



ANALYSING THE LOAD DEFLECTION BEHAVIOUR OF JUTE FIBRE TREATED PAVEMENT SHOULDER

Dr. Rumi Sutradhar¹ and Dr. Arpan Laskar²

1. Lecturer (Senior Scale), TTAADC Polytechnic Institute, Tripura, India

2. Associate Professor, Techno College of Engineering Agartala, Tripura India

Abstract: The problem of poor pavement performance is a serious issue in the rural roads for developing countries. Different types of pavement structural failures are forming in the roads, viz. edge drop, vertical depression, potholes, rutting etc. In few cases these types of failures are extending towards subgrade layer also. These types of failures are hampering riding comfortability, pavement serviceability and also increasing the vehicle operating cost. Pavement shoulder has a vital role on the occurrence of road failures, as it bears the lateral impact of wheel load and acts as emergency lane. A poor shoulder weakens the pavement edges, forms shoulder-drop and causes edge failure, which may further lead to different pavement failures. The present study is an attempt to improve the performance of pavement shoulder using jute fibres and analysing its acceptability as compared to existing untreated shoulder. PLAXIS 3D software is used to create the 3D model of the pavement section and analyse the load-deflection behaviour which shows a significant result for the treated shoulder.

Keywords: Jute Fibre, Load-Deflection Behaviour, Pavement Performance, Pavement Shoulder, PLAXIS 3D.

1. Introduction

Pavement shoulder keeps a vital role on the stability and performance of a road. It serves as emergency lane, supports the pavement structure from subgrade to surface course layer. It also acts as temporary parking plot. A stiff and stable shoulder can resist the lateral impact of wheel load. During movement of vehicles, the axle load is applied in vertical direction, but there is a lateral impact of the axle load which directly affects the shoulder subgrade. Again, during movement of vehicles, the wheels often cross the edges of the pavement section and moves over the shoulder section. For poor and untreated shoulder, the shoulder subgrade is subjected to a high wheel load and it deforms vertically. In most of the flexible pavements, with earthen shoulder, it is observed that the edge portions of the pavements are broken vigorously. One of the vital reasons of these edge failures are presence of weak pavement shoulder. The shoulder subgrades are failing to carry the high impact of wheel load and thus, shoulder subgrades are settling down and edge drops are forming. Wheel load applied on these

sharp edges are further deteriorating the pavement structures. Thus, a poor shoulder structure affects the overall performance and serviceability of a road. It also forms different types of pavement failures viz. shoulder drop, rutting, depression etc.

In the present study, an attempt is taken to make the pavement edges more stable by treating the shoulder earth using jute fibre. Jute is very strong in carrying tensile load. As soil is weak to carry tensile load, hence, jute fibres act as reinforcement and improves the bearing capacity of soil sample. As the pavement shoulder provides emergency lane and carries a large impact of wheel load, thus, it is also required to check the load carrying behaviour of the modified shoulder sections. Therefore, Finite Element Analysis is conducted by using PLAXIS 3D software to evaluate the load-deflection behaviour of the treated and untreated shoulder section. Vertical settlement is evaluated for treated and untreated shoulder section, under wheel load on the pavement section.

2. Objective:

Objectives of the present research work, may be listed as:

- To improve the strength of existing earthen pavement shoulder using jute fibre
- To analyse the load deflection characteristics of pavement shoulder using PLAXIS 3D software.
- To compare the load deflection behaviour of treated and untreated pavement shoulder

3. Subgrade Properties and Material Overview:

3.1. Subgrade

The tests are conducted considering the condition of existing earthen shoulder in local rural roads in Tripura, India. The basic engineering properties of this subgrade soil sample are evaluated through laboratory experiments. All the engineering properties are tabulated in Table 1. This sample is further treated with jute fibre and load-deflection analyses are conducted.

3.2. Jute fibre

Jute is a natural fibre and can be used to improve subgrade stability. It increases the tensile strength of subgrade soil, absorbs a huge amount of moisture content, and enhances the durability of the sample. Normal decomposition period of jute fibre is 2-3 years. Period of decomposition may be increased by coating the fibres with tar. General physical properties of the Jute Fibre (Fig. 1), used in this study are listed in Table 2. In this study, jute fibres are mixed with shoulder soil to improve shoulder stability.

Table 1. Physical properties of the subgrade soil sample.

Physical properties	Experimental data
Specific Gravity	2.6
Sand Particles (4.75mm-0.075mm, %)	4.79
Silt Particles (0.075mm-0.002mm, %)	38.43
Clay Size (< 0.002mm, %)	56.78
Classification	CL
AASHO Classification	A-6
Group	Silty-Clay
Liquid Limit (%)	51

Plastic Limit (%)	28
Plasticity Index (%)	23
Optimum moisture content, OMC (%)	17.15
Maximum dry density, MDD (gm/cm ³)	1.7

Table 2. General Physical properties of selected natural fibres

Particulars	Jute Fibre
Average Thickness	0.5 mm
Length	2 cm
Water absorption	68 %
Tensile Strength	167 MPa



Fig. 1. Jute Fibres

Table 3. Engineering Properties of Treated and Untreated Shoulder Samples

Subgrade Samples	Untreated Sample	Jute Fibre Treated Sample
MDD (kN/m ³)	18.1	11.84
OMC (%)	12.9	19.78
Soaked CBR (%)	4.5	10.25
Un-soaked CBR (%)	8.25	14.48
UCS (kPa)	630	715

4. Analytical Justification using PLAXIS 3D:

PLAXIS 3D software is designed for computing complex Finite Element Analysis for solving different problems in engineering field. Finite Element Analysis is widely using nowadays, to solve complicated differential equations in a simple and approximate manner. In engineering field, different softwares are available to conduct Finite Element Analysis. In present study, settlement analysis is carried out for pavement shoulder section, under a static wheel load applied in pavement section.

A three-dimensional geometrical model of size 10 m × 7.5 m × 0.475 m is created in PLAXIS, to represent the pavement with both side shoulder sections. The cross section of the pavement section is 10 m × 3.75 m and the cross section of each shoulder section is 10 m × 1.875 m (as per IRC: SP:20:2002). The depth of the section is defined by creating a 0.475 m bore hole where pavement layers are created as 0.3 m subgrade, 0.15 m base course and 0.025 m surface course. The model is prepared as shown in the Fig. 13. The load applied on the

section is considered as per rare axle load of a standard vehicle, where two numbers of wheel loads of 40 kN & 40 kN are applied at 1.8 m apart from each other. The axle is located at 0.3 m away from the pavement edge.

The user interface consists of three sub-programs: input, calculation and output. To define the problem geometry, input program interface is used. After inputting the general information and problem geometry, "Consolidation Analysis" is selected as type of calculation. To inspect the results of calculations in 3D views of pre-selected geometry points, output program interface is used.

4.1 General Information and input program

In this interface, general information about material properties, forces and stresses are incorporated. After inputting the general information, geometry of the problem is created followed by assigning subgrade soil layer, shoulder material layer and pavement material layer. Initial stresses in a soil body, by the weight of the pavement materials and soil are also assigned where, pore-water condition is also considered. After assigning problem geometry and material properties, 2 dimensional and 3 dimensional mesh is created.

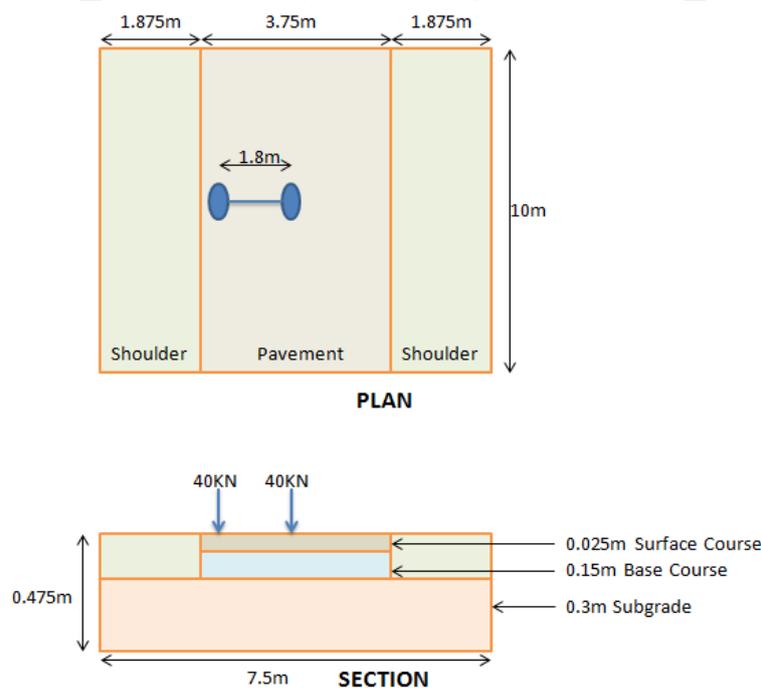


Fig. 2. Geometrical dimensions of the PLAXIS 3D model

Table 4. General configuration of the PLAXIS 3D model

Particulars	Input Information
No. of total Nodes	1845
No. of Element	576
Average Element Size	215.38×10^{-3} m
Mesh Type	Three Dimensional
Element Type	Triangular
Analysis Type	Elasto-plastic Settlement
Materials Type	<ul style="list-style-type: none"> • Mohr-Coulomb and Drained (Subgrade and fibre treated samples) • Linear Elastic and Drained (WBM and Bituminous Macadam)
Boundary Condition	Open in all direction
Global Error	0.1

Table 5. Characterization of the materials used in the model

Material Category	Unit Weight (kN/m^3)	Elastic Modulus (kN/m^2)	Poisson's Ratio	Angle of Friction ($^\circ$)	Cohesion (kN/m^2)
Surface Course	25	1500000	0.3	-	-
WBM Course	22	100000	0.35	-	-
Subgrade Soil	18	4000	0.45	10	170
Jute Fibre Treated Soil	15	5500	0.4	20	180

4.2 Execution of Calculation Process

Geometry modelling process is completed with 3-dimensional mesh generation. The calculation process is divided into several sequential calculation phases. The first calculation phase i.e. initial phase is a calculation of initial stresses, for the initial geometrical configuration by means of K0 procedure. After the initial phase, subsequent calculation phases are created for elasto-plastic settlement analysis of the materials. Calculation process is executed after defining all the construction stages and calculation phases.

4.3 PLAXIS Output

The main outputs of Finite Element Method are the deflections and stresses. It contains stress and deflection of individual node and total deformation as well under the specific stress. The deflection against wheel load of 40 kN is found as 5.38 mm, and 4.12 mm for earthen shoulder, and jute treated shoulder respectively, which are shown in Fig. 14 and Fig. 15. Contour lines of the deflected area are shown in Fig. 16 and Fig. 17. Thus, it can be said that, the impact of wheel load on shoulder section can be reduced by treating the shoulder section with tar coated bamboo fibre.

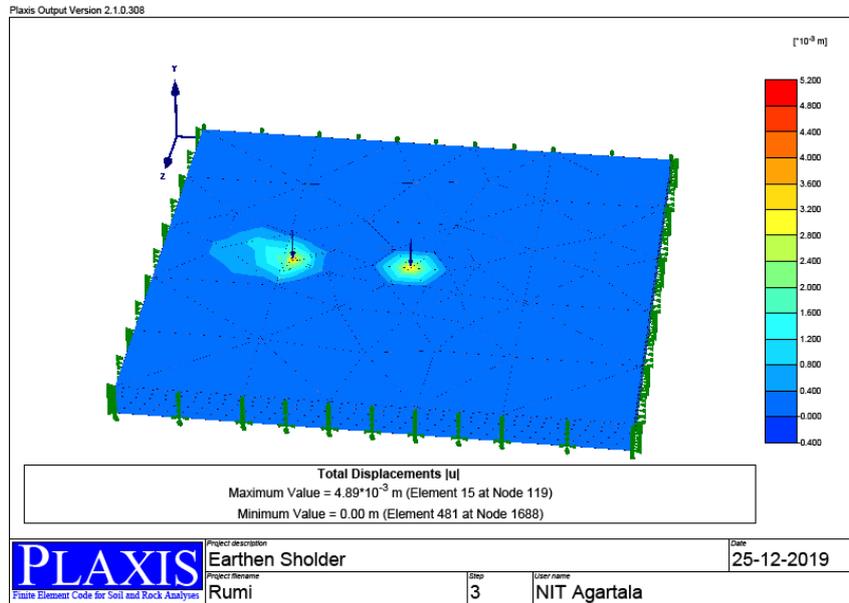


Fig. 3. Effect of wheel load at pavement edge, for untreated sholder

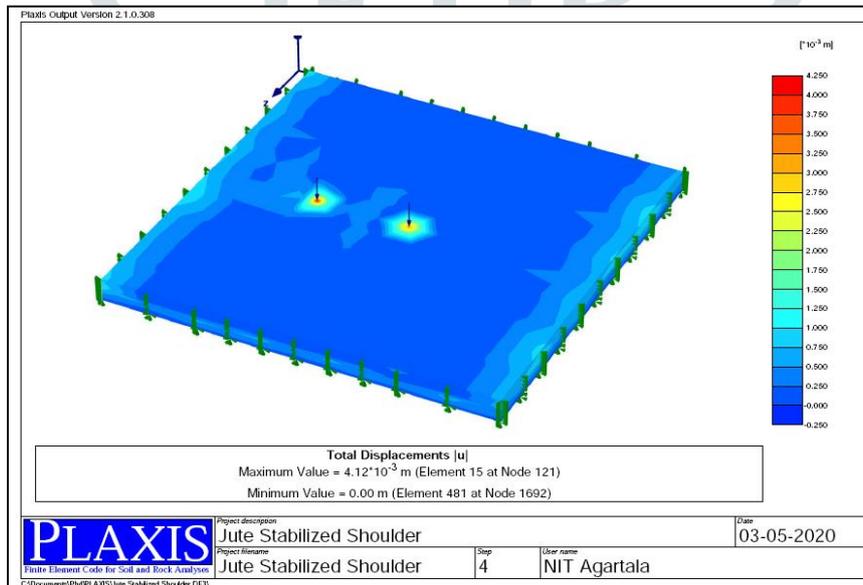


Fig. 4. Effect of wheel load at pavement edge, for jute fibre treated sholder

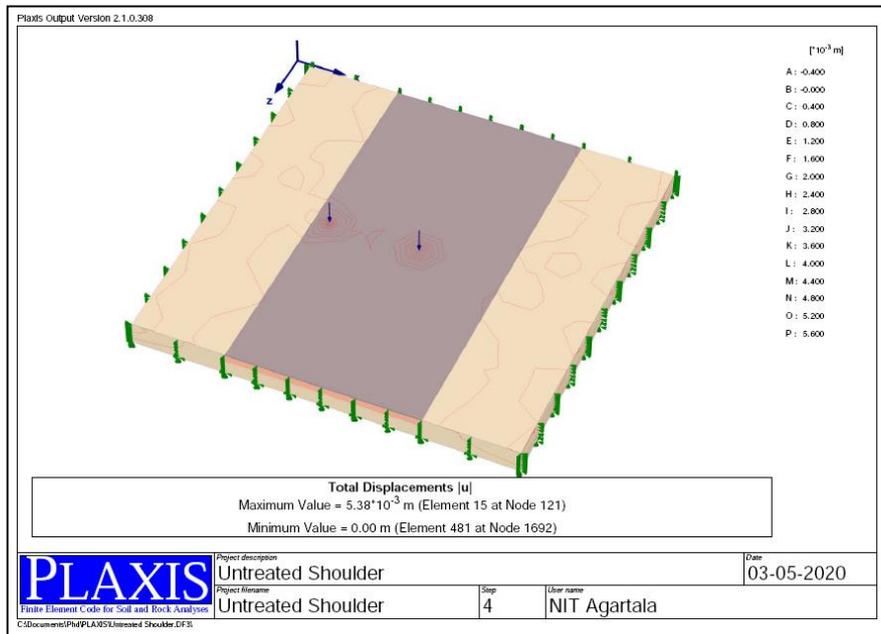


Fig.5. Contour lines of deformed area for untreated shoulder

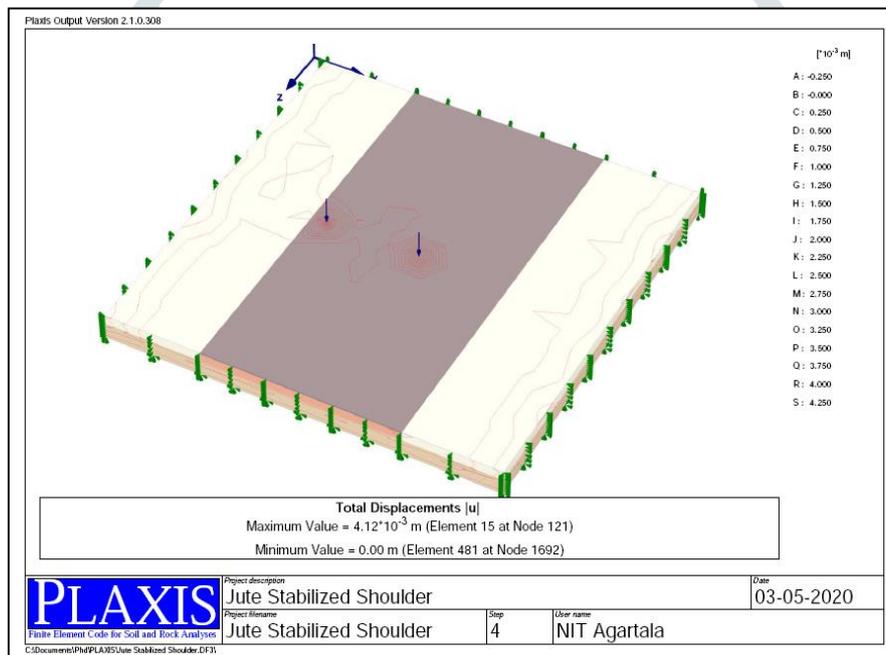


Fig. 6. Contour lines of deformed area for jute fibre treated shoulder

5. General Discussion:

As pavement shoulder provides lateral stability to pavement structures and it acts as a support at each side of the structure. Due to untreated earthen shoulder and lack of proper maintenance of the shoulder section, a huge number of shoulder failures are found to observe viz. shoulder drop, depression, edge breaking, erosion of the shoulder materials etc. Often the wheel track is dislocating from the pavement black top portion and directly applying loads on shoulder subgrade section causing a severe shoulder drop which is forming a support-free, unconfined pavement section. Consequently, when the wheels are passing through these free edges repeatedly, the edges become weaker and after a certain period it collapses. Application of treated shoulder increases the bearing capacity of shoulder section, reduces shoulder drop and makes the section more stable. Thus the problem of pavement deterioration in edge portions can be diminished to a large extent.

6. Conclusion:

After successfully conducting the total project work and based on the results obtained from the analytical models, the concluding remarks may be drawn as:

- Jute fibres can be used to make a stiff and stable pavement shoulder section, which will reduce shoulder settlement and increase the overall pavement performance.
- As per Finite Element Analysis, using PLAXIS 3D software, maximum deflection found on the shoulder section, under wheel load at pavement section, are recorded as, 5.38 mm and 4.12 mm for untreated and jute fibre treated shoulder respectively.

Conflict of Interest: The authors declare that there are no conflicts of interest regarding the publication of this paper.

Reference

1. Thilak Gowda N, Dr. P Shivananda, (2018). Pavement Shoulder Maintenance: Case Study. International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, No. 7. 166-168.
2. Khabiri Mohammad M. and Kargaran Bafki Moahammad R. (2008) “Effect of Pavement Boundaries Depths on the structural Strength of Roadway”. Journal of Applied Sciences Research 4(1). INSInet Publication. 103-109.
3. Manish Pal and Dipankar Sarkar (2013), “Study of Young’s Modulus of Laterite Soil-Bamboo Fibre Mix”, 1st Annual Conference on Architecture and Civil Engineering (ACE-2013), pp-455-457.
4. Lee L., Charles R., Simpson N., (2016), “Stress-strain behaviour of asphalt concrete in compression”, 21st European Conference on Fracture, ECF21, 20-24 June 2016, Catania, Italy. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).
5. Perez, S.A., Balay, J. M., Tamagny, P. and Petit, Ch. (2007) “Accelerated pavement testing and modelling of reflective cracking in pavements.” Engineering Failure Analysis, ELSEVIER, 14, 1526–1537.
6. Khaled Sandjak and Boualem Tiliouine. (2014). “Experimental Evaluation of Non-Linear Resilient Deformations of Some Algerian Aggregates Under Cyclic Loading”. Arab J Sci Eng 39:1507–1516. DOI 10.1007/s13369-013-0737-4.
7. Magdi M. E. Zumrawi, (2016), “INVESTIGATING CAUSES OF PAVEMENT DETERIORATION IN KHARTOUM STATE”, International Journal of Civil Engineering and Technology (IJCIET), Volume 7, Issue 2, March-April 2016, pp. 203–214, Article ID: IJCIET_07_02_018.
8. Kumar P. and Patel V. (2009) “Effect of Various Parameters on Performance of PMGSY Roads.” IE (I) Journal–CV, 90, 1 - 8.
9. J.-C. Du, D.-H. Shen, S. Cross, (2008) “Pavement rutting dynamic prediction model”, Int. J. Pavement Res. Technol. 64–71.
10. Fabricio Leiva-Villacorta, Adriana Vargas-Nordbeck and Jose´ P. Aguiar-Moya (2017), “Pavement deformation and deflection relationship from pavement condition assessment”, International Journal of

Pavement research and Technology, Production and hosting by Elsevier B.V. pp-352-359, <http://dx.doi.org/10.1016/j.ijprt.2017.03.005>.

11. D. K. Maharaj and Sanjib Gill (2014), “The Behaviour of Flexible Pavement by Non Linear Finite Element Method”, International Journal of Latest Research in Science and Techniligy, ISSN (Online): 2278-5299, Volume 3, Issue 1: Page No.53-57.
12. Washington State Department of Transportation (2013) “Pavement Edge Treatment”, post construction report, office of research and library service, Engineering and regional operations construction divisions, State materials Laboratory, report no. WA-RD 798.1.
13. Xiaoduan Sun and Subasish Das (2012), “Safety Improvement from Edge Lines on Rural Two-Lane Highways”, Department of Civil and Environmental Engineering, University of Louisiana, Lafayette, LA 70504, Technical Report, FHWA LA.11/487.
14. IRC code Special Publication 20, 2002 Edition.
15. M. Vinoth, P. S. Prasad and U. K. Guru Vittal (2019), “Performance Analysis of PLAXIS Models of Stone Columns in Soft Marine Clay”, Technical Paper, INDIAN HIGHWAYS, pp-25-30.
16. Pane, I., Hansen, W. and Mohamed, A. R. (1998) “Three-dimensional finite element study on effects of nonlinear temperature gradients in concrete pavements.” Transportation Research Record No. 1629, Washington, DC: TRB, National Research Council; 58– 66.
17. Akbulut, H. and Aslantas, K. (2005) “Finite element analysis of stress distribution on bituminous pavement and failure mechanism.” Materials and Design, ELSEVIER, 26, 383–387.
18. Dere, Y., Asgari, A., Sotelino, E. D. and Archer, G. C. (2006) “Failure prediction of skewed jointed plain concrete pavements using 3D FE analysis.” Engineering Failure Analysis, ELSEVIER, 13, 898–913.