CHAPTER 9

RUT BEHAVIOUR OF COIR GEOTEXTILE REINFORCED UNPAVED ROADS

9.1 GENERAL

A road continuously deteriorates under the combined action of traffic loading and the environment. The most common indicators of pavement performance, the ability of roads to satisfy the demands of traffic and environment over its design life, are surface rutting, fatigue cracking, riding quality and skid resistance.

Geotextiles increase the stability and improve the performance of weak subgrade soils primarily by separating the sub base from the subgrade. Placing geotextile at subgrade - sub base or sub base - base interface, subgrade restraint can be enhanced which will facilitate the mobilization of heavy construction machinery at site. The mechanisms attributing to this are increased bearing capacity in addition to lateral restraint and tension membrane effect. Substantial life cycle cost saving is possible with geosynthetic reinforced aggregate base course in pavements.

Mechanistic method for flexible pavement design is regarded as the most powerful pavement design methodology and is becoming increasingly popular amongst various countries. In India too Indian Roads Congress has updated the specifications for flexible pavement design by changing the design methodology from empiricism to mechanistic design principles. In the mechanistic approach, the two design criteria, the fatigue failure and rutting failure corresponding to the horizontal tensile strain at the bottom of the bituminous layer and the vertical compression strain on the subgrade are considered (Chakrobority and Das, 2003).
Rutting is the permanent deformation along its wheel path. It is a manifestation of two different phenomena: i) densification and ii) shear deformation of pavement layer materials and subgrade (Yoder and Witczak, 1975). Rutting is very important because of its safety implications. The contributions to rutting from various layers could be different. It is reported that 46% of rutting took place from bituminous surface and granular base course, while sub base and subgrade contributed 54% of the total rutting (AASHO, 1962). The vertical strain on the subgrade is assumed as the index of rutting to occur in a pavement.

In the present study, the rut behaviour of unpaved roads with coir geotextile reinforcements placed at subgrade – sub base interface and also between layers of sub base under the action of static loads and repetitive loads were studied. The details of the testing programme and discussion of the results obtained are described in this chapter.

9.2 RUT BEHAVIOUR UNDER STATIC WHEEL LOADS

Plate bearing tests were performed to investigate the behaviour of coir geotextile reinforced unpaved roads under static loads. The test section consisted of 600mm thick subgrade overlain by water bound macadam (WBM) 150 mm thick.

9.2.1 Experimental Set-up

The experimental set-up consisted of a plate load test facility as described in section 8.3. The loading was done with the help of a 200 kN capacity hydraulic jack and self reaction frame made of mild steel I sections. The load was applied through 200mm square mild steel plate, 25.4mm thick to simulate Equivalent Single Wheel Load.
(ESWL). Rut measurements were made using LVDTs. The schematic arrangement of the test set-up is shown in Fig. 9.1.

**Fig. 9.1 Schematic test set-up to study rut behaviour under static loads**

### 9.2.2 Preparation of Test Bed

For the present study two types of subgrades, red soil (Soil - 1) and Clayey silt soil (Soil - 3) were used. Three types of coir geotextiles (Woven – H2M6 and H2M8 and Non - Woven) were used as reinforcing layer. Water bound Macadam was constructed using granite aggregates and screenings.

The subgrades were prepared at a dry unit weight of 15 kN/m³ and with a water content of 10% for red soil and 4% for clayey silt soil subgrade. Required quantity of wet soil was prepared by mixing dry soil with water. Soil was filled in the tank in layers of compacted thickness of 100 mm each up to a total height of 600mm in all
trials. Coir geotextiles cut to the inside dimension of the tank was placed over the prepared sub grade. Water bound macadam of grade II was laid over the compacted subgrade. The quantities of coarse aggregate and screenings were taken as per MORD specifications (0.91m³ to 1.07m³ of coarse aggregate and 0.12m³ to 0.13m³ of screening for a compacted thickness of 75mm per 10m²).

9.2.3 Testing Procedure

The tests were done as per the current Indian Standard test procedure for plate load tests. The load was applied through the thick square mild steel plate. Rut measurements were taken by LVDT placed one each at four corners of the plate. Load was applied at regular intervals and corresponding settlements were noted. Each load was kept constant until the rate of settlement reduces to less than 0.025mm/minute. Fresh soil samples, aggregates and coir geotextiles were used for each testing. The details of the different tests carried out are summarised in Table 9.1.

9.2.4 Results and Discussion

The principal criterion for determining the thickness of flexible pavements is the vertical compressive strain on top of the subgrade imposed by standard axial load. In India the standard axial load is 81.7 kN. Excessive vertical subgrade strain causes permanent deformation in the subgrade, which is manifested in the form of rutting on the pavement surface. Acceptability level of rut depth is different in different countries. IRC: 37-2001 recommended an allowable rut depth of 20 mm to estimate the rutting life of the pavement in terms of standard load repetition. IRC: SP: 20-2002 recommends that the maximum rutting that can be accepted in rural roads may be taken as 50 mm before rehabilitation work is needed.
Table 9.1 Summary details of tests conducted to study rut behaviour

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Type of subgrade soil</th>
<th>Sub base (WBM) thickness</th>
<th>Type of reinforcement</th>
<th>Location of reinforcement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Soil - 1</td>
<td>One layer - 150 mm</td>
<td>No reinforcement</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Soil - 1</td>
<td>One layer - 150 mm</td>
<td>H2M8</td>
<td>At interface</td>
</tr>
<tr>
<td>3</td>
<td>Soil - 1</td>
<td>One layer - 150 mm</td>
<td>H2M6</td>
<td>At interface</td>
</tr>
<tr>
<td>4</td>
<td>Soil - 1</td>
<td>One layer - 150 mm</td>
<td>Non Woven</td>
<td>At interface</td>
</tr>
<tr>
<td>5</td>
<td>Soil - 1</td>
<td>Two layers - 75mm each</td>
<td>H2M8</td>
<td>At interface and at mid depth of WBM</td>
</tr>
<tr>
<td>6</td>
<td>Soil - 1</td>
<td>Two layers - 75mm each</td>
<td>H2M6</td>
<td>At interface and at mid depth of WBM</td>
</tr>
<tr>
<td>7</td>
<td>Soil - 1</td>
<td>Two layers - 75mm each</td>
<td>Non Woven</td>
<td>At interface and at mid depth of WBM</td>
</tr>
<tr>
<td>8</td>
<td>Soil - 3</td>
<td>One layer - 150 mm</td>
<td>No reinforcement</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>Soil - 3</td>
<td>One layer - 150 mm</td>
<td>H2M8</td>
<td>At interface</td>
</tr>
<tr>
<td>10</td>
<td>Soil - 3</td>
<td>One layer - 150 mm</td>
<td>H2M6</td>
<td>At interface</td>
</tr>
<tr>
<td>11</td>
<td>Soil - 3</td>
<td>One layer - 150 mm</td>
<td>Non Woven</td>
<td>At interface</td>
</tr>
</tbody>
</table>

9.2.4.1 Rut behaviour of red soil subgrade

Fig. 9.2 shows the performance variation in terms of rut depth due to applied wheel loads for unpaved road sections with and without coir geotextiles placed at subgrade-sub base interface. It could be observed that the control section without coir geotextile reinforcement can sustain a wheel load stress of 192.5kPa for a rut depth of 20 mm and 317.5kPa for a rut depth 50mm. When H2M6 coir geotextile was introduced at subgrade - sub base interface, this load carrying capacity was increased to 262.5kPa and 462.5 kPa respectively. Also these values were respectively 325 kPa and 560 kPa for non-woven coir geotextile and 337.5kPa and 542.5kPa for H2M8 coir geotextiles. The percentage increase in the load carrying capacity is worked out to be 37%, 69% and 75% for H2M6, NW and H2M8 coir geotextiles respectively at 20 mm rut depth and 48%, 77% and 71% at 50 mm rut depth. Again at greater rut depths the
percentage increases in stress were found to be still higher. The increase in the load carrying capacity is attributed to the separation of aggregate from the subgrade in addition to the strength gain due to friction or interlock developed between the aggregate and geotextiles. The contribution due to lateral restraint is very less for non-woven geotextile whereas that due to separation and bearing capacity is very high for non-woven coir geotextile.

![Equivalent wheel load stress (kPa)](image)

**Fig. 9.2 Rut depth due to wheel load stress in WBM with red soil subgrade**

9.2.4.2 Rut Behaviour of clayey silt subgrade

The rut depth behaviour for unpaved road section on clayey silt subgrade under static load condition is shown in Fig. 9.3. For the control section, a wheel load stress of 300kPa produced 20 mm rut depth. The wheel load stress for the same rut depth for coir reinforced sections with H2M6, H2M8 and NW were 355 kPa, 450 kPa and 537.5 kPa respectively. For 50mm rut depth the corresponding value for un-reinforced case was 475 kPa and for the reinforced cases the values were 562.5 kPa, 712.5 kPa and 837.5kPa respectively for H2M6, H2M8 and NW coir geotextiles placed at subgrade-sub base interface. In this case the Non-woven coir reinforced unpaved
section is found to be superior to H2M8 and H2M6 reinforced one. The subgrade soil, being more clayey in nature is expected to be more flexible and the Non-woven geotextile may be more adaptable to follow the undulations. This may increase the performance of geotextile as separator and as reinforcement due to membrane effect.

![Diagram](image)

**Fig. 9.3 Rut depth due to wheel load stress in WBM with clayey silt subgrade**

**9.2.4.3 Effect of additional reinforcement layer**

In order to explore the possibility of further improving the rut behaviour by using coir geotextiles, an additional layer of coir geotextile was provided within the subbase and analysed. When two layers of coir geotextiles were placed (one at subgrade – sub base interface and other within the sub base itself at mid depth), the load carrying capacity was further improved as shown in Fig 9.4. A comparison between single layer system with coir geotextiles at the interface and two-layer system with an additional reinforcement layer within the WBM section (red soil subgrade) shows that while
there was a noticeable difference between reinforced and unreinforced cases, there exists a marginal difference among the single layer and two-layer reinforced cases.

![Graph showing Equivalent wheel load stress (kPa) vs. Rut depth (mm)]

Fig. 9.4 Effect of additional layer of coir geotextile

It could be observed from the test results that, in the case of Non-woven coir geotextiles for a rut depth of 20 mm the carrying capacity was 295 kN/m² with single layer reinforcement and 327.5 kN/m² with two layers showing only 11% increase due to additional layer of reinforcement. With H2M8 reinforcement the percentage increase in carrying capacity due to additional layer of reinforcement is only 15.5%. For 50mm rut depth, the carrying capacity with single layer reinforcement and two-layer reinforcement was 552.5 kN/m² and 562.5 kN/m² for NW coir geotextile and 537.5 kN/m² and 625 kN/m² for H2M8 coir geotextile, inferring a little effect on carrying capacity due to the additional layer of reinforcement in the case of Non-woven geotextiles.

9.2.4.4 Effect of type of coir geotextile

While analysing the rut behaviour of unpaved road section with red soil subgrade (Fig. 9.2) the percentage increase in carrying capacity was 37%, 69% and 75% in the
order of H2M6, NW and H2M8 coir geotextiles for a rut depth of 20 mm. For 50 mm rut depth, the corresponding increases were 46%, 77% and 71% respectively. For unpaved section with clayey silt subgrade, the performance was remarkable when H2M8 and NW coir geotextiles were placed at the interface. For 20 mm rut depth the percentage increase in load carrying capacity in relation to unreinforced case was 19%, 50% and 80% with H2M6, H2M8 and NW coir geotextiles whereas at 50 mm rut depth, the percentage increase in carrying capacity was respectively 19%, 50% and 77%. When two layers of reinforcements were placed, H2M8 coir geotextile gave the highest performance and the contribution due to additional layer of NW coir geotextile was meagre.

9.3 RUT BEHAVIOUR UNDER REPETITIVE LOADS

In order to study the benefits of applying coir geotextile reinforcement in improving rutting resistance of unpaved roads, laboratory wheel tracking tests were performed. The details of the study are explained in the following sections.

9.3.1 Wheel Tracking Apparatus

Laboratory wheel tracking tests is the most practical tool to study the rutting behaviour of pavement materials under simulated moving traffic loads (Wasage et al., 2004). A wheel-tracking machine was designed and fabricated in the present work to study the effect of load repetitions. Track bed was made in a steel tank measuring 1.5m x 0.75m x 0.75m. A 0.5 HP constant torque geared motor was used to control the motion of the wheel. The wheel was 200mm diameter and 45mm wide with a rubber ring over it. The motor was mounted on a frame, which moves on four 60mm diameter wheels, on rails provided on the top of two long sidewalls of the tank. The
Fig. 9.5. Wheel tracking apparatus
tracking machine had an in-built counter that can register the number of passes of the wheel. Arrangements were provided for simulating ESWL by placing steel plates on the frame. Rut measurements were made using a depth gauge. The longitudinal section and sectional plan of the test set-up are shown in Fig. 9.5 and its photograph is given in Fig. 9.6.

![Fig. 9.6 Photograph of wheel tracking apparatus](image)

### 9.3.2 Testing Programme

To prepare the test bed, the tank was filled with red soil (soil-2) in layers and compacted to a density of 1400 kg/m³. The subgrade was filled to a height of 600mm. Coir geotextile was placed over the subgrade and then WBM layer was laid over it using aggregates of size 22.4mm down and screenings of grading B. The compacted thickness of the WBM layer was 150 mm. Four series of experiments were done, viz.,
(i) Control test with no geotextiles,

(ii) Test with Non-woven coir geotextile at the subgrade - base interface,

(iii) Test with H2M8 coir geotextile at the subgrade - base interface, and

(iv) Test with H2M6 coir geotextile at the subgrade - base interface.

Rut measurements were taken at the top surface of WBM section after the specified number of wheel passes using the depth gauge at 25 locations which are represented by A1, B1, ....... , E5 as shown in Fig. 9.7.

![Fig. 9.7 Locations of rut measurement](image)

9.3.3 Test Results and Discussion

From the observed data, rut profiles in the longitudinal direction and transverse direction were drawn for the controlled section and coir-reinforced section for
different wheel load passes. Fig 9.8 gives the transverse rut profile at center (through A3, B3, C3, D3 and E3) for the control section. It could be seen that a rut depth of 20mm, which is the allowable rut depth by the IRC, has occurred at about 55 number of wheel passes. The development of rut was very fast in the initial stages of wheel passes and afterwards it was observed that the increase in rut depth was gradual. Accordingly, a rut depth of 29mm, which was obtained for 500 passes became 49mm only, after 1750 number of wheel passes. The soil on either side of the wheel was bulged due to loading, which is manifested as negative settlement in the figure. Fig.9.9 shows the variation of rut depth after 1750 wheel passes along the centre (through A3, B3, C3, D3 and E3) for the reinforced and unreinforced cases. It was observed that due to placement of the coir geotextile the rut depth was reduced considerably. Thus, when rut measurements were taken at C3 location, on the section reinforced with Non-woven geotextile, it was only 2mm, whereas it was 48.5mm for the unreinforced case. Similar effects were noted with other geotextiles like H2M8 and H2M6, which gave maximum rut depths of 24mm and 30mm respectively after 1750 passes of the wheel. The percentage reduction in rut depth amounts to 55%, 50% and 38% respectively with Non-woven, H2M8 and H2M6 after 1750 wheel passes. At B3 location the bulging was eliminated when coir geotextiles were placed. Thus it can be concluded that coir geotextiles function both as separator and as reinforcement in the case of repetitive loads also. From the profiles drawn it was observed that, heaves on both sides of the rut had approximately in equal volume to the volume of rut. This suggests that displacement of the materials rather than densification of the layers contributed to the rut formation. While comparing reinforced and unreinforced cases, it was observed that there existed no heaving in coir-reinforced sections.
Fig. 9.8 Transverse rut profile for control section

Fig. 9.9 Rut profiles for reinforced sections after 1750 wheel passes

Fig. 9.10 shows the variation of rut depth with the number of wheel passes when coir geotextiles are placed at subgrade - sub base interface. It could be seen that a rut depth
of 20mm was produced due to 55 wheel passes in the case of control section whereas coir reinforced section with H2M8 coir geotextile needed 1050 passes for the same rut depth to take place. Also, sections with Non-woven and H2M6 coir geotextiles produced 20 mm rut after 950 and 450 number of passes. Variations in rut depth for 500, 1000 and 1500 passes are compared in Fig. 9.11 for different geotextiles. It is clear from the figure that H2M8 and Non-woven coir geotextile produced similar performance. Fig. 9.12 shows typical graphs for 1750 wheel passes along the centreline and along a path 125mm away from the centreline.

![Graph showing variation of rut depth with number of wheel passes](image)

**Fig.9.10 Variation of rut depth with number of wheel passes**
Fig. 9.11 Effect of coir geotextile on rut depth

Fig. 9.12 Longitudinal rut profile

(a) along centreline  
(b) away from centreline
9.4 SUMMARY

From the experimental results it was observed that coir geotextiles placed at the interface between subgrade soil and sub base can substantially reduce the rut depth due to static as well as repetitive wheel loads. In both cases, it was noticed that H2M8 and Non-woven coir geotextiles produced almost identical results.