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Analytical Investigation of Hypothetical Layered Pavement Slab Comprising High Volume Fly Ash Concrete and Fiber Reinforced High Volume Fly Ash Concrete Subjected to Negative Temperature Gradient

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Abstract: In the regions where temperature fluctuations are large ranging from below freezing in winter to high temperatures in summer and also variation of temperature in day and night time presents the impact of daily ambient temperature on the pavement surface heat exchange and subsequent slab temperature stress development Concrete highway pavements fail because of temperature stresses and poor durability rather than lack of strength. Hypothetical Layered pavement technique had been proposed to negotiate the temperature stress and its impact on the warping stresses is studied in this research. Analytical model were created by using software package SAP2000 for negative temperature gradient. Nine types of layered profiles have been modeled and the result are discussed.

Keywords: Temperature stresses, Hypothetical layered pavement technique, High Volume fly ash Concrete, Fiber reinforced High Volume Fly Ash Concrete

I. Introduction

The economic development of the country and the consequent surge in the demand for the transport services and also strategic need of the country necessitated expansion as well as improvement to the road network. India has the second largest network of road. The total length of the road in the country exceeds 3.34 million kilometers

As per present estimate road network carries nearly 65% of freight and 85% of passenger traffic. Traffic on the road is growing at a rate of 10% per annum while the vehicle population is of the order of 12% per annum. The road network developed should centre the needs of increasing traffic and axle loads. This can be achieved by selecting superior material of concrete pavement which can provide strength; enhanced service life and durability, superior material like high Performance concrete selected for the construction of pavement can enhance the service life of the pavement and also reduce maintenance cost. Concrete is a composite material composed of coarse aggregate bonded together with fluid cement that hardens over time. But the production of cement generates large amount of carbon dioxide that contribute to green house effect. Considerable amount of Carbon dioxide could be reduced if the production of cement could be reduced. Concrete is the most versatile and widely used construction material. Normally, conventional concrete is manufactured with Portland cement, which acts as a binder. The production of cement releases considerable amount of CO_2 into the atmosphere and it consumes significant amount of natural resources. In order to reduce this impact, there is a need to develop sustainable alternatives to Portland cement utilizing the industrial by products such as fly ash, ground granulated blast furnace slag, etc. which are pozzolanic in nature.

II. Significance of the Project

[1] To create a Hypothetical analytical model of a layered pavement slab of different coefficient of thermal expansions comprising high volume fly ash concrete(HVFAC) and fibre reinforced high volume fly ash concrete(FRHVFAC)
[2] To investigate the effect of layers on temperature stresses of pavement slab model.
[3] To determine the most effective layer profile in the negotiation of Negative temperature gradient's stresses.

III. Analysis Method

3.1 Finite Element Method

Finite Element Method is defined as a numerical technique for finding approximate solutions to partial differential equations (PDE) and their systems, as well as integral equations. In simple terms, FEM is a method for dividing up a very complicated problem into small elements that can be solved in relation to each other. A rigid pavement is modeled as a slab. Linearly varying Negative temperature gradient is applied as temperature load. The FEM solution approach is based either on eliminating the differential equation completely(steady state problems), or rendering the PDE into an approximating system of ordinary differential equations, which are then numerically integrated using standard technique such as Euler's method, Runge-Kutta,etc,.

IV. Stresses in Pavements

4.1 Stresses in Rigid Pavement

- Temperature Stresses
- Frictional Stresses
- Wheel Load Stresses

4.2 Temperature Stresses

Due to the temperature differential between the top and bottom of the slab, curling stresses (similar to bending stresses) are induced at the bottom or top of the slab.

Temperature differential between the top and bottom of the slab causes curling (warping) stress in the pavement • If the temperature of the upper surface of the slab is higher than the bottom surface then top surface tends to expand and the bottom surface tends to contract resulting in compressive stress at the top, tensile stress at bottom and vice versa

4.3 Temperature Differentials

Temperature differential between the Top and Bottom fibers of concrete pavement causes the concrete slab to curl, giving rise to stresses. The Temperature differential is a function of solar radiation received by the pavement surface, wind velocity, thermal diffusivity of concrete, latitude, longitude and elevation of the place.

4.4 Negative Temperature Differential

The variation of temperature with depth is nearly linear during night hours. Temperature differentials are negative when the slab has the tendency to have a concave shape during night as the temperature at the top fibers of the pavement slab is comparatively lower than the temperature at the bottom fibers of the slab.

V. Inite Element Model

5.1 Pavement Slab

A Hypothetical profile of slab of length 3 m, Width 3 m and Thickness 0.2 m is modeled. The slab is discredited into elements of maximum 50 mm size. The Thickness of the slab is divided into four layers of 50 mm thickness. The bottom layer solid elements are assigned with springs representing subgrade reactions of 39 Mpa/m, 63 Mpa/m, 92 Mpa/m respectively.

Material properties HVFAC and FRHVFAC is defined and assigned to layers as briefed below

H – Homogeneous Slab of HVFAC
1LB – One bottom most Layer of FRHVFAC and rest HVFAC
2LB – Two bottom most Layer of FRHVFAC and rest HVFAC
1TB – One Top most Layer of FRHVFAC and rest HVFAC
2TB – Two Top most Layer of FRHVFAC and rest HVFAC
ABL – Alternating Bottom Layer of FRHVFAC
ATL – Alternating Top Layers of FRHVFAC
EL – Extreme layers of FRHVFAC
NL – Near Layers (Adjacent to centre) of FRHVFAC

A Negative Temperature differential of 15°C is applied on the model. Temperature at the top fibers is 15°C and Bottom fibers is 30°C

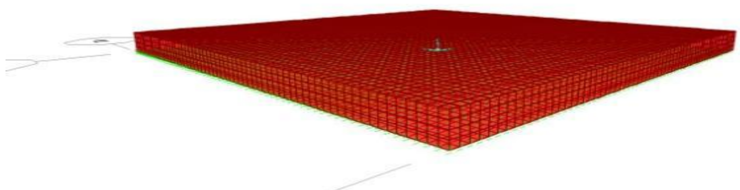

Fig. 5.1 FEM model

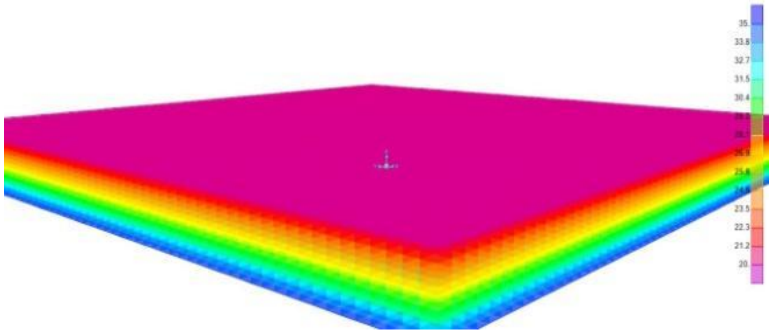

Fig. 5.2 Temperature Gradient

Fig. 5.3 1LB

Fig. 5.4 2LB

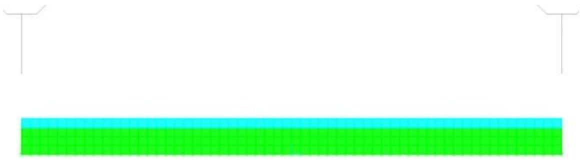

Fig. 5.5 1LT

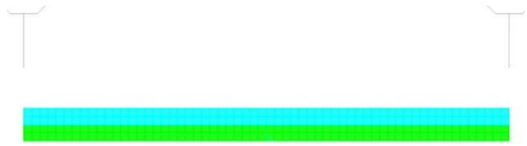

Fig. 5.6 2LT

Fig. 5.7 ABL

Fig. 5.8 ATL

Fig. 5.9 EL

Fig. 5.10 NL

VI. Results and Discussion

The Nodal Displacement results and Maximum nodal displacements for the nine profiles with Three Subgrade values are presented below.

6.1 DISPLACEMENT ALONG DIAGONAL NODES IN THE SLAB FOR ALL NINE PROFILES

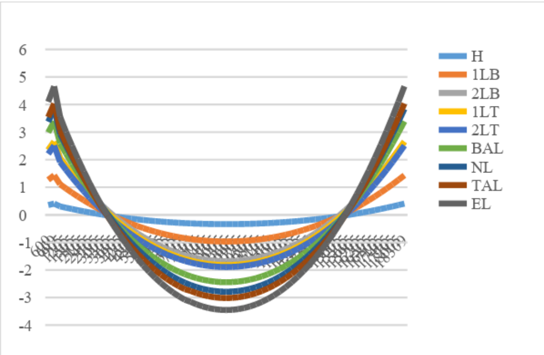

Fig. 6.1 Subgrade 39 Mpa/m

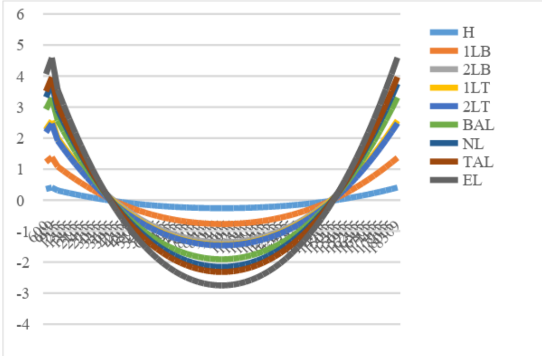

Fig. 6.2 Subgrade 63 Mpa/m

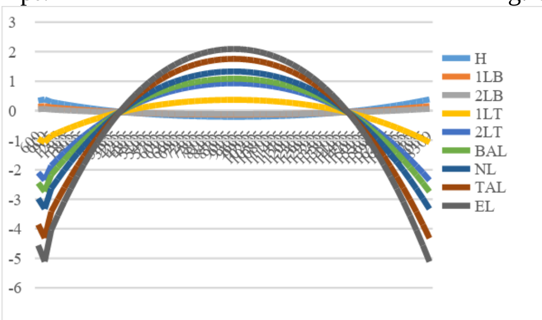

Fig. 6.3 Subgrade 92 Mpa/m

6.2 DISPLACEMENT IN CORNER NODE

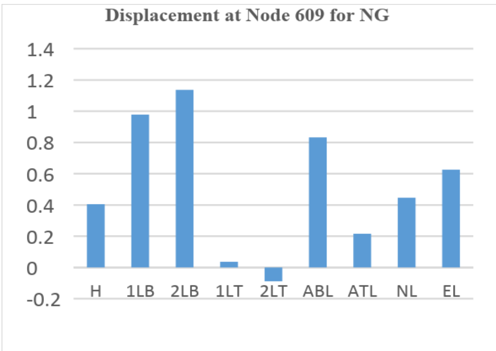

Fig. 6.4 Subgrade 39 Mpa/m

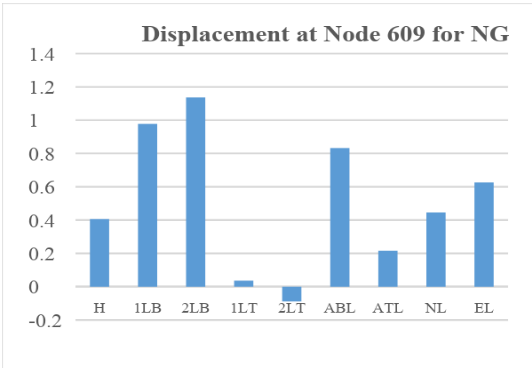

Fig. 6.5 Subgrade 63 Mpa/m

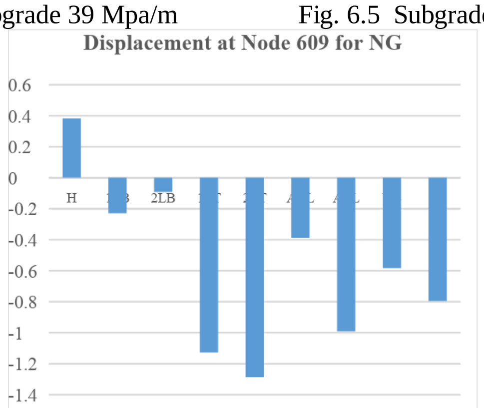

Fig. 6.6 Subgrade 92 Mpa/m

6.3 DISPLACEMENT IN CENTER NODE

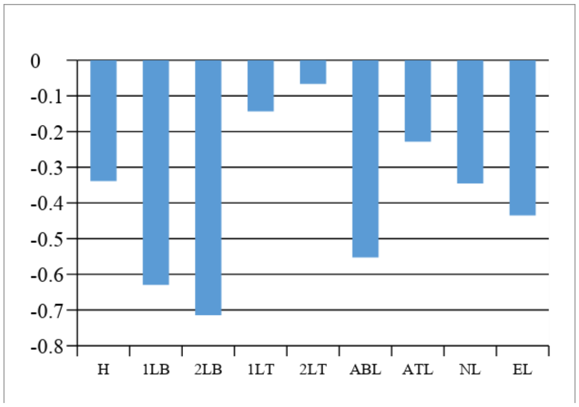

Fig. 6.7 Subgrade 39 Mpa/m

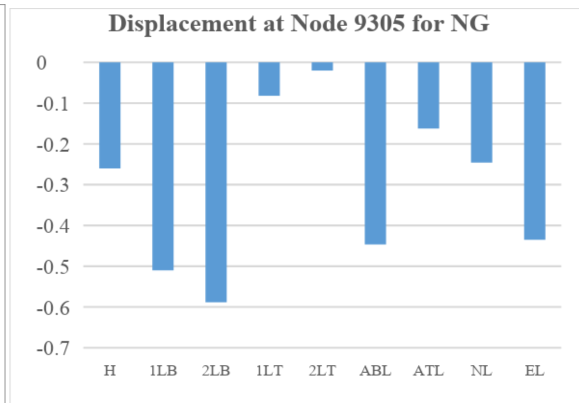

Fig. 6.8 Subgrade 63 Mpa/m

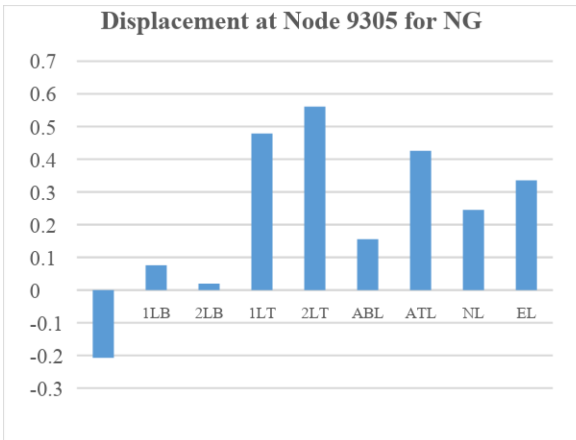

Fig. 6.9 Subgrade 92 Mpa/m

VII. Conclusion

The following points are concluded from this investigation:

[1]. The Hypothetical Model negotiates the curling behavior caused by the Temperature differential.

[2]. From the results obtained from the package sap2000, it is concluded that the layers of 2LB- Two-layer bottom, ABL- Bottom alternative layer and EL- Extreme layer will be having a reduction in temperature stresses as well as in displacement.

VIII. References

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