International Journal of Civil Engineering and Infrastructure
Vol. 1, No. 2, October 2021

# NUMERICALLY PREDICTING SETTLEMENTS OF WASTE COCONUT FIBER (WCF) MIXED FLEXIBLE PAVEMENT IN HOMOGENEOUS SANDY SOIL BY USING PLAXIS 3D

Md. Foisal Haque[1]
[1]M.Sc. in Geotechnical Engineering, GS Research & Design, Dhaka-1230, Bangladesh
Correspondence email : gsresearch.design@gmail.com

Received May 4, 2021 | Accepted July 15, 2021

***ABSTRACT***

*Surface settlement of flexible pavement in coastal reason occurs for the movement of heavy vehicle, liquefaction of soil layer during seismic shaking, land sliding etc. In coastal area, surface settlement is higher than other geographical area because several sandy layers present in the coastal reason. Surface settlement disturbs the longevity of flexible pavement in homogeneous sandy layer. Waste coconut fiber (WCF), fly ash, coir etc. are suitable additives for reducing such types of settlement. In the present study, numerical analysis performs PLAXIS 3D and various (5, 10, 15, 20, 25) percentages of WCF mix with the asphalt by weight for reducing surface settlement of flexible pavement. Mohr-Coulomb failure criterion uses in the numerical analysis and liquefaction has not considered in the present study. However, WCF increases elastic modulus of flexible pavement and it reduces settlement of the pavement. Minimum surface settlement occurs at the maximum percentage of WCF and it is 1.68mm. Therefore, mixer of WCF protects the flexible pavement against severe damage.*

***Keywords:*** *Waste Coconut Fiber, Sandy Soil, Homogeneous, Flexible Pavement, Settlements.*

## 1. INTRODUCTION

Flexible pavement is more suitable than rigid pavement because it is easily repairable, economy and ductile capacity. Admixture increases the ductile capacity of flexible pavement. In coastal area, pavement construction is more critical than other region. Another difficulty, when flexible pavement stands on sandy soil. To overcome such types of problem, various admixtures mix with asphalt or soil or base-coarse by weight. Normally, fly ash and waste coconut fiber are more suitable admixture for the flexible pavement in sand. Recycled aggregates have been used as a base, sub-base material in the construction of flexible pavement (Kawade *et al*., 2018). Coconut coir has been used to construct road and it performs better results (Mittal and Singh, 2014). A series of direct shear tests have been performed on dry sand reinforced with different synthetic, metallic and natural fiber to evaluate the effects of parameters such as fiber orientation, fiber content, fiber area ratio and fiber stiffness on contribution to shear strength (Gray and Ohashi, 1983). Several authors (Rao *et al.*, 2006 and Singh, 2013) to construct pavement have used various types of fibers by weight of soil or asphalt. Stiffness of sand is essential for the analysis of road pavement. Loose sand stiffness has been increased by using admixture (Akl *et al.*, 2021). During numerical analysis, waste coconut fiber mixed flexible pavement considers as a plate element. Numerical analysis of roller compaction on pavement has been shown better performance against various types of failure of pavement (Famili and Vafaei, 2016). In the numerical model, waste coconut fiber mixed flexible pavement stands on the sandy soil and interaction shows between sand and flexible pavement. Soil-structure interaction of the construction of various types of foundations, flexible pavement etc. has been observed by several authors (Ahmed *et al.*, 2014; Bobet, 2010 and kapackci and ozkan, 2012) based on numerical analysis and get various results.

Surface settlement is critical for flexible pavement in sand. Numerical analysis expresses exact variations of surface settlement for waste coconut fiber mixed flexible pavement in sand. Waste coconut fiber mixes asphalt by weight for better performance against failure of pavement. Various percentage of coconut fiber are used in this research. Higher percentage of coconut fiber ensures the stability of the flexible pavement and it reduces surface and overall settlement.

## 2. MATERIAL PROPERTIES AND NUMERICAL MODEL

Waste coconut fiber (WCF) had been collected from dry coconut head. After collection, it was mixed with 80/100 grade asphalt by weight. Mixing percentages of coconut fiber were 5%, 10%, 15%, 20% and 25%. Sample of waste coconut fiber and 80/100 grade asphalt are represented by Figure 1.

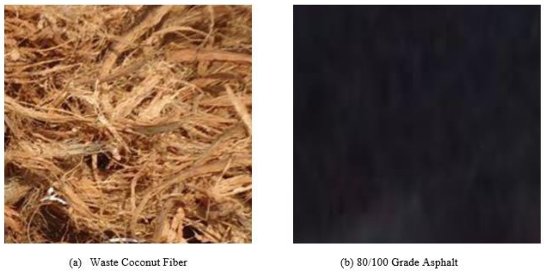


Figure 1. Sample of waste coconut fiber and asphalt

WCF mixed flexible pavement places on the sandy soil layer for numerical analysis. Truck loading provides on the WCF mixed flexible pavement. Numerical model of this research is shown in Figure 2. Various parameters of the numerical model are shown in Table 1.

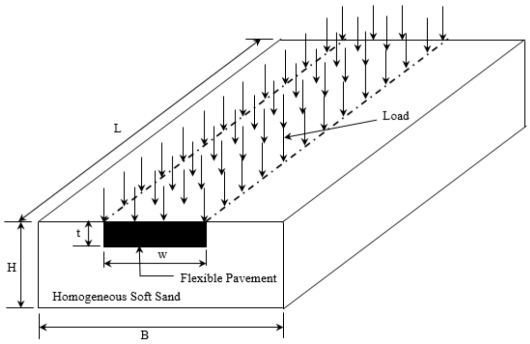


Figure 2: Numerical model of WCF mixed flexible pavement

Table 1: Geometric parameters of numerical model

| Parameters Name | Symbol | Values |
|---|---|---|
| Length of sandy soil and WCF mixed flexible pavement | L | 30m |
| Width of sandy soil | B | 15m |
| Depth of sandy soil | H | 4m |
| Width of pavement | w | 9m |
| Thickness of pavement | t | 0.5m |
| Loads on pavement | - | 12 kN/m$^2$ |

Numerical analysis has been performed by PLAXIS 3D. This analysis follows finite element method. Medium mesh performs during numerical analysis. During analysis, WCF mixed flexible pavement considers as a plate element. Soil element represents 10 nodded tetrahedral with 4 point Gauss integration rule, plate element represents 6 nodded triangular with 3 point Gauss integration rule and interface element represents 12 nodded triangular with 6 point Gauss integration rule. For soil, Mohr-Coulomb material model with drained condition has been performed during analysis. In PLAXIS 3D, analysis conducts initial phase and two plastic phase. Iteration proceeds until convergence achieved. Finite element model for various conditions is shown in Figure 3.

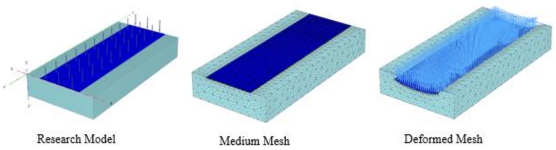


Figure 3: Unmeshed, meshed and deformed mesh model

Material properties of sandy soil and WCF mixed flexible pavement are shown in Table 2 and Table 3. For WCF mixed flexible pavement (plate element), linear elastic model has been considered during analysis. Material properties of sandy soil had been found from tri-axial test. Elastic modulus of WCF mixed flexible pavement for various percentage of WCF had been found from compressive test.

Table 2: Material properties of sandy soil

| Parameter | Name | Lower fine sand | Units |
|---|---|---|---|
| Material Model | Model | Mohr-Coulomb | - |
| Bulk unit weight | $\gamma_{unsat}$ | 17.5 | kN/m$^3$ |
| Saturated unit weight | $\gamma_{sat}$ | 19 | kN/m$^3$ |
| Young's Modulus | E' | 26100 | kN/m$^2$ |
| Poission's Ratio | ν' | 0.27 | - |
| Cohesion | $C'_{ref}$ | 1.0 | kN/m$^2$ |
| Friction Angle | φ' | 34 | degree ($^0$) |
| Dilatancy Angle | ψ | 4 | degree ($^0$) |

Table 3: Material properties of waste coconut fiber (WCF) mixed flexible pavement

| Parameters | Name | Pile Cap | Unit |
|---|---|---|---|
| Isotropic | - | Yes | - |
| Thickness | d | 0.5 | m |
| Weight | γ | 20 | kN/m$^3$ |
| Young's modulus (Variable) | $E_1$ | 551581 (0% WCF), 586054 (5% WCF), 620528 (10% WCF), 655002 (15% WCF), 689476 (20% WCF), 723950 (25% WCF) | kN/m$^2$ |
| Poisson's ratio | $\nu_{12}$ | 0.20 | - |

## 3. RESULTS AND DISCUSSIONS

Settlement influences the behaviour of WCF mixed flexible pavement and sandy soil. It varies along the length of the pavement. Equivalent truck loading has applied along the length of the flexible pavement.

Therefore, variations of settlement is critical along depth of the soil body as well as pavement. Overall variations of settlement is represented by Figure 4. This variation has been taken for 5% WCF mixed flexible pavement. Legend shows that maximum possible value of settlement is 2.80mm. This settlement value stands within limit from severe damage of road. At first, settlement increases with the increment of depth and it decrease after crossing a certain depth.

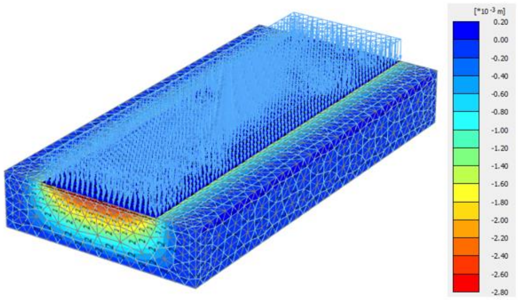

Figure 4: Settlement profile of numerical model

Surface settlement decreases gradually with the increment of percentage of waste coconut fiber. When waste coconut fiber added with asphalt, modulus of elasticity of WCF mixed flexible pavement is increase. WCF is the function of material properties of flexible pavement. Elastic modulus is the inverse function of settlement. Maximum value of surface settlement varies with variations of different percentage (5%, 10%, 15%, 20% and 25%) of WCF. This variation shows in Figure 5. Minimum value of maximum surface settlement is 1.68mm at 25% WCF.

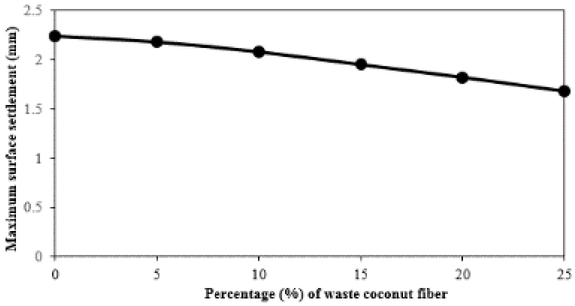


Figure 5: Variations of maximum surface settlement with the various percentages of WCF.

Initially settlement increases with the increment of depth of sandy soil and then it decreases with the increment of depth. These variations are shown in Figure 6. Maximum value of settlement has been observed at 0.8m depth for various percentages of WCF. Uniform variations of settlement profile have been observed for different percentages of WCF. Difference of settlement between any of two percentages of WCF is 0.2mm. Higher percentage of WCF represents lower value of settlement.

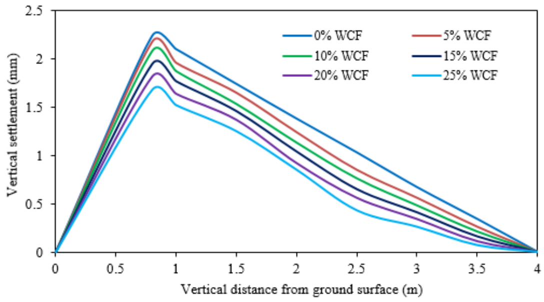


Figure 6: Variations of vertical settlement for various percentages of WCF

Without waste coconut fiber, settlement is maximum and it is decreasing gradually with the increment of percentages of WCF. Top and Bottom surface settlement of homogenous sand layer represents as zero. Uniform variations of settlements indicate accuracy of results.

## 4. CONCLUSION

Actual behaviour of soil is anisotropic and non-linear. Actual behaviour of waste coconut fiber mixed flexible pavement is non-linear. Evaluation of anisotropic and non-linear behaviour is very complex. Coastal area sandy soil represents liquefaction properties. In the present research, non-linearity, anisotropy and liquefaction have not been considered in the numerical analysis to avoid complexity.

Surface settlement and overall settlement influence the stability of WCF mixed flexible pavement and sandy soil. Higher percentage of WCF reduces settlement and it increases stiffness of flexible pavement. Minimum surface settlement value (1.68mm) has lower than limiting value (10mm) of severe damage during seismic shaking, land sliding and liquefaction although this study has not deals about seismic phenomena, land sliding and liquefaction. Sequential variations of settlements represent accuracy of finite element analysis.

## REFERENCES

[1] Ahmed M., Mohamed M.H., Mallick J. and Hasan M.A., 2014. 3D-analysis of soil-foundation-structure interaction in layered soil, Open Journal of Civil Engineering (OJCM), 4, 373-385. http://dx.doi.org/10.4236/ojce.2014.44032

[2] Akl S.A., Zidan A.F. and Metwally K.G., 2021. Numerical and experimental investigation of loose sand-scrap tires mixture stiffness, International Journal of GEOMATE, vol. 20, issue 80, pp. 1-8.

[3] Bobet A., 2010. Numerical Methods in Geo-Mechanics, The Arabian Journal for Science and Engineering, **35**, 27-48.

[4] Famili A. and Vafaei M., 2016. Numerical analysis of roller compacted concrete pavement, Saudi Journal of Engineering and Technology, vol. 1, issue 1, pp. 20-25.

[5] Gray D.H. and Ohashi H., 1983. Mechanics of fiber reinforcing in sand, Journal of Geotechnical Engineering, ASCE 112(8): 335-353.

[6] Kapackci V. and Ozkan M.Y., 2012. A Simplified Approach Applicable to the Settlement Estimation of Piled-Raft, *ACTA Geo-Technica Slovenica*, **1**, 77-84.

[7] Kawade A.N., Chalke A.S., Dawale S.N., Jangam S.U. and Parulekar G., 2018. Design and qualitative analysis of flexible pavement by using waste material, International Research Journal of Engineering and Technology (IRJET), vol. 5, issue 4, pp. 1800-1803.

[8] Rao A.S., Rao K.V.N., Sabetha G. and Surest L. K., 2006. Load deformation behaviour of fiber-reinforced gravel beds overlying soft clay, A National Conference on Corrective Engineering Practices in Troublesome Soils (CONCEPTS), Kakinad, pp. 187 -190.

[9] Singh R.R. and Mittal E.S., 2014. Improvement of local subgrade soil for road construction by the use of coconut coir fiber, International Journal of Research in Engineering and Technology (IJRET), vol. 3, issue 5, pp. 707-711.

[10] Singh H.P., 2013. Effects of Coir Fiber on CBR Value of Itnagar Soil, International Journal of current and Engineering and Technology, ISSN 2277 – 4106.