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STUDY OF LOAD TRANSFER EFFICIENCY OF DOWEL BAR

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Abstract – ***Use of dowel bars as a load transfer device in rigid concrete pavement is increasing in road construction. This concept has so far have found significant application in the country. The mechanistic analysis presented in this project is only a beginning of new approach for understanding the real joint load transfer capability on highway concrete pavements. A numerical model is developed by ANSYS workbench of jointed concrete pavement subjected to static load is presented in the project. The objective of this study focuses on quantifying the static effects of a wheel while it is crossing a joint on a pavement. The analysis is conducted using a model of two-slab system on spring foundation under a static wheel with variable load and foundation reaction modulus k. The deflection is found and joint load transfer efficiency is calculated further researches are needed for appropriate applications of the new model.***

Key Words: Rigid pavement, Joint load transfer efficiency, Foundation reaction modulus, Deflection

1. INTRODUCTION

In this study 3D-FE analysis that includes detailed consideration of slab constraints by dowel bars is used to analyze the problem of efficiency of dowel bars and excessive deflection occurring in the jointed concrete pavements without dowel bars. This approach enhances the accuracy of FE solution with solid elements simulating the concrete slab and supporting layers. The model has the capability to handle different applied impact loads affecting the pavement, it also handles the various design conditions, including: (a) dowel bar diameter, (b) dowel spacing,(c) slab Thicknesses,(d) concrete Grade. The objective is to reveal the interaction laws between dowel bars and surrounding concrete at the doweled joints under realistic conditions of impact loads generated by traffic.

1.1 RIGID CONCRETE PAVEMENT WITH DOWEL BAR

1.1.1 Subgrade

Subgrade is foundation soil which is compacted to achieve an appropriate strength. There are three types of Subgrade model which are classified as:

1. Liquid Foundation
2. Elastic Foundation
3. Layer Foundation

Liquid foundation or Spring foundation is used to analyze the model. The liquid foundation is the simplest model of soil idealization. It was developed by Winkler (1864) and Westergaard (1948). Modulus of subgrade reaction is the required parameter which is assumed to be constant during soil deflection under the applied load. The subgrade modeled as a spring of independent springs in this method fig2.2. However development of finite element programs requires the use of spring models idealization. Hence the liquid foundation was replaced with concentrated springs at the nodes of the element. The method is only able to consider vertical deflection at the nodes, the spring does not show any resistance to the deformation.

1.1.2 Joints

Great care is needed in the design and construction of joints in Cement Concrete Pavements, as these are critical locations having significant effect on the pavement performance. The joints also need to be effectively sealed, and maintained well. Cement Concrete Pavements have transverse and longitudinal joints. Different types of transverse joints are:

i) Contraction joints
ii) Construction joints
iii) Expansion joint
iv) Longitudinal joint

The model is analyzed at the expansion joint as dowels are placed at this joint. The main reason for utilizing the expansions joints is to avoid failure due to thermal and moisture movement in the structural element. Expansions joints are widely employed in bridges and long length or width structures.

1.1.3 Load Transfer efficiency

Aggregate interlock and mechanical devices may be employed to transfer the shear force across joints. Mechanical load transfer devices are placed within the joint to physically transfer the applied shear force between slabs on the opposite side of the joints. Dowel bar and tie bar are example of common mechanical devices that are widely used in pavement construction.

Dowel has fundamental role in transverse joints particularly when the pavement is not reinforced. Dowels are typically round with a diameter of 1/8 of concrete slab thickness and 350 to 460 mm long. Dowels are placed at mid depth of the base with an even space of 300 mm centre to centre and positioned perpendicularly to the transverse joints (FHWA 1983). Since one side of dowel is always coated by a debonding layer, longitudinal movement of the concrete slabs on both sides of the transverse joints where not

restrained. Standard mild steel epoxy coated dowels bar, Fiber reinforced polymer(FRP), solid stainless steel dowels, grouted stainless steel dowel, stainless steel clad dowels, and stainless steel pipe dowels are employed worldwide. Dowels with other cross- sections including I-beam, oval dowels, and flat plate are also used to decrease the bearing stress in the concrete slab under vehicular loads by increasing the bearing area.
Basically this method involves reducing the structure to its cinematically determinate form (all degrees of freedom restrained) as explained in the previous section. The structure can be analyzed by developing the individual matrices for each element of the Structure and assembling them to form global matrices. Though this method is systematic, and is generally encouraged, it often involves long matrix operation (repetitive multiplication) during the transformation from the local to the global system. The direct method (manual computations) is discussed first, and the computerized version of the method is presented later for a few typical examples. In the direct method, the D.O.F. are released one at a time and the forces developed in the system corresponding to all the D.O.F. are computed these forces developed in the system for unit displacements are the coefficients of the stiffness matrix by definition. The load matrix for the given loading system is developed in the same way as described for beams. The solution of the stiffness matrix system yields the displacements in the structure corresponding to the applied loading system.

2. FINITE ELEMENT ANALYSIS AND DESIGN OF DOWEL BAR

2.1 Design of dowel bar

Dowel bar is designed as per IRC 58-2011 and checked for safe load bearing and for appropriate thickness of road slab.

2.2 Finite element Analysis

Analysis is carried out by using ANSYS workbench software and the model is created using CATIA

2.3 Parametric Study

This study is carried out for stiffness variation and load variation for two cases:

1. Axle Load at the middle of road slab
2. Axle Load at the edge of road slab

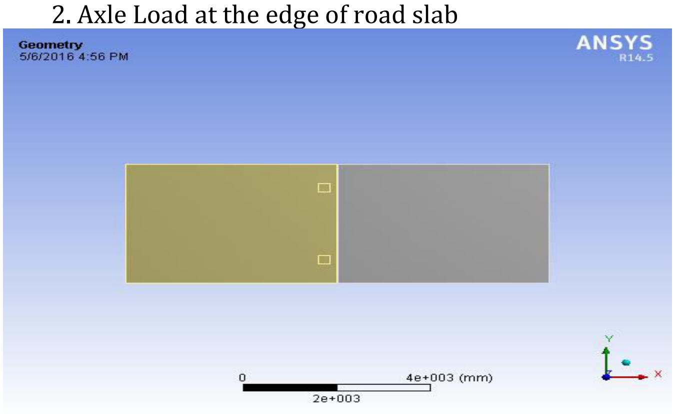


Fig.1Model of road slab with dowel at middle loading

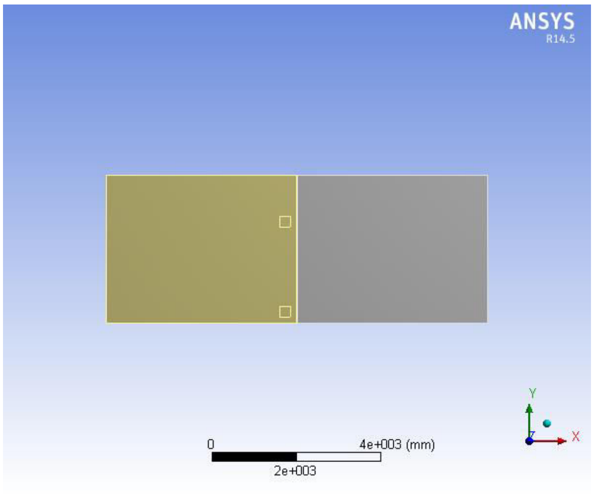


Fig.2 Model of road slab with dowel at edge loading

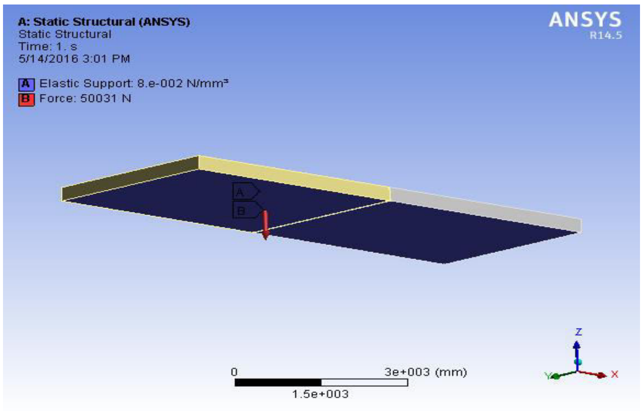
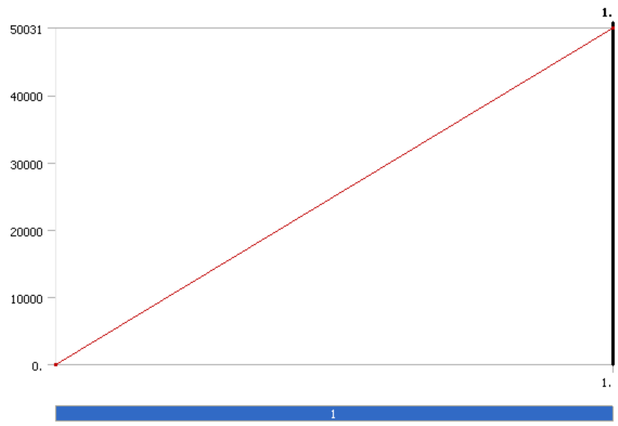


Fig.3 Applied Foundation Stiffness

Fig.4 Loads applied on patch shown as B



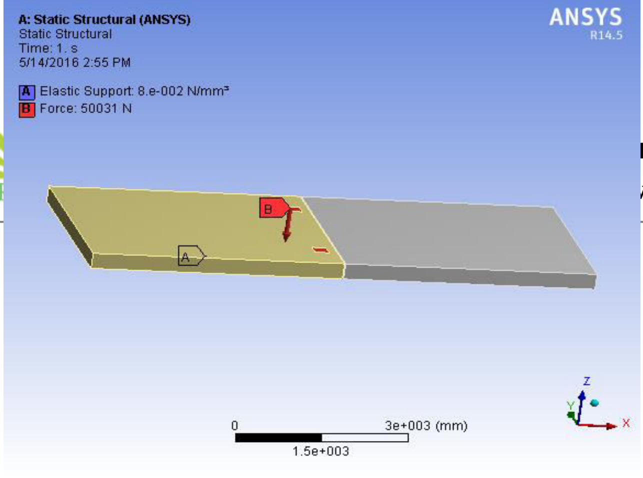


Chart.1 Load applied on the patch in one step

The above fig. shows static load applied in one step for 5 tonne of load. The model is analyzed in the same way as above for load of 10 tonnes, 15 tonnes, 20 tonnes, 25 tonnes, 30 tonnes, 35 tonnes, and 40 tonnes which are represented as 'A' in fig. below. The elastic support is provided at the bottom as the model is analyzed with spring foundation or with elastic supports. The deflection for each case is then tabulated.

2.4 Load transfer efficiency (LTE)

After the finite analysis load transfer efficiency is calculated for each case.LTE is an important factor in performance of transverse joints and cracks. It is measured to evaluate joint operation under the applied load. It can be calculated by following equation:

$$\text{LTE\%} = \frac{\partial_u}{\partial_L} \times 100$$

(Where, ∂_u is the deflection of the unloaded slab and ∂_L is the deflection of the loaded slab.)

LTE is affected by dowel size, aggregate interlock, width of joints, and sub base or sugared strength. Based on results of Harvey et al(2003), the LTE did not change by changing the traffic volume on the section reinforced with DBR. Furthermore, the LTE was less sensitive by temperature changes. In addition to the use of suitable dowels, the improvement of subgrade strength can improve the LTE as reported by Hossain and Wojakowski (1996).

The variation of load transfer efficiency for each case is shown in graphs below:

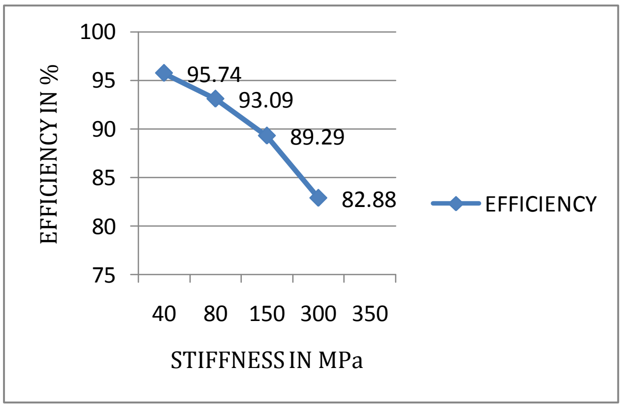


Chart.2 Stiffness vs Efficiency (At Mid)

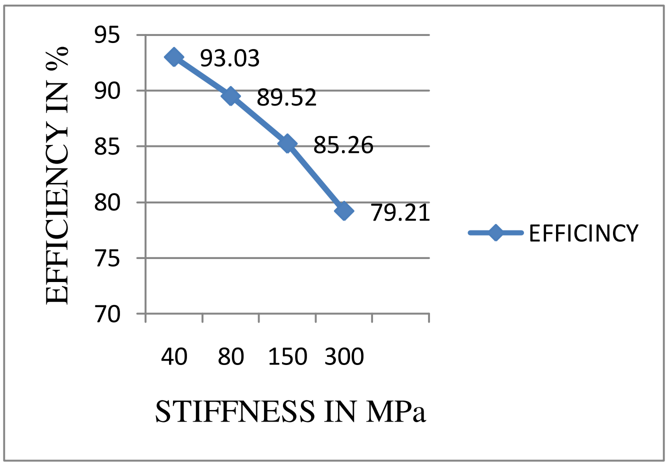


Chart.3 Stiffness vs. Efficiency (At Edge)

3. CONCLUSIONS

1. The deflection and principle stresses obtained by the FEM model analysis are close to the results in previous literature therefore present FEM model can be applicable for dowelled joint analysis.
2. For uniform foundation stiffness the effect of change of load on transfer efficiency is negligible for both mid and edge loading cases.
3. As the foundation stiffness increases there is decrease of load transfer efficiency observed

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