Experimental Investigation of Bituminous And Numerical Simulation of Rigid Pavements to Determine Temperature Distribution on Different Climatic Conditions

Kundan Kumar[1], Amit Kumar Ahirwar[2]
[1, 2] Dept of Civil Engineering
[1, 2] University Institute of Technology AISECT University Bhopal, India

Abstract- *The discussion of the structural damage of a pavements are due to the combined influence of traffic loading and environmental considerations has been the thought that this knowledge, measured in terms of stress, strain and deflection, could be applied in some way to the pavement analysis, performance prediction, and design. Such application cannot be realized, however without the ability to determine the state of stress that occurs within the pavement due to the effect of loading and environmental factors. In addition, mechanistic-empirical pavement design methods for pavement are based on the assumption that the pavement performance and life are inversely proportional to the magnitude of the traffic induced pavement strains, which in turn, varies with temperature. Because these relationships are nonlinear, the additional pavement life consumed at higher-than-average temperature is not offset by savings at lower than-average conditions. Moisture damage in mixtures is defined as the gradual loss of structural integrity caused by the presence of moisture.*

In present analysis experimental investigation was performed on flexible pavements to determine temperature distribution with respect to depth and time, in our study a base paper was considered in which experimental analysis was performed on rigid pavements, A numerical simulation is performed in Indian and European climatic conditions for determination of temperature by ANSYS (Fluent), thus results shows that when titanium oxide mixed with concrete of rigid pavements increases its ability to resist weather conditions in both climatic zones, with respect to other dense, coarse graded material.

The analysis also concludes that rigid pavements should be preferred for road construction with an mixed proportion of titanium oxide because it has capability to with stand in critical climatic condition, the present analysis also signifies that the comparison of bituminous with different graded material shows comparatively high temperature thus titanium oxide mixed concrete shows converged thermal effect on both countries climatic conditions.

Keywords- Pavement, asphalt, stress,

I. INTRODUCTION

A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure must be capable of provide a floor of suitable riding satisfactory, good enough skid resistance, favorable light reflecting traits, and coffee noise pollutants. The closing goal is to make sure that the transmitted stresses due to wheel load are sufficiently decreased, so that they'll not exceed bearing potential of the sub-grade. Two forms of pavements are usually diagnosed as serving this motive, namely flexible pavements and rigid pavements. This chapter gives an overview of pavement types, layers, and their functions, and pavement failures. Improper design of pavements leads to early failure of pavements affecting the riding quality.

II. TYPES OF PAVEMENT

2.1 Flexible Pavement

The major flexible pavement failures are fatigue cracking, rutting, and thermal cracking. The fatigue cracking of flexible pavement is due to horizontal tensile strain at the bottom of the asphaltic concrete. The failure criterion relates allowable range of load repetitions to tensile strain and this relation can be determined in the laboratory fatigue check on asphaltic concrete specimens. Rutting occurs only on bendy pavements as indicated by means of everlasting deformation or rut depth alongside wheel load path. Two layout methods have been used to manipulate rutting: one to limit the vertical compressive strain on the pinnacle of subgrade and other to restriction rutting to a tolerable amount (12 mm usually). Thermal cracking includes both low-temperature cracking and thermal fatigue cracking. Are the ones pavements which mirror the deformation of subgrade and the following layers to the surface. Flexible, typically asphalt, is laid without a reinforcement or with a specialized cloth reinforcement that allows restricted waft or repositioning of the roadbed underground modifications.

1.2.2 Rigid Pavement-

The rigid characteristic of the pavement are associated with rigidity or flexural strength or slab action so the load is distributed over a wide area of subgrade soil. Rigid pavement is laid in slabs with steel reinforcement. The rigid pavements are manufactured from cement concrete both plan, strengthened or prestressed concrete. Critical circumstance of pressure in the inflexible pavement is the maximum flexural strain occurring in the slab because of wheel load and the temperature adjustments. Rigid pavement is designed and analyzed by the use of the elasticconcept.

III. REQUIREMENTS OF A PAVEMENT

- Sufficient thickness to distribute the wheel load stresses to a safe value on the sub-grade soil,
- Structurally strong to withstand all types of stresses imposed upon it,
- Adequate coefficient of friction to prevent skidding of vehicles,
- Smooth surface to provide comfort to road users even at high speed,
- Produce least noise from moving vehicles,
- Dust proof surface so that traffic safety is not impaired by reducing visibility,
- Impervious surface, so that sub-grade soil is well protected, and
- Long design life with low maintenance cost.

IV. LITERATURE REVIEW

Emanuele Toraldo et.al.[1] This paper reports the results of an investigation focusing on the evaluation of the effects of environmental conditions on five materials currently used in Europe for wearing courses for urban road pavements. The investigation lasted one year and was carried out on paving slabs. Environmental conditions and pavement temperatures at two depths from the surface were measured, analyzing the effects of air temperature on pavements throughout the whole period of observation and during the hottest and coldest days. The study shows the potential of lighter colored pavements used in urban areas to mitigate the Urban Heat Island phenomenon.

Apurva J Chavan [2] investigated Disposal of waste materials including waste plastic bags has become a serious problem and waste plastics are burnt for apparent disposal which cause environmental pollution. Utilization of waste plastic bags in bituminous mixes has proved that these enhance the properties of mix in addition to solving disposal problems. Plastic waste which is cleaned is cut into a size such that it passes through 2-3mm sieve using shredding machine. The aggregate mix is heated and the plastic is effectively coated over the aggregate. This plastic waste coated aggregate is mixed with hot bitumen and the resulted mix is used for road construction. The use of the innovative technology will not only strengthen the road construction but also increase the road life as well as will help to improve the environment. Plastic roads would be a boon for India’s hot and extremely humid climate, where temperatures frequently cross 50°C and torrential rains create havoc, leaving most of the roads with big potholes. In my research work I have done a thorough study on the methodology of using plastic waste in bituminous mixes and presented the various tests performed on aggregates and bitumen

Migle Paliukaite and Audrius Vaitkus [3] Durability of asphalt pavement mainly depends on pavement structural strength. Environmental conditions (temperature, moisture, intensity of sun, etc.) influence variation in asphalt pavement strength during the year. In order to analyze behaviour of asphalt pavement structure under Lithuanian climatic conditions, taking into account temperature and moisture, as one of the most important climatic factors influencing structural strength of road asphalt pavement, the experimental research was carried out. The results of experimental research encourage determining pavement strength and Eo modulus dependence on moisture and surface temperature, measured by the Falling Weight Deflectometer (FWD) in different seasons. To evaluate the values of road pavement strength and Eo modulus, the obtained measuring results were reduced to their equivalent values under standard temperature and load. Thus, the values of Eo modulus were adjusted to the standard temperature of +20 °C, using the revised temperature correction factor.

V. COMPUTATIONAL FLUID DYNAMICS (CFD)

5.1 INTRODUCTION: Computation Fluid Dynamics (CFD) is the branch of fluid science which deals with a variation occurs on fluid flow, basically computational fluid dynamics opt an finite volume method as methodology and for base equation it follows the eulerian equation, i.e. when gravity forces were not consider, pressure force and viscous force are used to simulate the desired fluid flow problem.

5.2 FLUENT SOLVER: Computation Fluid Dynamics consists of several domains to solve fluid flow problem like CFX, fluent (poly flow), fluent (blow moulding), fluent, fluent solver works under computational fluid dynamics, it obeys the three governing equation w.r.t base equation (Eulerian equation) i.e. energy equation, momentum equation and continuity equation by applying or solving through this algorithm, the further results were obtained and variation could be determine.

Boundary condition for solving problem on fluent solver: In a finite volume method w.r.t. to governing equation, boundary conditions were applied to simulate to present model, “inlet” this boundary condition indicate the inlet of fluid with a desire velocity on a model, “outlet” this definition of fluid indicates that the outlet flow of fluid, further heat flux, radiation, convection, mixed (conduction + convection) were applied on present model for simulation.

5.3 FINITE VOLUME METHOD: Finite Volume Method is used to solve the fluid flow problems by obtaining the convergence of eulerian equation and governing equation, this method works on volume of fluid or volume of fraction, it consists of energy equation, momentum equation and continuity equations w.r.t. pressure force, viscous force or gravity force to solve the fluid flow problem, in case of heat exchanger, radiation, turbulence, laminar flows, acoustics and also deals with aerodynamics, HVAC etc.

VI. MODELLING

6.1 Development of solid model

Here in this analysis the geometric dimension of the Pavement block is based on the dimension of sample used for the experimental analysis performed by Toraldo et. al. the dimension of the sample are shown in the table

Parameters	Value (mm)
Length	300
Width	200
thickness	50

6.2 Creating the geometry

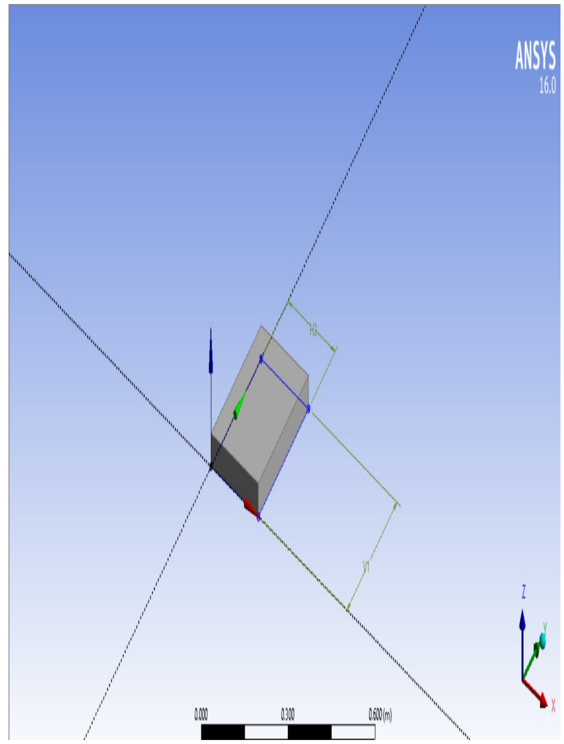

Fig. 6.1 showing the geometry of the Pavement block

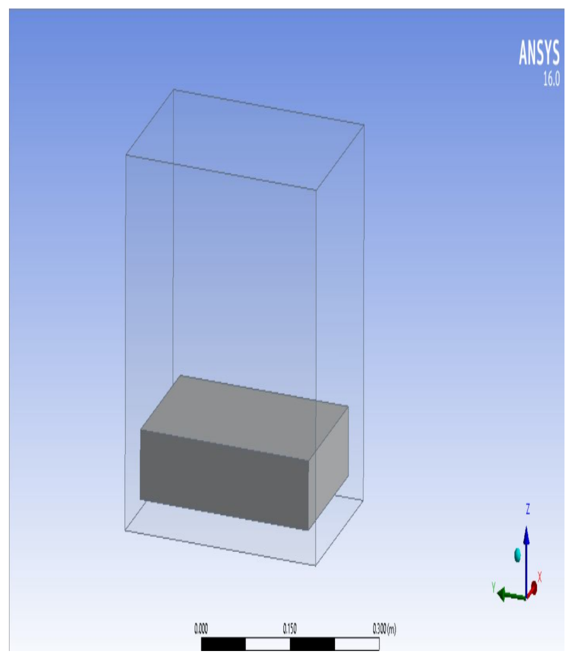

Fig. 6.2 Showing the environmental condition surrounding to pavement block

VII. RESULT AND DISCUSSION.

7.1 Experimental Investigation on Bituminous Pavements and comparison with numerical simulated data of rigid pavements

Time (hr)	Temperature (K) at 1 cm beneath	Temperature (K) at 1 cm beneath (Bituminous)
10	320	322.58
13	326	330.66
15	324.6	333.8
18	318	325.68
19	317.6	327.8

Fig 7.1 – Thermometer used for temperature measuring in bituminous

Fig 7.2 – Upsetting of bituminous

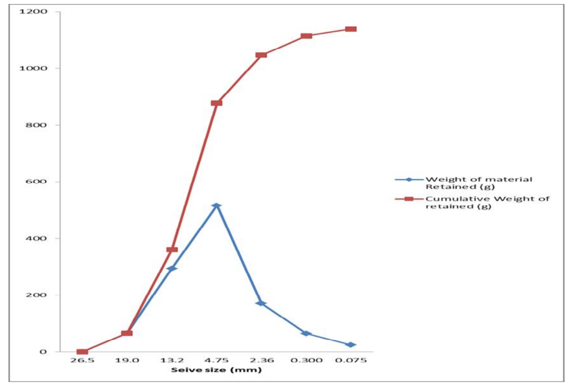

Fig.7.3Experimental data obtained during extraction of bituminous

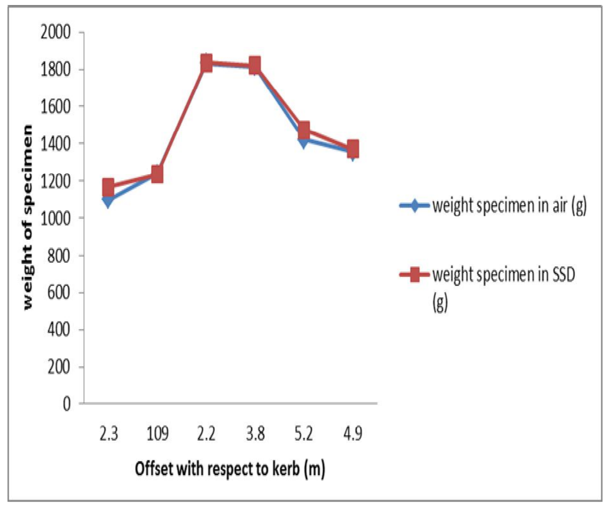

Fig. 7.4 Experimental data obtained during determination of density of compacted bituminous layer

7.2 Case-1 Case-1 Dense graded Asphalt concrete (DG)

Here in this case dense grade asphalt concrete is used to manufacture of pavement block. The material properties of pavement block are mention in the above section. During the analysis of this case the solar irradiation is 200 w/m2. The geographical condition of India during the hottest day is given to the system as shown in the fig.

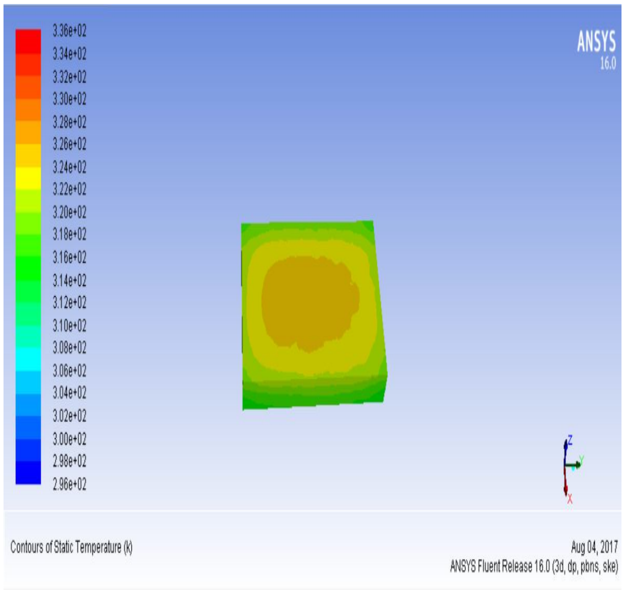

Fig. 7.5 Showing the temperature of Pavement block at 13 hour

Likewise the above analysis it had calculated the value of Pavement block temperature for different time interval, to analyze the effect of solar radiation. The value of temperature for different time interval is shown in the table.

Table 7.1 showing the temperature of pavement block for different time zone

Time	Temperature (K) at 1 cm below
10	320
13	326
15	324.6
18	318
19	317.6

7.3 Case-2 Open Grade asphalt concrete

Here in this case Open grade asphalt concrete is used to manufacture of pavement block. The material properties of pavement block are mention in the above section. During the analysis of this case the solar irradiation is 200 W/m^2. The geographical condition of India during the hottest day is given to the system as shown in the fig.

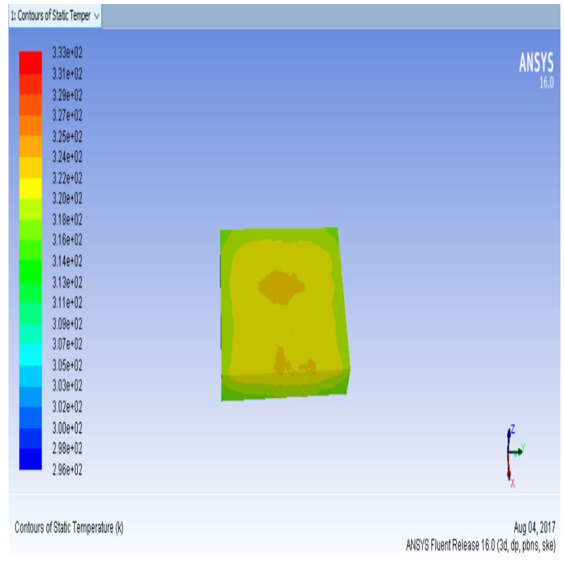

Fig. 7.6showing the contours of temperature for open grade asphalt concrete at 13 hour

Table: 7.2 showing the value of temperature for different time interval

Time	Temperature (K) at 1 cm below
10	319
13	324
15	323.2
18	317.4
19	315.8

7.4 Case-3 Fine grade asphalt concrete

Here in this case fine grade asphalt concrete is used to manufacture of pavement block. The material properties of pavement block are mention in the above section. During the analysis of this case the solar irradiation is 200 W/m^2. The geographical condition of India during the hottest day is given to the system as shown in the fig.

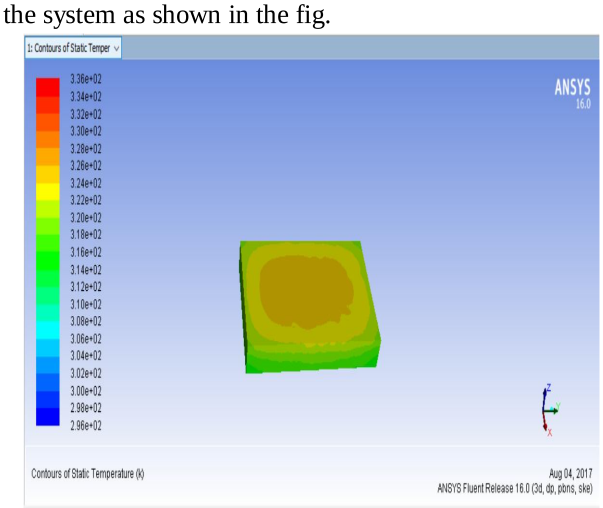

Fig. 7.7 showing the contour of temperature at 13 hour

Likewise it can calculate the value of temperature at different time interval and mention in the table shown below

Table: 7.3 showing the value of temperature at different time interval

Time	Temperature (K) at 1 cm below
10	319.8
13	325.2
15	324.6
18	318
19	317

7.5 Case-4 Open grade asphalt concrete with Titanium dioxide

Here in this case fine grade asphalt concrete is used to manufacture of pavement block. The material properties of pavement block are mention in the above section. During the analysis of this case the solar irradiation is 200 W/m^2. The geographical condition of India during the hottest day is given to the system as shown in the fig. after going through the all for different material analysis it is found that the temperature of open grade asphalt concrete with titanium dioxide pavement block below 1cm depth is less as compared to other three materials. It analyzed that the solar ray falling on the Open grade asphalt concrete with Titanium dioxide pavement block is mostly get reflected from the surface and less amount of rays get absorbed. So it is conclude that the open graded asphalt concrete with titanium dioxide is the best material to construct pavement block in India. It also reduces the global warming

Table: 7.4 showing the value of temperature at different time interval

Time	Temperature low
10	313
13	318
15	317.2
18	314.9
19	313.5

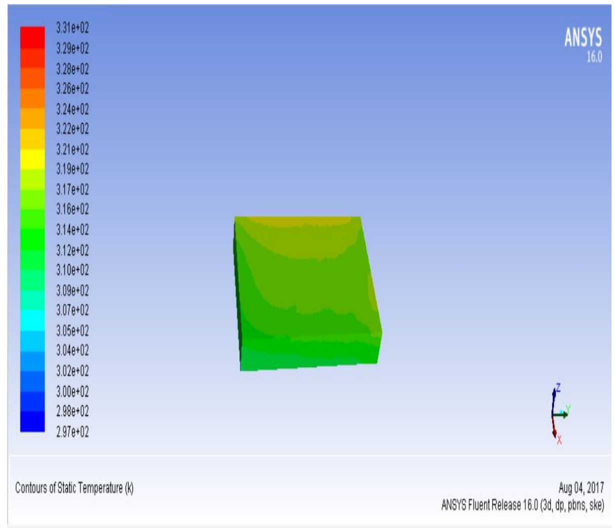

Fig. 7.8 showing the value of temperature at 13 hour

The comparison of temperature for all the four different types of pavement block is shown in the table and it is found that the temperature of pavement block at all the time interval, Open grade asphalt concrete with Titanium dioxide is having the lesser value as compare to other three values. So in order to reduce the building heating effect and also to reduce the temperature of block asphalt concrete with Titanium dioxide material is best for construction.

Time	Dense graded Asphalt concrete (DG) temperature (K)	Open Grade asphalt concrete block temperature (K)	Fine grade asphalt concrete block Temperature (K)	Open grade asphalt concrete with Titanium dioxide block temperature (K)
10	320	319	319.8	313
13	326	324	325.2	318
15	324.6	323.2	324.6	317.2
18	318	317.4	318	314.9
19	317.6	315.8	317	313.5

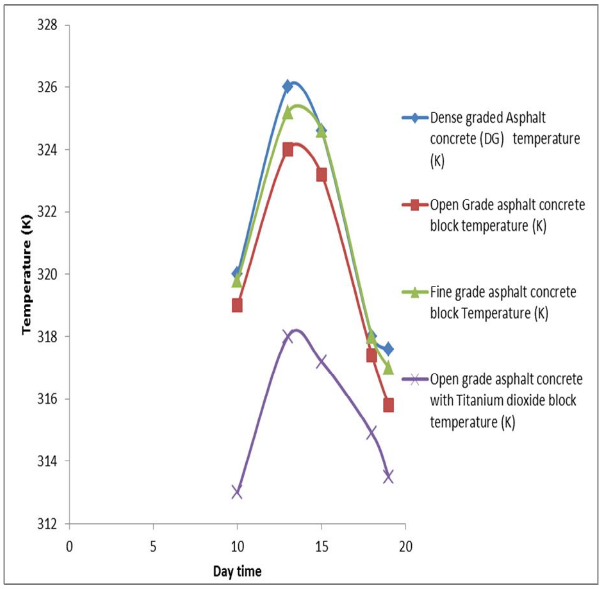

Fig. 7.9 showing the comparison of pavement blocks temperature for all the materials

After analyzing the all four materials it is found that the value of pavement block temperature is less in case of open grade asphalt concrete with titanium dioxide block temperature. So it is the best material for the construction of pavement block in India

VII. CONCLUSION

In order to increase the reflectivity of the pavement block different materials were used to increase the reflectivity of the Pavement surface. The temperature at 1 cm below is near about 300 K. and at below 4 cm it is near about 299.3 K. it is showing that temperature is decreasing as the depth of the pavement block increases. The temperature of pavement block made from open grade concrete at different time interval is shown in the fig. Table showing the value of temperature of Pavement for different time interval at a depth of 1 cm below the surface expose to solar radiation. The comparison of temperature for all the four different types of pavement block is shown in the table and it is found that the temperature of pavement block at all the time interval, Open grade asphalt concrete with Titanium dioxide is having the lesser value as compare to other three values. So in order to reduce the building heating effect and also to reduce the temperature of block asphalt concrete with Titanium dioxide material is best for construction. After analyzing the all four materials it is found that the value of pavement block temperature is less in case of open grade asphalt concrete with titanium dioxide block temperature. So it is the best material for the construction of pavement block in India

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