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Study on the Performance of Railway Ballasted Track Reinforced with Geogrid

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Abstract

During the past twenty-five years, biaxial geo-grids have been used as reinforcement in the construction of railroad beds and ballasts to improve their performance and structural integrity. In the present study geosynthetic reinforced railway track were modeled using the software PLAXIS 8.2 with high geogrid stiffness at various placement depths and compared with unreinforced section. The result shows that reinforced railway track can be used to improve the performance of track with reduction in the stress and deformation of subgrade.

Keywords: Ballasted Track, Geogrids, Reinforcement

1. Introduction

The economic development and growth of industries needs a better transportation of goods and passenger services. To meet the demands and growing traffic needs, railways introduced faster and heavier trains in recent years. Most of the routes constructed in Indian Railways provided the lower axle load traffic (20 to 22.5tons) earlier and this have been subjected to an increased axle load upto 32.5 tons at present. Due to the use of high speed and heavy axle load in the existing track, subgrade failure takes place and it causes high maintenance cost. Presently the formation of track super structure is found to be increased as per the Guidelines and Specifications in the Design of Formation for Heavy Axle Load (2009). Improvement in top layer of railway subgrade by providing suitably designed sub-ballast layer is essential to withstand the higher stresses, however laying of thick sub-ballast layer is highly expensive. The use of geosynthetics in rail tracks has been studied in the past and it is proved that the geosynthetics can improve the track performance by reducing subgrade stress, deformation and degradation. In the present study, geogrids reinforced railway track were modeled using PLAXIS 8.2 with different geogrid stiffness at various placement depths and compared with unreinforced section.

2. Geogrid

A geogrid is defined as a polymeric (i.e., geosynthetic) material consisting of connected parallel sets of tensile ribs with apertures of sufficient size to allow strike-through of surrounding soil, stone, or other geotechnical material. Their primary functions are reinforcement and separation. Reinforcement refers to the mechanism(s) by which the engineering properties of the composite soil/aggregate are mechanically improved. Separation refers to the physical isolation of dissimilar materials like ballast and sub-ballast layer (or) sub-ballast and subgrade layer such that they do not commingle. Netlon Ltd. of the United Kingdom was the first producer of geogrids. The initial extruded geogrids developed by Netlon Ltd. were of two types as shown in the Figure 1.

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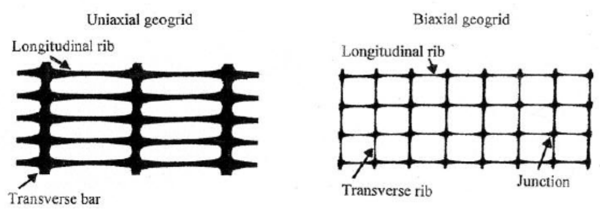

Figure 1. Extruded uniaxial and biaxial geogrid.

3. Track Components

The purpose of a railway track structure is to provide safe and economical rail transportation. This requires the track to serve as a stable guide-way with appropriate vertical and horizontal alignment. To achieve this role, each component of the system must perform its specific functions satisfactorily, in response to the traffic loads and the environmental factors imposed on the system.

Table 1 shows the main components of a ballasted railway track structure with the dimensions. These may be grouped into two main categories:

- Superstructure
- Substructure

The Superstructure consists of the rails, the fastening system, and the sleepers (ties). The Substructure consists of the subgrade, the embankment fill, the sub-ballast and the ballast layers. Thus, the superstructure and substructure are separated by the sleeper-ballast interace.

Table 1. Dimensions of track components

Track Component	Dimensions
Rail	150 × 170 mm
Sleeper	2750 × 210 × 200 mm
Ballast	300 mm
Blanket/Sub-ballast	1000 mm
Embankment fill/Formation layer	2000 mm

4. Parametric Study

In this study, the finite element program in PLAXIS 2D (Brinkgreve *et al*. 2006) was used to analyze the strain conditions of 15 node elements for the parametric study. Due to symmetry, only one half of the track section was considered in the numerical model shown in Figure 2.

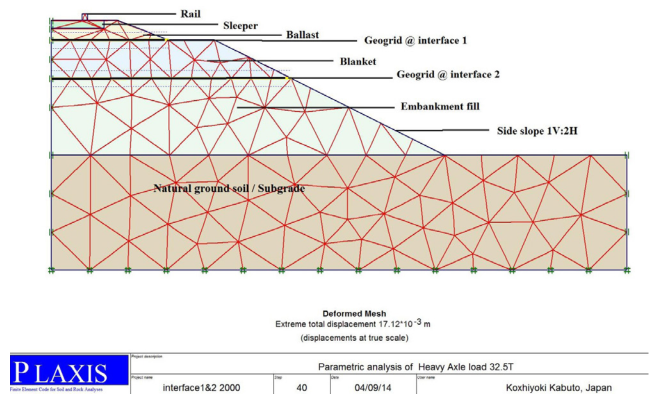

Figure 2. Meshed track structure.

The geometry and material property of the model are taken from the Guidelines and Specification of the Design of formation for Heavy Axle load (2009) and various literatures. With respect to the boundary condition, both sides were set to move vertically while the bottom was fixed to prevent any movement. Initial condition is analyzed by simulating the settlement of the model due to weight of the soil layers and followed by the simulation of the reinforcement using geogrid within track substructure; The simulation is also carried out for the traffic load on the geogrid-reinforced track substructure. For the traffic loading, an equivalent dynamic wheel load (Pdl) for a given static wheel load (Psl) was computed as per the Research Design and Standard Organization (RDSO 2009) approach and is given by:

$$P_{dl} = DIF \times P_{sl} \quad (1)$$

According to RDSO, the dynamic impact factor (DIF) is considered to be 1.5. Based on equation (1), an equivalent dynamic wheel load of 243.75 kN was applied for the vehicle speed equal to 160 km/hour, 1.372 meter of wheel diameter, and 162.5 kN of static wheel load. With regard to the geogrid modeling, a geogrid element provided by PLAXIS was employed along with interface elements that are connected with adjacent track substructure layers. The only property in a geogrid data set is the Elastic Axial stiffness (EA) in terms of force per unit width. For the parametric study, EA value were accounted to gauge the influence of its integrity on the track substructure response. In addition, the optimum location of geogrid was identified with various layers that yields the best effectiveness in restraining the deformations.

Table 2. Reference material properties used in the finite analysis

Material	Rail	Sleeper	B	SB	E fill	SS	Geogrid
Model	Elastic	Elastic	HS	MC	MC	MC	Elastic
E (MPa)	2.1×10^5	3×10^4	–	140	67	40	–
E_{50}^{ref} (MPa)	–	–	65	–	–		–
E_{oed}^{ref} (MPa)	–	–	65	–	–		–
E_{ur}^{ref} (MPa)	–	–	195	–	–		–
EA (kN/m)	–	–	–	–	–		1000 & 2000
γ (kN/m³)	78	24	15.6	19	17	18	–
M	0.3	0.2	–	0.37	0.37	0.37	–
μ_{ur}	–	–	0.2	–	–		–
C (kPa)	–	–	0	0	0		–
Φ	–	–	58	45	40	30	–
Ψ	–	–	0	0	0	0	–

The following locations were considered in this study:

- Interface between ballast and blanket/ subballast
- Interface between blanket/subballast and embankmentfill
- Combination of both the interfaces

From the results, it is observed that the reinforcement at both interfaces and at interface 2 only reduces the vertical stresses better than the section reinforced at interface 1.

5. Result and Discussion

5.1 Vertical Stress

There are key properties of geogrid that play a crucial role in enhancing load bearing capacity of geomaterials. The tensile strength is deemed one of key properties that produce lateral confinement for surrounding granular materials. The only property in a PLAXIS geogrid data set is the elastic axial stiffness, EA, in terms of force per unit width. Two levels of EA value were considered for this evaluation. The results for the variation of vertical stresses beneath the rail seat versus the depth of track for reinforced and unreinforced sections of ballast with 30 cm thickness is shown in the Figure 3. Vertical stresses for unreinforced section at the top of subgrade is 189.6 kPa and after the reinforcement, it is reduced to 175 kPa at interface 1 and 160 kPa at interface 2 and 146 kPa at both the interfaces for subballast with 30 cm thickness. The reduction of vertical stresses in the subgrade layer with the reinforcement on both interfaces is about 23 percent, whereas the reduction of vertical stresses for reinforcement at interface1 and 2 is about 8 percent and 16 percent respectively. It is observed that the vertical stress got reduced in the case of reinforcement at interface2 and both interfaces comparatively than the interface 1.

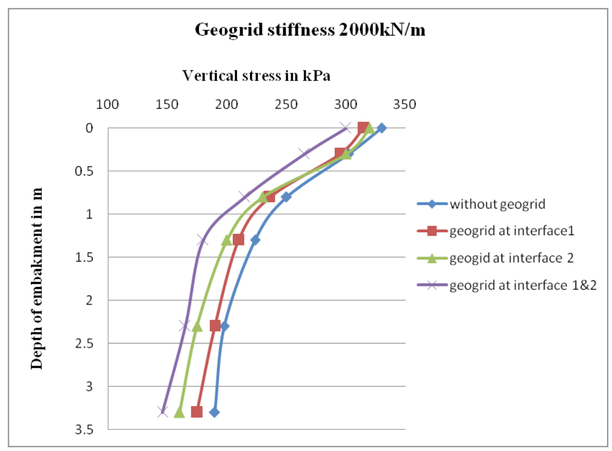

Figure 3. Vertical stresses beneath the rail seat versus depth for ballast 30 cm thickness.

5.2 Displacement

The results for the variation of displacement beneath the rail seat versus the depth of track for reinforced and unreinforced sections of ballast with 30 cm thickness is shown in Figure 4.

Displacement for unreinforced section at the top of subgrade is found to be 10.5 mm which is reduced to 9.5 mm for the interface 1 and 9 mm for the interface 2 and 8 mm for both interfaces. It is observed that the displacement got reduced from 10.5 mm to 8 mm as the reinforcement of geogrids are provided in the layer. The reduction of displacement in the subgrade layer with the reinforcement on both interfaces is about 24 percent, whereas the reduction of vertical stresses for reinforcement at interface 1 and 2 is about 9 percent and 14 percent respectively. Reinforcement in both the interfaces reduces the displacement better than the section reinforced at interface 1 and 2

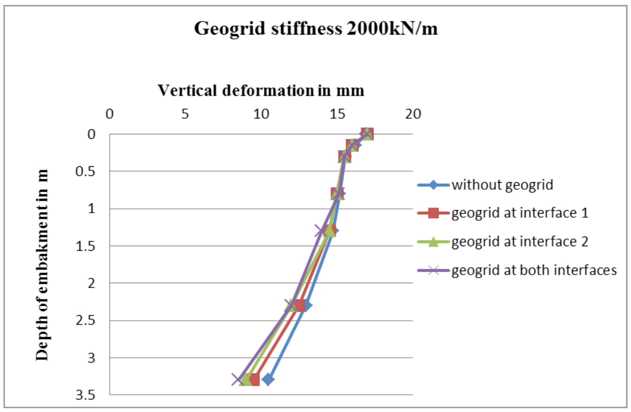

Figure 4. Displacement beneath the rail seat versus depth for ballast 30 cm thickness.

6. Conclusion

From this study, it is clearly evident that the reinforcement between sub-ballast and embankment fill, between ballast and subballast and the reinforcement at both the interfaces reduces the induced vertical stresses and displacements significantly. It is clear that to reduce the maintenance cost and to reduce the shear failure, the reinforcement between subballast and subgrade, between ballast and subballast and the reinforcement at both the interfaces are the best options.

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