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STUDY OF TEMPERATURE DIFFERENTIAL IN DIFFERENT CONCRETE SLABS OF VARYING SLAB THICKNESS IN DIFFERENT REGIONS

S.Santhosh Kumar
M.Tech structural engineering department of civil engineering,
Prist university, vallam, THANJAVUR.

Mr. Tamilalagan M.E
Assistant professor ,
Department of civil engineering ,
PRIST university, Vallam, Thanjavur.

Abstract— In this paper the curling behavior 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.

1.INTRODUCTION

The damage that fire can cause leads to loss of life and property. In the past two decades, a significant amount of research has been conducted into the performance of composite structures in fire. Concrete is specified in civil engineering projects for several reasons, sometimes cost, and sometimes speed of construction or architectural appearance, but one of concretes major inherent benefit is its performance in fire. Concrete does not require any additional protection because of its built-in resistance to fire. It is non-combustible and has a slow rate of heat transfer, which makes it a highly effective barrier to the spread of fire. Many of experimental studies are going on to determine the fire resistance of concrete. When concrete remains exposed for long time at high temperatures results in loss of mechanical and physical properties. Calculating the changes of the temperature field in the reinforced concrete members under fire is very important for the

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analysis on the change law of the intensity, deformation and fire resistance performance in high temperature building construction. Analyzing the bearing capability of RC slabs after sustaining fire requires the knowledge of temperature distribution in the cross sections. This is determined by the thermal properties of the material, such as the Specific heat and thermal conductivity. A simple thermal model, which is generally to all slabs with a rectangular cross section, has been assessed in a separate serious of studies. The modeling results achieved reasonable agreement with isothermal contours obtained by Lin (1985) [16] who analyzed the temperature distribution of pure concrete according to the time-temperature curve of standard fire.

2. LITERATURE SURVEY

Teller Sutherland et al [1] 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 Westergaards solution, Bradbury arrived at a solution for a slab with finite dimension. Teller and Sutherland reported the results of tests conducted on concrete pavements to study the effects of temperature variations on pavement stresses. There results showed that temperature distribution throughout the pavement thickness is highly non-linear. Analytical solutions 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. However majority of current analysis including that give in IRC 58 – 2002 are still limited to linear temperature distribution.

Dan et al.[2], have studied Mathematical model of temperature changes in concrete pavements. When concrete pavement is subjected to a change in temperature, some time must elapse before a condition of equilibrium is again reached. In the transient heating and cooling processes that take place in the interim, there are three basic energy transfer modes:

(1) Radiant;
(2) Convective; and
(3) Conductive heat transfer.

As a concrete pavement"s thermal environment changes, the physical mechanisms that underlie the heat-transfer modes cause fluctuating temporal zones to occur within the pavement slab. For instance, during a freeze-thaw cycle the upper portion of the pavement may be subject to thawing and refreezing while the bottom portion of the slab remains frozen. By using a finite-difference computer model coupled with field and laboratory observations, they discuss how the rate and depth of temperature change can be accurately predicted. Freezethaw cycles in which surface scaling occurred were used to illustrate one of the different kinds of exposure conditions that can be accurately simulated.

Eyad et al[3], studied finite-element analysis of temperature effects on plain- jointed concrete pavements. They developed three dimensional (3D) model for four slabs separated by longitudinal and transverse joints. The interaction between the ground and the concrete slab along with interaction at the joints were modeled using interface elements. These elements gave the model the capability to solve for partial contact between curled slabs and the ground to investigate the effect of compressive stresses that may develop at the joints during curling, and to study the influence of friction between slabs and the ground. The data obtaine during the finite elements model has shown

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reasonable agreement with the results obtained from three computer models: KENSLABS, ILLI-SLAB,JSLAB and the analytical solution proposed by Bradbury. The best correlation was obtained with JSLAB. The model was used to perform parametric studies on curling and thermal-expansion stresses to study the effect of superposition of both stresses and to address the effect of uniform temperature changes on joint opening. Another simpler model using nine layers across the depth of a pavement slab was used to introduce the effects of nonlinear temperature distribution. The arithmetic addition of positive curling stresses and thermal – expansion stresses were less than those stresses obtained by superposition. In some cases, the calculated joint openings were higher than the allowable joint opening. Nonlinear temperature distribution caused higher tensile stresses than the linear distribution of temperature. The difference in tensile stresses between the two distributions was approximately 3-13% of the modulus of rupture of concrete.

3. Model validation

To validate modeling, boundary conditions and loading procedures, a nonlinear heat transfer analysis performed on the slab. By applying initial ISO-834 temperature curve shown in Fig.2 and the analysis is performed using „Heat transfer" analysis. And the ABAQUS result was compared with the temperature profiles given in EN1992-1-2. Temperature distribution curve of the FE Model was plotted using the resulting values.

4. Slab thickness

Concrete slab thickness has been taken up for studying the variation of temperature profiles, five different thicknesses have been modeled using ABAQUS. From the graphs obtained it is very clear that the temperature variation is significant up to 100 mm thickness later as the slab thickness is increased there is no much variation in the temperature profiles as the time increases for which the slab is exposed to temperature. Also, while keeping the depth at which the temperature is calculated and studying the temperature from 100 degrees to 400 degrees for the subjected reaction times, the slab having 100mm depth was taken up as the critical depth for study, from the fig 5 – 8 it is observed that only 100mm depth slab is having higher temperatures when compared to other slabs. Probably this is due to the fact that other slabs having more thickness absorb the excess temperature compared to 100mm depth slab.

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5. Parametric study

5.2.1 Effect of slab length on curling stresses

show the effect of slab length on positive curling stresses. From the table it was observed that as the temperature increases the stress and deflection also increase but under a particular positive curling (temperature at the top of a slab is higher than that at the bottom) as the slab length increase, the stress will remain approximately constant. But the deflection of slab will increase.

The maximum stress obtained for a slab length of 8m under a positive curling temperature of 11.1oC was 1.11N/mm2 and a deflection of about 3.868mm. Table 5.3 show the effect of slab length on negative curling stresses, from the table it is observed that as the temperature increases the stress and deflection also increase but under a particular negative curling (temperature at the bottom of a slab is higher than that at the top) as the slab length increase, the stress will remain approximately constant. But the deflection of slab will increase.

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The maximum stress is obtained for a slab length of 8m under a negative curling temperature of 8.3oC is 0.825 N/mm2 and a deflection of about 2.84mm. The contour of stress for this case is show in plate 5.10 5.2.2 Effect of slab thickness on curling stresses The effect of slab thickness on positive gradient is shown in table 5.4 from the table it can be observed that, as the temperature gradient increase the stress and deflection also increase. On the other hand under a particular temperature gradient as the slab thickness increases the stress and deflection also increases. The deflected shape and positive gradient is show in plate 5.12 and 5.13. The maximum positive curling stress is obtained for a slab thickness of 300mm under a positive temperature gradient of 0.463oC/cm was 1.38 N/mm2 and a deflection of 1.673mm

6. The damage that fire can cause leads to loss of life and property.

In the past two decades, a significant amount of research has been conducted into the performance of composite structures in fire. Concrete is specified in civil engineering projects for several reasons, sometimes cost, sometimes speed of construction or architectural appearance, but one of concrete‟s major inherent benefit is its performance in fire. Concrete does not require any additional protection because of its built-in resistance to fire. It is non-combustible and has a slow rate of heat transfer, which makes it a highly effective barrier to the spread of fire.

Many of experimental studies are going on to determine the fire resistance of concrete. When concrete remains exposed for long time at high temperatures results in loss of mechanical and physical properties.Calculating the changes of the temperature field in the reinforced concrete members under fire is very important for the analysis on the change law of the intensity, deformation and fire resistance performance in high temperature building construction. Analyzing the bearing capability of RC slabs after sustaining fire requires the knowledge of temperature distribution in the cross sections. This is determined by the thermal properties of the material, such as the Specific heat and thermal conductivity. A simple thermal model, which is generally to all slabs with a rectangular cross section, has been assessed in a separate serious of studies.. The analytical stage in the modeling process is to increment the time of the model such that the temperature experienced by the slab is increased. The increase in the ambient temperature changes the temperature distribution inside of slab‟s cross-sections. After sustaining high temperature, the mechanical properties of reinforced steel and concrete vary according to the fire-induced temperature. It makes the stress distribution in such slab structures a nontrivial problem [19]. To determine the fire behaviour of concrete structures, there are many methods in literatures. These methods are based on tests and experiences, simplified methods and numerical methods which provide to be carried out thermal analysis by computers. In this study it is used a developed computer programmer (ABAQUS) based on finite element method for thermal analyses. Heat Transfer through Concrete Slab Heat transfer is nothing but transfer of energy between two points of different temperatures. The heat transfers continue until the two objects have reached thermal equilibrium and are at the same temperature. The heat transfer in concrete structures can be done by three modes. Those are conduction, convection and radiation. Convection is the transfer of internal energy into or out of an object by the physical movement of a surrounding fluid that transfers the internal energy along with

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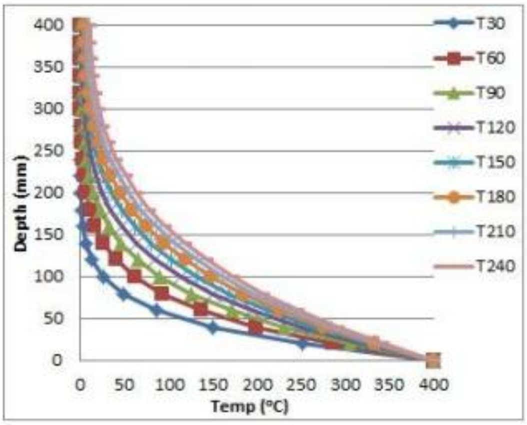
its mass. In convection, the bulk transfer of heat energy comes from the motion of the fluid.



7. Material Properties

General Computer packages (ABAQUS) are heavily dependent upon the material definitions provided as an input. Therefore in order to assess the adequacy of thermal analysis to determine the temperature distribution of concrete structures at elevated temperatures, a thorough investigation of the material models available also required. Thermal Properties of Concrete In this section the mechanical behaviour of concrete elevated temperatures is described. In a fully developed fire, the thermal properties of concrete such as thermal conductivity, specific heat and high thermal expansion varies with the effect of temperature. Thermal Conductivity Thermal conductivity is the capability of a material to conduct heat. It represents the uniform flow of heat through concrete of unit thickness over a unit area subjected to a unit temperature difference between the two opposite faces. The thermal conductivity of siliceous aggregate concrete as represented in Eurocode 2.

Specific Heat The specific heat of a material is the amount of heat per unit mass which is required to change the temperature of the material by a degree. The specific heat of concrete with siliceous aggregates as a function of temperature according to Eurocode 2, in section 3.3.2 is shown in Fig.1 (a). Mechanical Properties of Concrete In this section the mechanical behaviour of concrete elevated temperatures is described. The material models devised to characterize this behavior are described. Modulus of Elasticity The modulus of elasticity of the concrete in Fig.1 (b) decreases with an increment in temperature. The reduction of the modulus of elasticity is due to the rupture of bonds in the microstructure of the cement paste when the temperature increases. Thermal expansion when it is subjected to a temperature change.

8. CONCLUSION AND FUTURE WORK

In this study behavior of concrete slabs subjected to temperatures starting from 100 degrees to 400 degrees were studied using a FEM model in ABAQUS. ISO834 was used initially to obtain the temperature profiles for developing the model, as shown in fig 3 the temperature profiles are very close to the EN 1992-1-2- 2004. The various temperature to which the slab was subjected was principally obtained by following the ISO standard fire curve i.e., ISO834. The obtained temperature profiles have been observed to be in accordance with the available literature, having validated the present FEM model the slab was taken up for further parametric study. Five concrete slab models were considered to study three different parameters namely: the concrete slab thickness; the exposed surface temperature; and reaction time

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