RAILWAY TRACKS ON CLAYEY SUBGRADE REINFORCED WITH GEOSYNTHETICS

L.S. Sowmiya, Research Scholar, Department of Civil Engineering, IIT Delhi, sowmiya_lazarus@yahoo.co.in
J.T. Shahu, Associate Professor, Department of Civil Engineering, IIT Delhi, shahu@civil.iitd.ac.in
K.K. Gupta, Associate Professor, Department of Civil Engineering, IIT Delhi, kkg@civil.iitd.ac.in

ABSTRACT: Indian Railways have now geared up to overhaul and upgrade its infrastructure to meet future demand of growing traffic. Special emphasis has been laid on spreading the railway network by laying new tracks and also on increasing transportation efficiency by running heavier, longer and faster trains. Use of geosynthetics in civil engineering has advanced rapidly in recent years and it is now an internationally accepted material for various applications. Geosynthetics provide an important option to improve track support stabilization and thereby reduce the track maintenance costs and operation costs due to train delays. In the present study geosynthetic reinforced railway tracks were modeled using ABAQUS 6.9 with different subballast thicknesses and compared with unreinforced section. The result shows that the reinforcement can be used to improve the performance of railway tracks on clayey subgrade.

INTRODUCTION
Due to the use of high speed and heavy axle loads on the existing track, subgrade failure take place and it causes delay in train schedules and increases maintenance cost. Following are the various categories of subgrade failure associated with train loading based on the mechanism of failure (Selig and Waters, 1994) [3]:
- Massive shear failure.
- Progressive shear failure, also known as general subgrade failure.
- Excessive subgrade plastic deformation.
- Attrition, also known as local subgrade failure.

When the failure occurs due to any one of the above stated mechanism, excessive track maintenance will be required (Li and Selig, 1998) [2]. Continuous increase in the maintenance costs and operation costs due to train delays has given impetus to research on improving track stabilization of which the use of geosynthetics is the most important option. Applications of geosynthetics represent a rapidly growing field of geotechnical engineering. Figure 1 relates the four classical functions of three types of geosynthetics. Among the various varieties of geosynthetics, geotextiles are the most versatile type of the geosynthetics shown in Fig.1, which perhaps explains why they are so widely used in roads and railways.

![Fig. 1 Typical Functions of Some Geosynthetics](image-url)

Role of Geosynthetics in Railways
In railroad construction, geosynthetics may be installed within or beneath the ballast or subballast layers or both. Geosynthetics that are commonly used in this application are geotextiles, geogrids, geocomposites and geocells. Railroad track is one of the few geosynthetics applications which utilizes all four of the classical functions.

FINITE ELEMENT ANALYSIS
The potential use of geosynthetics in improving the deformation characteristics of rail ballast and formation soil was investigated by Indraratna et al. (2006) [1]. The prospective use of different types of geosynthetics was investigated using a large-scale prismatic triaxial rig, and a plane strain finite element analysis using PLAXIS. Shahu et al. (1999) [5], Shahin and Indraratna, (2006) [4] and Sowmiya et al. (2010) [6] carried out the detailed parametric studies for different type of nominal track models with 3D20N, PLAXIS and MIDAS/GTS models respectively. Based on those parametric studies it was evident that the subgrade modulus has a significant role to reduce the vertical stresses and displacements beneath the rail seat. In this present study the subgrade modulus is taken as 10MPa (Table 1) to represent the weak subgrade. ABAQUS 6.9 finite element software was used to simulate the railway track in the present study. ABAQUS 6.9 is a finite element program, designed to model the behavior of any structure under externally applied loading. This software provides a consistent, graphical interface for creating geotechnical models, interactively submitting and monitoring and evaluating results from post work data simulations. ABAQUS 6.9 has number of modules, where each module defines a logical aspect of the modelling process (e.g., defining the geometry, defining the material properties, generating a mesh, applying load and boundary conditions).
3D Finite Element Analysis (ABAQUS 6.9)

In this study, a railway track section is modelled and analysed using the finite element analysis software ABAQUS 6.9. Elastic analysis using ABAQUS/CAE was carried out for the railway track unreinforced section and the sections reinforced with geosynthetics. The effect of geosynthetic reinforcement on railway tracks with double axle load was already investigated by Sowmiya et al. (2011) [7]. In this present study single axle point load was applied at a distance of 1.2 m to represent the bogie load. 325 kN axle load was applied with the impact factor 1.5, thus the total axle load was 487.5 kN (point load representing axle load of 243.75 kN). The track model was meshed utilizing 20 node quadrilateral brick elements for all layers of the track section. Due to symmetry, only one half of the track is considered in numerical model. Rollers supports were applied on the lateral (vertical) faces and the bottom face was kept fixed. No boundary conditions were applied to the sloping face of ballast and sub-ballast, and to the sides of the rail. Simulating the 3D model 4.45 m running length was considered. The modeled track is shown in Fig. 2. The track parameters used in the model are given in Table 1. First the unreinforced track section was modeled then the reinforcement was introduced between the interfaces. In the second section the geogrid was introduced between ballast and subballast (interface 1). Third section was reinforced with geotextile between subballast and subgrade (interface 2). Fourth section was reinforced with geogrid at interface 1 and geotextile at interface 2.

RESULTS AND DISCUSSION

Vertical Stress

Subballast 30 cm thickness

The vertical stress contours of the unreinforced section are given in Fig. 3. Results for vertical stresses beneath the rail seat versus depth for track for reinforced and unreinforced sections for subballast thickness 30 cm is given in Fig. 4. Vertical stresses for unreinforced section at subgrade top were 61.72 kPa and it was reduced to 51.90 kPa and 49.90 kPa when the reinforcement at interface 1 and interface 2, vertical stresses reduced to 47.60 kPa when the reinforcement on both interfaces for subballast thickness 30 cm (Fig. 4). 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 interface 1 and 2 is about 16 percent and 19 percent respectively. Reinforcement at both interfaces and the reinforcement at interface 2 only reduce the vertical stresses better than the section reinforced at interface 1.
Subballast 70 cm thickness

Vertical stresses for unreinforced section at subgrade top were 44.83 kPa and it was reduced to 39.97 kPa and 37.22 kPa when the reinforcement at interface 1 and interface 2, vertical stresses reduced to 36.58 kPa when the reinforcement on both interfaces for subballast thickness 70 cm (Fig. 5).

Subballast 30 cm thickness

The displacement contours of the unreinforced section are shown in Fig. 6. Results for displacement beneath the rail seat versus depth for track for reinforced and unreinforced sections for subballast thickness 30 cm and 70 cm are shown in Fig.7 and Fig.8 respectively. Displacement for unreinforced section at subgrade top was 7 mm and it was reduced to 5.20 mm and 4.80 mm for the reinforcement at interface 1 and interface 2, displacement reduced to 4.43 mm when the reinforcement on both interfaces for subballast thickness 30 cm (Fig. 7).

Displacement

Subballast 30 cm thickness

The displacement contours of the unreinforced section are shown in Fig. 6. Results for displacement beneath the rail seat versus depth for track for reinforced and unreinforced sections for subballast thickness 30 cm and 70 cm are shown in Fig.7 and Fig.8 respectively. Displacement for unreinforced section at subgrade top was 7 mm and it was reduced to 5.20 mm and 4.80 mm for the reinforcement at interface 1 and interface 2, displacement reduced to 4.43 mm when the reinforcement on both interfaces for subballast thickness 30 cm (Fig. 7).

Table 1 Track Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Rail</th>
<th>Sleeper</th>
<th>Ballast</th>
<th>Subballast</th>
<th>Subgrade</th>
<th>Geogrid/Geotextile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elastic Modulus, E (MPa)</td>
<td>200000</td>
<td>30000</td>
<td>130</td>
<td>100</td>
<td>10</td>
<td>200</td>
</tr>
<tr>
<td>Poisson’s ratio, ν</td>
<td>0.30</td>
<td>0.20</td>
<td>0.33</td>
<td>0.33</td>
<td>0.37</td>
<td>0.25</td>
</tr>
<tr>
<td>Thickness (cm)</td>
<td>13.5</td>
<td>21.0</td>
<td>30.0</td>
<td>30,70</td>
<td>250</td>
<td>0.3</td>
</tr>
<tr>
<td>Length (m)</td>
<td>4.45</td>
<td>2.75</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The reduction of vertical stresses in the subgrade layer with the reinforcement on both interfaces is about 18 percent, whereas the reduction of vertical stresses for reinforcement at interface 1 and 2 is about 11 percent and 17 percent respectively.

The reduction of displacement in the subgrade layer with the reinforcement on both interfaces is about 37 percent, whereas the reduction of vertical stresses for reinforcement at interface 1 and 2 is about 26 percent and 31 percent respectively. Reinforcement in both interfaces and the reinforcement in interface 2 only reduce the displacement better than the section reinforced at interface 1.

Fig. 5 Vertical Stresses beneath the Rail Seat versus Depth for Subballast 70 cm Thickness

Fig. 6 Displacement Contours for Unreinforced Section

Fig. 7 Displacement beneath the Rail Seat versus Depth for Subballast 30 cm Thickness
Subballast 70 cm Thickness

Displacement for unreinforced section at subgrade top was 5.60 mm and it was reduced to 4.70 mm, 4.50 mm for the reinforcement at interface 1 and interface 2, displacement reduced to 4.30 mm when the reinforcement on both interfaces for subballast thickness 70 cm (Fig. 8). The reduction of displacement in the subgrade layer with the reinforcement on both interfaces is about 23 percent, whereas the reduction of vertical stresses for reinforcement at interface 1 and 2 is about 16 percent and 20 percent respectively.

CONCLUSIONS

From this study, it is clearly evident that the reinforcement between subballast and subgrade, between ballast and subballast and the reinforcement at both the interfaces reduces 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.

REFERENCES