Effect of Joint Width and Sealing Material on Performance of Bituminous Block Pavement using Finite Element Method

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Abstract **- Historically bituminous block pavement is used for road construction purpose at some places around the world. The performance of the block pavements principally depends on the joint width and sealing material. Very few experimental studies are reported in bituminous block pavement. However, there are no studies on the performance evaluation of bituminous block using the finite element technique. The finite element method reduces the constraints in experimental studies on performance evaluation of joint width of block pavement such as time-consuming and complex. This study aims to analyse the performance of block pavement with different joint width and sealing material using the finite element model. The finite element model was designed using ABAQUS software. Different joint widths between the bituminous block for this study is 0mm, 2mm, 3mm. The research includes two joint sealing materials such as sand and bituminous material is used for the analysis of bituminous block pavement. From the finite element analysis result, better performance of the bituminous block is achieved by using bituminous material as a sealing material.**

Keywords: Bituminous Blocks, Joint Width, Sealing Material,Finite Element Method, ABAQUS.

I. INTRODUCTION

Road network plays a vital role in the economic development of a country. The majority of the road networks are constructed using bituminous material i.e. flexible pavement. The flexible pavement should provide safe riding to the passengers and vehicles without any discomfort[1]. With the rapid change in the vehicle loading pattern and climatic condition, the flexible pavement is subjected to distresses. The durability of any pavement structure depends upon various factors such as quality of materials, environmental condition and thickness of each layer[1]. Lack of construction and poor maintenance of flexible pavement increases the occurrence of distress. Potholes are the major distress which occurs in the flexible pavement, sometimes the artificial potholes are made especially in the developing country like India. Road service works such as repairing water connections, drainage works, etc. are the major cause of artificial potholes. Distresses cause road accidents which affects the economy of the country.

In India, as per the road accidents statistics, the socio-economy costs about 0.77% of GDP because of road accidents in the year 2018[2]. The potholes are repaired using concrete as a time being measure. A huge quantity of materials are wasted due to improper maintenance work, it can be reduced by implementing new techniques in road maintenance and construction works. Global scenario the bituminous block pavement is used for road construction purpose in some places[3]. In Georgia, the bituminous block pavement is used in the streets as historic pavements. The bituminous block pavement can be used as an alternative material for road repair works and also it can be used in place of faster construction. The performance of block pavements hugely depends on the jointing i.e. sealing material and joint width. The finite element method provides best result for optimizing the laying pattern of block pavements[4].

Evaluation of bituminous block pavement in the laboratory with different conditions is tedious and complex. The finite element method reduces the difficulties in experimental studies on bituminous block pavement performance. Various research works are done in flexible pavement analysis using an analytical tool. Using FEM the analysis of flexible pavement with varying thickness of pavement and different material properties the performance of flexible pavement is predicted[5]. Using the PLAXIS 2D finite element method the performance of flexible pavement using geo-grids are evaluated. Reinforced asphalt pavement using geo-grid shows less deformation when compared to unreinforced asphalt pavement using finite element method[1]. In another study, a complete numerical factorial is developed using the finite element method to determine the response asphalt pavement structure[6]. A finite element model for predicting the permanent deformation using ABAQUS software for the suitability of overlay condition[7]. To measure deflection basin of the block pavement the three dimensional finite element model was used[8]. Finite element method for comparing the concrete block pavement and asphalt pavement using ABAQUS with same properties of pavement layers[9]. Several research shows that joint width plays an important role in asphalt pavement blocks[10]. The main aim of this study is to analyse the performance of bituminous block pavement using the finite element method.

II. METHODOLOGY

A. Finite Element Model

In this study, a three dimensional model of block pavement were analysed using ABAQUS software. The pavement model consists of different layers with varying material properties. The three-dimensional models of bituminous block pavement are shown in Figure 1.

Initially, the pavement model parts and property of the material is assigned. The performance of block pavement is analysed by comparing the deformation of pavement structure subjected to contact pressure over the pavement i.e. static loading. The interaction between the pavement layers is provided with the surface to surface contact option in the finite element model. Each layer of the pavement is unrestrained in the normal direction as a boundary condition and the remaining sides are restrained fully.

Five different models are analysed in this study i.e. different joint width for the bituminous block pavement and two filling materials for the gap between the blocks. The joint width of the pavement block for this study is 0mm, 2mm, and 3mm. The pavement block arrangement plan view is shown in Figure 2. Sand and bituminous material are used as the filling material for the joint gap. The loading area and the pressure kept constant for all the five model and the test results are compared based on the deformation.

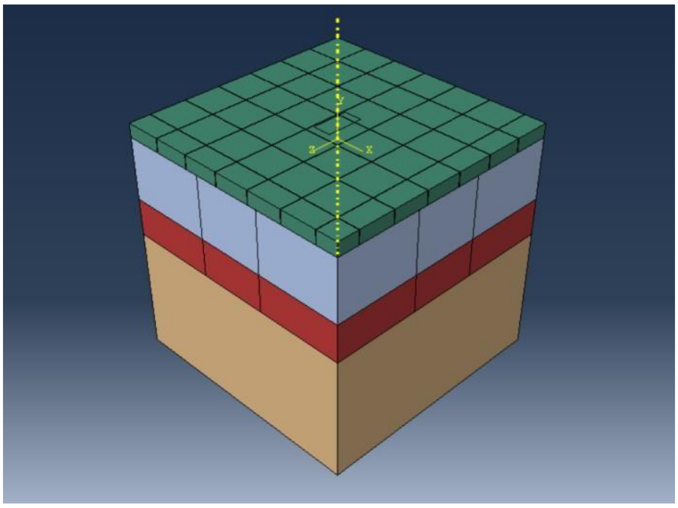

Fig. 1. Finite Element Model

B. *Pavement Composition*

The bituminous block pavement structure consists of four layers such as subgrade, subbase, base and block. The thickness of pavement layers is designed as per IRC 37:2018[11]. Initially, the CBR value of each layer is determined based on the gradation of materials as per the MORTH specifications[12]. The size of the bituminous block for this study is 150mm x 150mm in the square. The material property and the thickness of the pavement layer are prescribed in Table 1.

TABLE I. PAVEMENT MATERIAL PROPERTIES

Pavement Layer	*Thickness (mm)*	*Elastic Modulus (MPa)*	*Poisson's Ratio*
Subgrade	500	71.81	0.35
Subbase	150	136.92	0.35
Base	250	212.88	0.35
Bituminous Material	55	1000	0.35
Filling Material	2 & 3	50	0.3

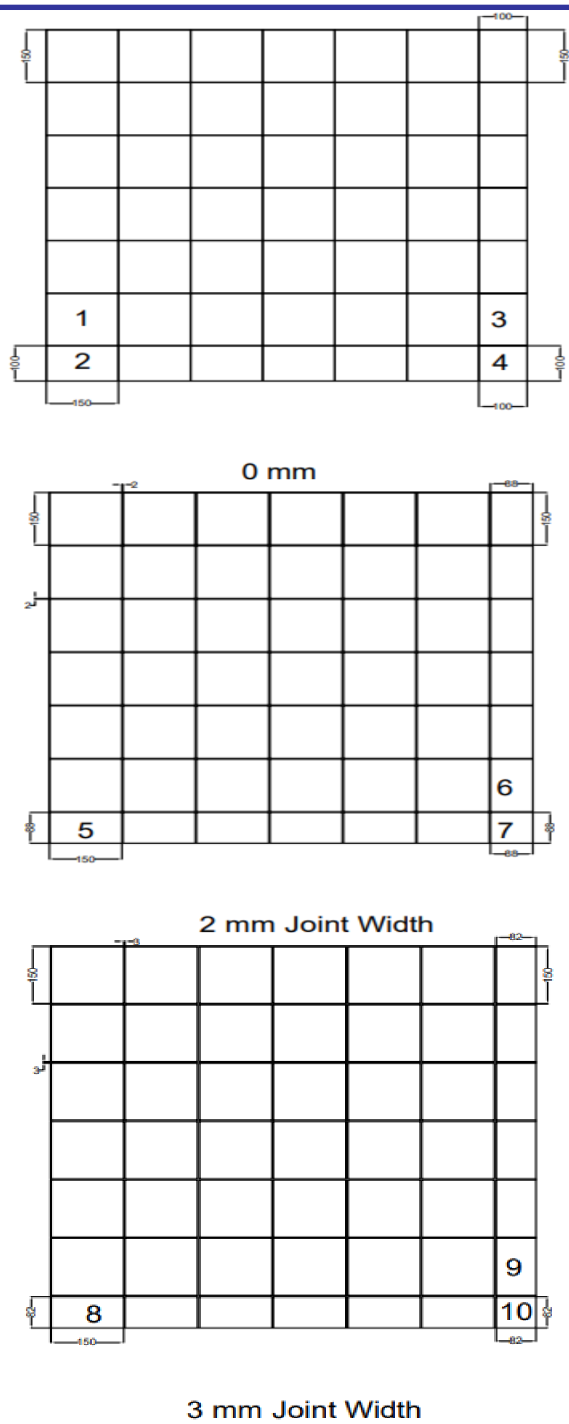

Fig. 2. Pavement Block Arrangement

III. RESULT AND DISCUSSION

In this present study, the effect of joint width using different sealing material in bituminous block pavement is analysed using the finite element method. The output result for the bituminous block with different joint width 0mm, 2mm and 3mm incorporating different sealing material such as sand and bitumen, as shown in the following figures.

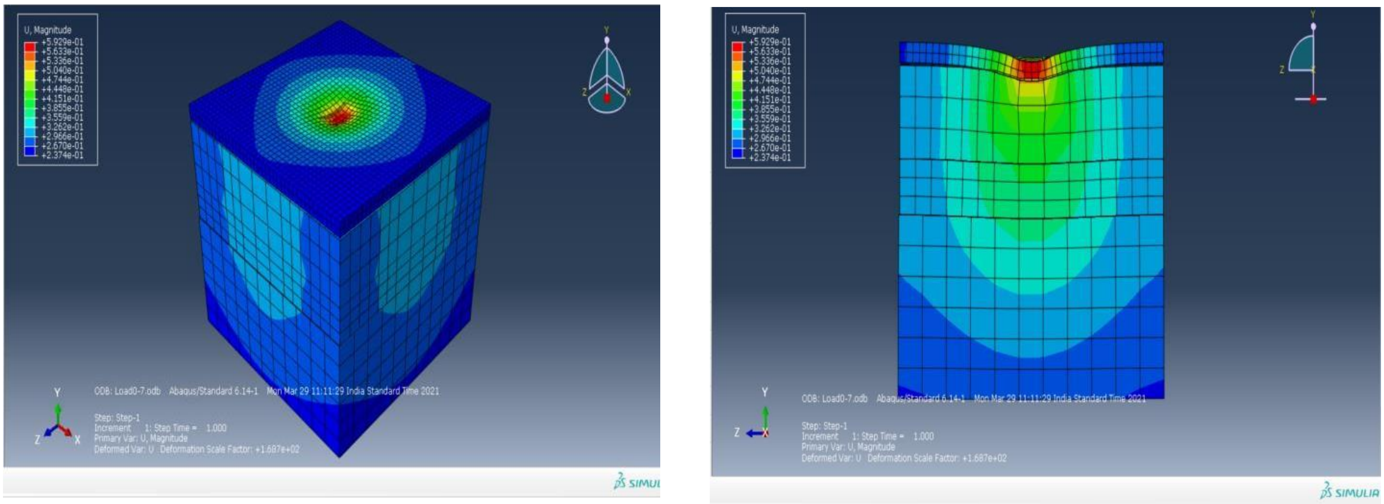

Fig. 3.Surface deformation profile for the bituminous block of 0mm joint width without sealing material

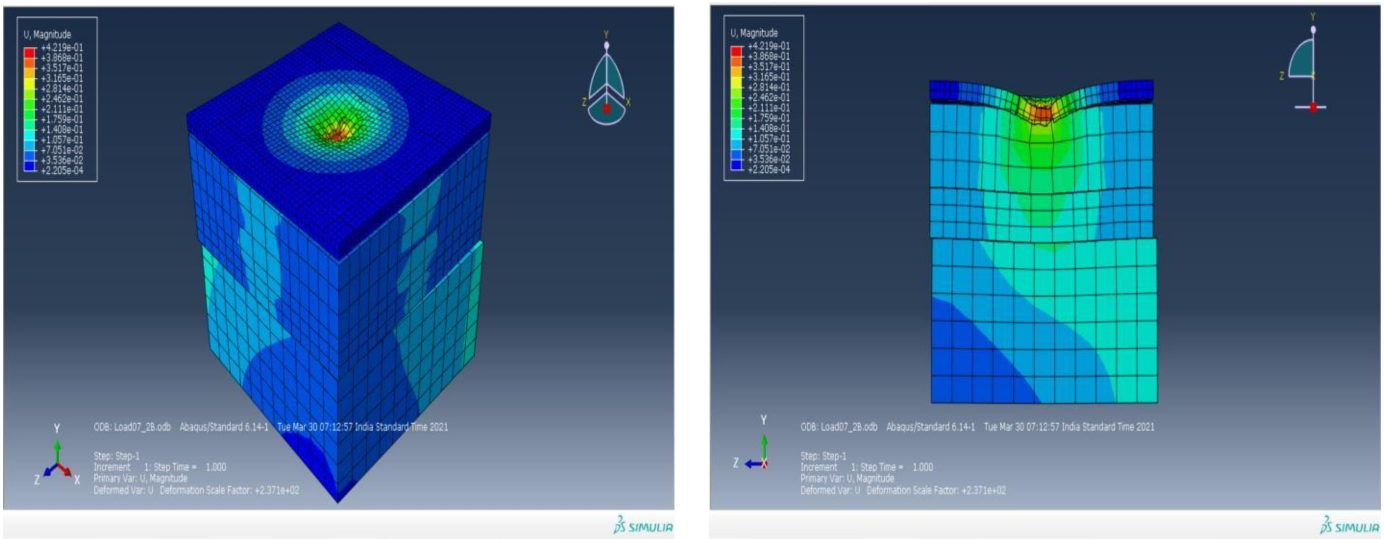

Fig. 4.Surface deformation profile for the bituminous block of 2mm joint width (Sealing Material - Bitumen)

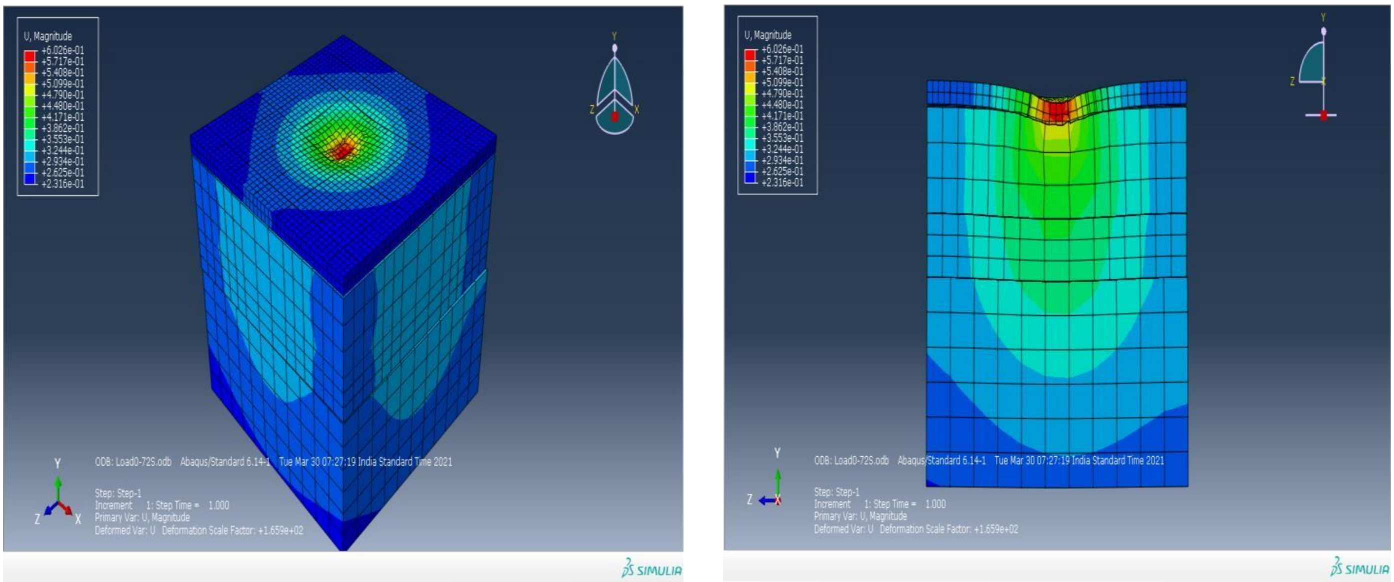

Fig. 5.Surface deformation profile for the bituminous block of 2mm joint width (Sealing Material – Sand)

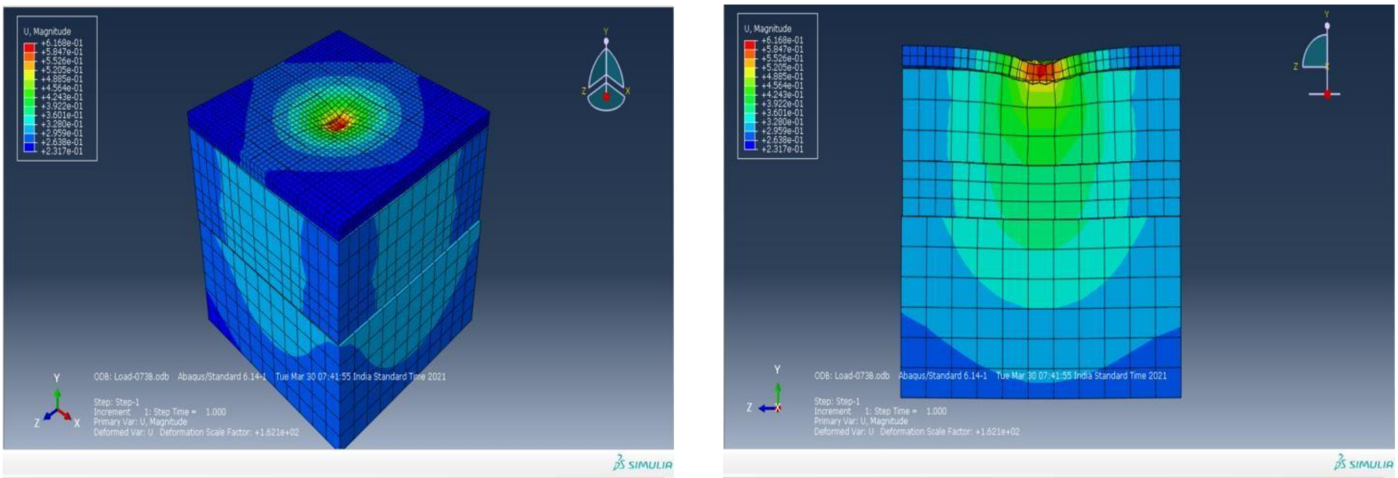

Fig. 6.Surface deformation profile for the bituminous block of 3mm joint width (Sealing Material - Bitumen)

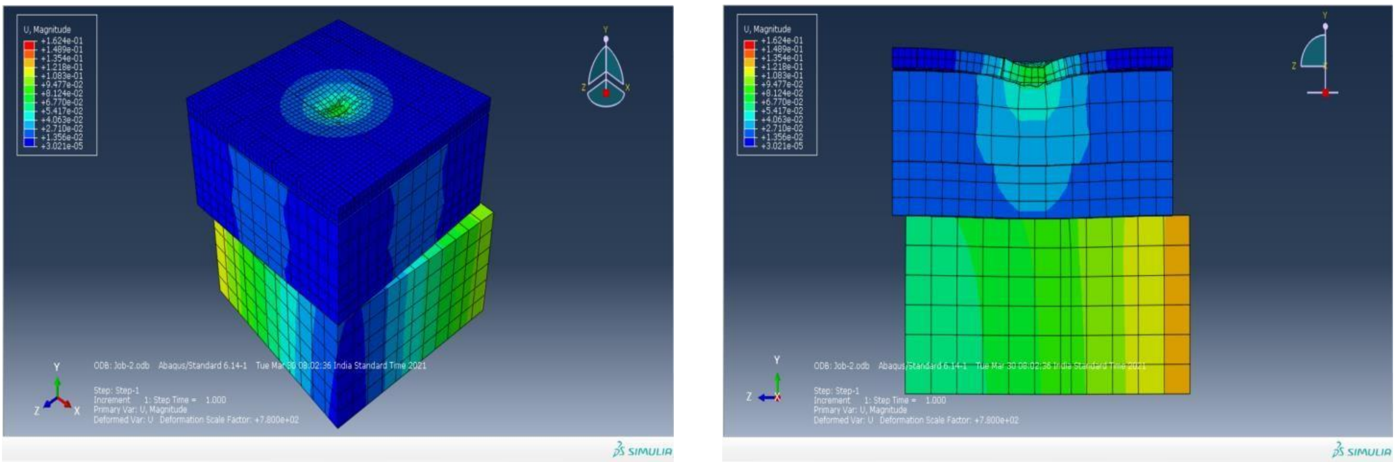

Fig. 7.Surface deformation profile for the bituminous block of 3mm joint width (Sealing Material – Sand)

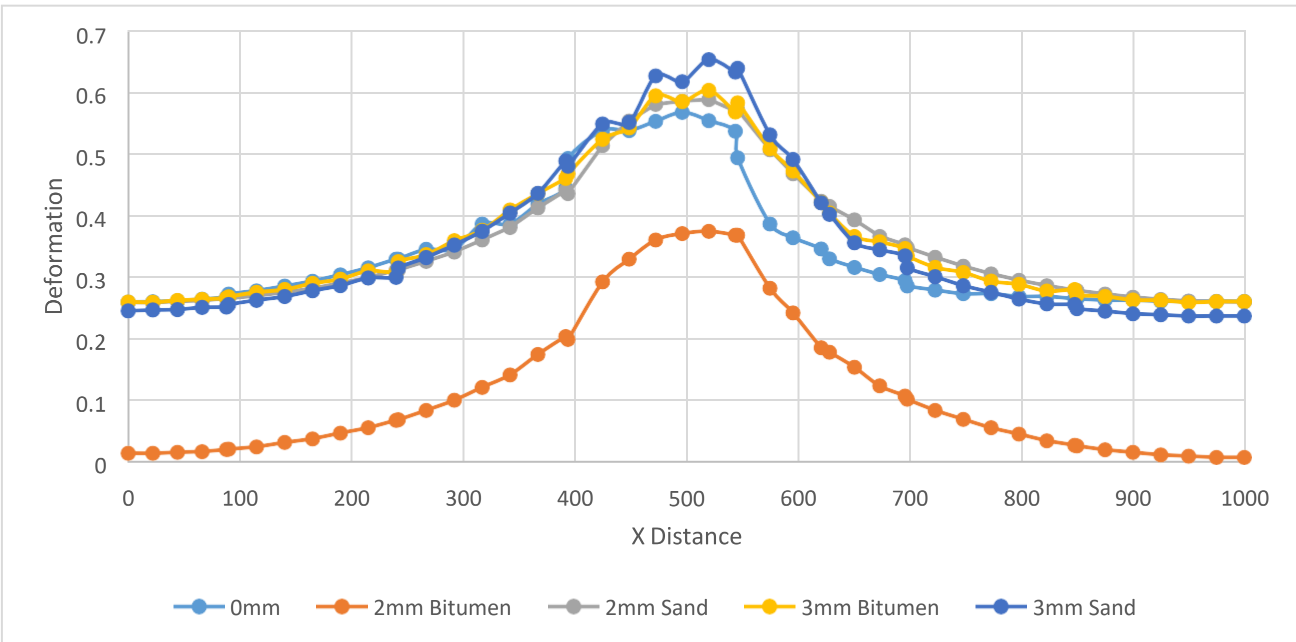

Fig. 8.Surface deformation profile for bituminous block pavement

The test results using the finite element method indicated that the 2mm joint width bituminous block pavement arrangement using bitumen sealing material has less deformation as compared to other arrangements for the same loading condition. Surface deformation in the vertical direction of the bituminous block pavement is shown in Figures 3 to 7 concerning variation in the joint thickness 0mm, 2mm width, 3mm width with bitumen and sand as sealing material respectively. The loading condition, base, subbase and subgrade layer thickness are the same for each arrangement of bituminousblock pavement.

The surface to surface contact type interaction is provided between the pavement layers for all type of arrangement. Figure 8 shows that the deformation values at a different distance in the X direction for all type of bituminous block pavement. The analysis result shows that 2mm joint width using bitumen sealing material has the deformation value of 0.381mm which isleast compared to others. This is due to the monolithic action of the bituminous top surface when compared to sand. The sand sealing material arrangement of bituminous block pavement topsurface act as modular blocks.

From Figure 4 and 5, it can be seen that for the same joint width of 2mm the deformation of bituminous sealing material isless compared to sand as sealing material. The deformation value of the bituminous block pavement with 2mm joint width increases from 0.381 mm to 0.595 mm. Similarly the deformation of the bituminous block pavement with 3mm joint width changes from 0.610 mm to 0.659 mm for the bituminous and sand sealing material. For the 0mm joint width without any jointing material the surface deformation of the bituminous block is 0.574mm.

It can be seen from Figure 8, increase in the surface deformation for the bituminous sealing material of 2mm and 3mm joint width is approximately 60%. Similarly, the surface deformation varies about 11% for the 2mm and 3mm joint width of bituminous block pavement with sand as sealing material. When compared to the bitumen and sand sealing material for the2mm and 3mm joint width the increase in surface deformation is 56.16% and 8% respectively. It can be observed that an increase in the joint width of bituminous block pavement with sand sealing material increases the surface deformation.

IV. CONCLUSION

The study was carried out to analyse the effect of joint widthand sealing material on the performance of bituminous block pavement using FEM analysis. From the finite element analysis,the major findings are given as follows:

- The bituminous block pavement arrangement of 2mm joint width with bituminous sealing material gives the better result of less deformation about 0.381mm.
- The vertical deformation of bituminous block pavement for 0mm and 2mm joint width are less compared to 3mm joint width.
- Bituminous sealing material gives better result for all type of joint width compared with sand as sealing material.

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