FIELD AND NUMERICAL INVESTIGATION ON TIME DEPENDENT BEHAVIOUR OF JUTE GEOTEXTILE (JGT) REINFORCED RURAL ROAD

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ABSTRACT: A Rural road section reinforced with Jute Geotextiles (JGT) sandwiched between thin sand layers has been constructed to study the strength improvement of subgrade soil. In this present investigation an attempt also has been made to develop a three dimensional (3D) finite element (FE) model of the JGT reinforced and unreinforced rural road sections using general purpose FE software ABAQUS. Numerical simulation of time dependent behavior for JGT reinforced rural road has been carried out using the data obtained from field investigation at regular time interval. In this present investigation subgrade soil has been modeled using Mohr-Coulomb plasticity model. Whereas JGT has been assumed as membrane type of material. From FE analysis pavement responses under traffic loading such as rut depth, maximum tensile strain developed at JGT, and vertical compressive strain developed at the top of subgrade soil has been evaluated. From the field investigation it has been found that the subgrade California Bearing Ratio (CBR) value is increased with increase in time under study. It has been found that the reinforced rural road sections are performing well in terms of rut depth than the unreinforced section.

KEYWORDS: Rural road, Jute Geotextile, 3D-FE analysis, ABAQUS, Subgrade

1 INTRODUCTION

1.1 Background of Present Study

Construction of rural road subgrade with poor local soil is causing an excessive deformation to the subgrade soil and result in the failure of rural roads. In recent days strengthening of the road subgrade with the help of natural fibers such as Jute and Coir are in practice. The problem of use of fabric made of natural fibers in civil engineering field is that loss of its tensile strength in a short time. From the previous literature [Ramaswamy and Aziz (1989) and Basu et al. (2009)] it has been found that the JGT may be efficiently use to strengthen the rural road subgrade. Field study on JGT reinforced road section by Rao (2003) indicated that the subgrade soil gain sufficient strength with time. In this present investigation an attempt has been made to study the behavior of the JGT reinforced rural road section under traffic loading by using FE based software "ABAQUS" based on field measured data.

1.2 Description of the Field Rural Road Section

In March, 2013 a rural road section reinforced with JGT has been constructed from Kanksa to Bati (KB) at Murshidabad district in West Bengal, India. In this JGT reinforced rural road section JGT has been placed in between Granular subbase (GSB) and Subgrade soil with the presence of sand layers on each side of it. Detail dimensions of the JGT reinforced rural road section has been shown in Figure 1. A monitoring schedule has been followed at regular interval of six month for two years. Soil parameters of the subgrade such as CBR value, dry density, cohesion and angle of internal friction have been determined for each monitoring. These field measured parameters are used in FE analysis to define the conditions of the subgrade soil at initial condition (after laying of JGT), 12-month, 18-month and at 24-month.

1.3 Plan for Numerical Analysis

In this present investigation two series (series A and series B) of model have been considered. In the Series A, unreinforced rural road sections has been considered with varying time. JGT reinforced rural road sections has been taken under series B. For both the series of models (series A and series B) the rural road subgrade CBR values has been taken from the field investigation. Based on the study conducted by Bera and Roy (2012) and Saha et al. (2012) half-life of JGT has been considered as 12 month and full degradation time of JGT has been taken as 18 month. Details plan and corresponding models name for the FE analysis has been presented in Table 1.

2 FE MODELING METHODOLOGY

2.1 Idealization of Geometry

In this numerical study geometry of the model has been idealized as a 3D model. Here only one fourth of the model has been taken for computational purpose (Saad et al., 2006). On the basis of the previous literature (Gupta et al. 2014) the depth of the subgrade soil has been taken as 2.5m in the present investigation.

Table 1 Plan for Numerical Study

FE model Series	Model Name	Time from installation of JGT	Subgrade CBR value
Series A (Unreinforced)	UR0	0	2.8
	UR12	12	3.8
	UR18	18	4.35
	UR24	24	5.57
Series B (Reinforced)	R0	0	2.8
	R12	12	3.8
	R18	18	4.35
	R24	24	5.57

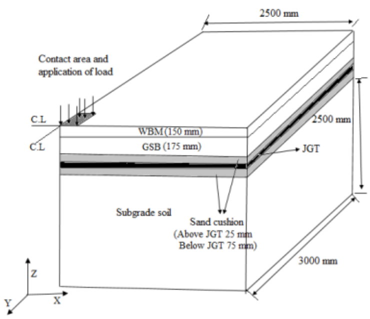

Fig. 1 Schematic diagram of reinforced section at initial condition.

2.2 Material Constitutive Behaviour

In the present paper subgrade soil has been considered as an elasto-plastic material. Plastic behavior of the subgrade soil has been defined by Mohr-Coulomb plasticity model and parameters has been obtained from field investigation data. Resilient modulus of the subgrade soil and top granular layers (Water bound macadam, WBM and Granular subbase, GSB) has been determined as per IRC 37:2012. In the present work JGT has been considered as a membrane type material. In this investigation JGT having a tensile strength of 20 kN has been used and elastic modulus of JGT has been determined at 2% strain from laboratory wide width tensile strength test. It has been assumed that the elastic modulus of JGT at half-life will be half of the initial elastic modulus of 61.22 MPa. Poisson's ratio of JGT has been assumed as 0.25. It has been also assumed that the sand used in the present study is medium dense sand.

2.3 Load and Boundary Condition

In this work traffic load has been simulated by triangular wave with a duration of 0.1 s based on previous literature [Saad et al. (2006) and Al-Khateeb et al. (2011)]. Peak wheel load has been assumed as 40 kN and a tyre contact pressure of 0.55 MPa has been applied on rectangular contact area. In the present paper the length and breadth of the rectangular contact area has been calculated and the corresponding values are 406.5 mm and 177.6 mm respectively. In this present FE analysis bottom of the model has been considered as fixed support. Verticals walls adjacent to the loading area has been assumed as plane of symmetry along the direction of axis. Similar boundary condition has been used successfully by Perkins and Edens (2002). Horizontal displacements has been restricted and only vertical displacements has been allowed on vertical faces away from loading area.

2.4 Meshing Criteria and Interaction properties

Finest mesh has been created near the loaded area to capture the step stress and strain gradient more precisely in these areas. Discretization method used in this study has been shown in Figure 2. In the present FE analysis implicit direct integration method has been adopted. Here interaction between pavement layers has been defined by tie constraints. Interaction between JGT and sand layer has been simulated by coefficient of friction. In this study JGT has been discretized by using M3D4R (a 4 node quadrilateral membrane element with reduced integration). An 8-node linear brick element (C3D8R) has been used to mesh the other pavement layers.

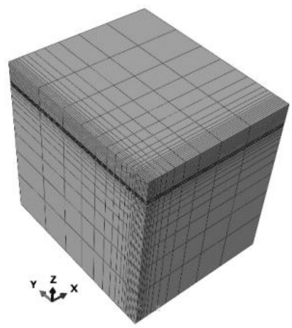

Fig. 2 Meshing technique adopted in the present investigation.

3 Results and Discussion

3.1 Verification of the Model

The 3D finite element model has been qualitatively verified in two aspects: i) Vertical stress distribution and ii) Vertical compressive strain distribution along depth under the center line of the loading area. For this purpose unreinforced rural road (UR0) has been idealize as a one layer pavement system. Results obtained from ABAQUS analysis and vertical stress and strain computed from theoretical solution available in Ahlvin and Ulery (1962) has been presented in Figure 3.

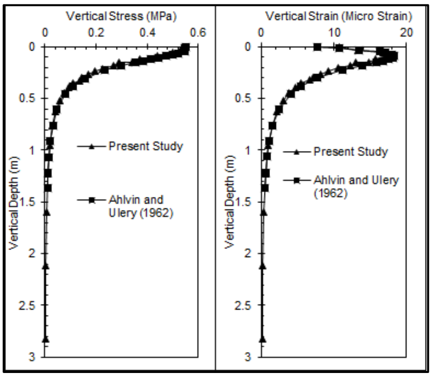

Fig. 3 Comparison between results obtain from FE analysis and theoretical solution.

3.2 Study on Strength Increment of Subgrade Soil

Results obtained from regular field investigation indicates that the subgrade CBR value has been increased with time (Table 1). From the Table 1, it has been seen that in 24 months the CBR value of subgrade soil increased about 1.98 times than the initial CBR value. Dry unit weight obtained from field monitoring with time is presented in the Figure 4. From the Figure 4, it has been also found that with time the values of dry unit weight of the subgrade soil is increases. Taskiran (2010) identified dry unit weight as the prime parameter influencing the CBR value of subgrade soil. Figure 4, also indicate that the dry unit weight has been increased about 1.04 time of its initial dry unit weight. Authors suggested that the increase in dry unit weight and subgrade CBR value may be happen due to consolidation process and compaction of the subgrade soil under traffic loading.

3.3 Utilization of JGT Strength Under Traffic Loading

In this present paper reinforced section R0 and R12 has been taken to study the utilization of JGT tensile strength under traffic loading. Maximum tensile stress and strain developed in JGT beneath the loading area has been taken from ABAQUS analysis. Utilization of JGT strength under traffic loading has been presented in Figure 5. From Figure 5, it has been seen that only a small fraction of tensile strength of JGT has been mobilized. In case of JGT reinforced section at initial condition only 0.6 % of tensile strength of JGT has been mobilized. It has been also observed that only 0.58 % of tensile strength has been mobilized after 12 month of laying of JGT. Tensile strain has been developed around 0.1% in both the reinforced section R0 and R12. Hufenus et al. (2006) reported that permanent strain in reinforcement under trafficking was usually below 0.5% and exceed 1% only in extreme cases. Numerical study performed by Patra et al. (2016) also reported that the tensile mobilized in reinforcement is in the range 0.57% to 1.2% for reinforced rural road section. It may be suggested that as the subgrade soil gain strength with time which allows the JGT to serve its desired function at lower tensile strength.

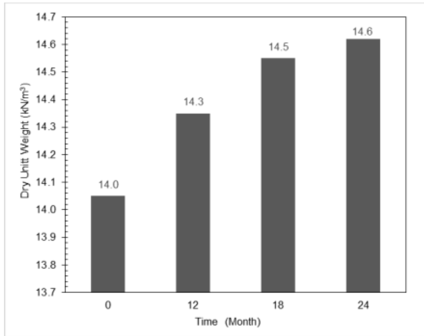

Fig. 4 Dry unit weight versus time curve for field JGT reinforced rural road section.

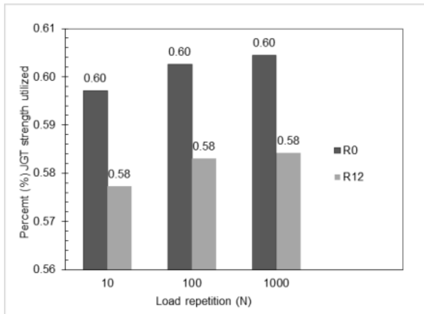

Fig. 5 Utilization of JGT strength under traffic loading.

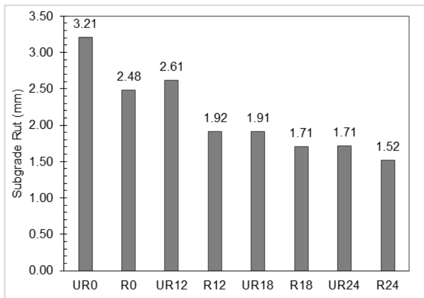

Fig. 6 Subgrade rut depth measured at top of subgrade soil beneath the loading area.

3.4 Study on Usefulness of JGT on Subgrade Deformation Behavior of Rural Road Sections

Figure 6, represent the subgrade deflection taken at the top of the subgrade soil under the loading area for unreinforced and JGT reinforced rural road sections considered in the present study. It has been seen that the subgrade rut has been reduced in the range of 22% to

26% for the reinforced section R0 and R12 with respect to the unreinforced section UR0 and UR12. In case of reinforced section R18 and R24, after degradation of JGT subgrade rut depth has been reduced about 10% to 11% with respect to the unreinforced section UR18 and UR24. Based on the result of the present FE analysis it has been clearly understood that presence of JGT reduces subgrade deformation significantly under traffic loading and allow the rural road section to sustain on subgrade soil with low CBR value due to membrane mechanism of the JGT. After degradation of JGT, subgrade soil already gain sufficient strength to become independent of JGT. In this study it has been also seen that after degradation of the fabric although the unreinforced and reinforced rural road section have same subgrade soil property the subgrade deformation is reduced in reinforced section than the unreinforced section. Authors suggested that it is due to the presence of sand layers which allow the subgrade to face lower stress magnitude during traffic loading. In this present investigation it has been observed that development of vertical compressive subgrade strain is reduced in the range of 16.96% to 35.73% in the JGT reinforced rural road section with respect to the unreinforced section.

4 Conclusions

Based on the present field investigation and FE analysis following conclusions has been drawn

- Reduction of subgrade rut depth of JGT reinforced rural road section than the unreinforced section are within the range of 22% to 26% and 10%to 11% before degradation of JGT and after degradation of JGT respectively.
- In case of JGT reinforced rural road section the vertical compressive subgrade strain has been reduced in the range of 16.96% to 35.73% with respect to the unreinforced section.
- Under traffic loading only a small fraction of JGT strength around 0.58% to 0.6% has been mobilized.
- From the field investigation the subgrade CBR value increases with increase in time under study.

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