model S1 (cast with Natural Sand): exhibits uniform variation of temperature differential across the thickness in comparison with ambient temperature.
2. Model S2 (cast with M – Sand): in initial days of curing, it exhibits higher variation of temperature differential across the thickness in comparison to ambient temperature.
3. Model S3 (cast with equal proportion of M-Sand and Natural Sand): In the initial days of curing it exhibits moderately varying temperature differential across the thickness with ambient temperature.
4. With reference to depth, temperature differential measured in model S1 is more consistent in comparison with S2 and S3.
5. As the variation of temperature is non-uniform across the thickness, temperature stresses will be nonlinear.

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