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Slope Repairing Methodologies in Railway Embankment

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Abstract. The generalized methodology of slope repairing for railway embankment considering several case histories in northern India is presented in this paper. There are many available literatures to assess the reason of recurring slope failures and it's preventive measures form construction point of view. However, there is no synthesize practical recommendations to overcome the issues of recurring slope failures and address the common methodology for already failed slope repairing system. The present study focuses on the slope repairing methodology under different scenario of rain-cut problems. The common issues like rainfall infiltration, slope height, soil types, fines content, level of compaction etc. Slope stability analysis has been performed for the respective sites with the already failed slope conditions to understand the requirement and utility of slope repairing techniques. About 7000 km of Indian railway track has been built on the weak formation it's inevitable to have slope failure and the high demand of high-speed railway track also support the requirement of long-term stable slope repairing methodology. Several case histories of the already failed railway embankment slopes have been discussed along with the proposed repairing techniques. The generalized methodology of the slope repairing techniques have been suggested considering all the aspects.

Keywords: Railway Embankment Stability, Slope Repairing, Vegetation.

1 Introduction

Erosion of railway embankments caused principally by the rainfall and winds. The topsoil of the embankment gradually destabilizes to weaken the existing formation of the railways due to the erosion. Due to vast variety of climatic conditions, rainfall and stratum characteristics no unified solutions have been found in the literature. Especially the railway embankment resting on silty clay to poor graded sands are very common in Northern part of India. The most part of the railway embankment track has been constructed by filled soil and height ranges from 6 m to 30 m. The tracks are generally constructed based on Indian Railway's division Research design and Standards Organization (RDSO) guidelines [1]. The standard slopes have been constructed with side slope 1:2 (H: V) and bench of 1.5 m width has been provided at an interval of 6 m from the ground level. Typical railway track formation section has been shown in Fig. 1. Typical railway formation has been constructed over compacted soil (typically clay or rock based), that allows railway lines to pass at an acceptable level and gradient over low lying ground.

Rainfall has been found to be most to be most triggering force in the instability of railway formations. Several past literatures have discussed the failure of railway embankment slopes under the rainfall infiltrations as reported in [2–7]. The mainly reduction in soil shear strength and decrease soil matric suction causes the slopes instability inside slopes. In the present study, detailed investigation has been done side slope failure in the dedicated freight corridor package with proposed repairing and protection methodology. The slope stability analysis has been done in Slope/W software an integrated module of GeoStudio [8].

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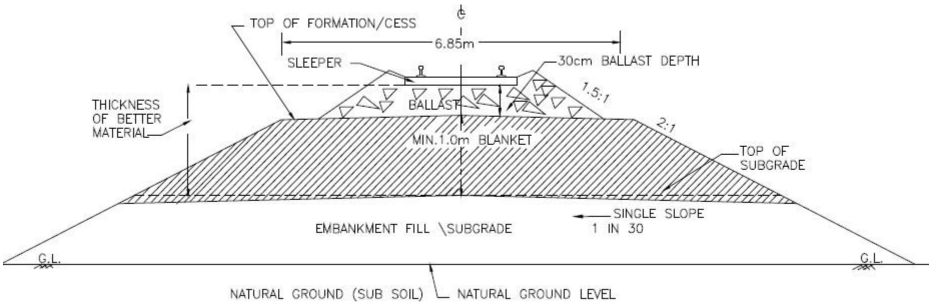


Fig. 1. Schematic diagram of railway track formation with various components [1].

2 Site Location

The present site is located between Rewari (Latitude: 28.552577° and Longitude: 76.619077°) and Dadri (Latitude: 28.552577° and Longitude: 77.554810°) (127 km stretch) which covered regions of Rewari-Alwar-Mewat-Gurgaon-Palwal-Faridabad-Gautam Buddha Nagar in the three states of Haryana, Rajasthan and Uttar Pradesh, India. This project is part of Western Dedicated Freight Corridor (WDFC) which stretches 127 km distance as shown on Fig. 2, named as CTP-14.

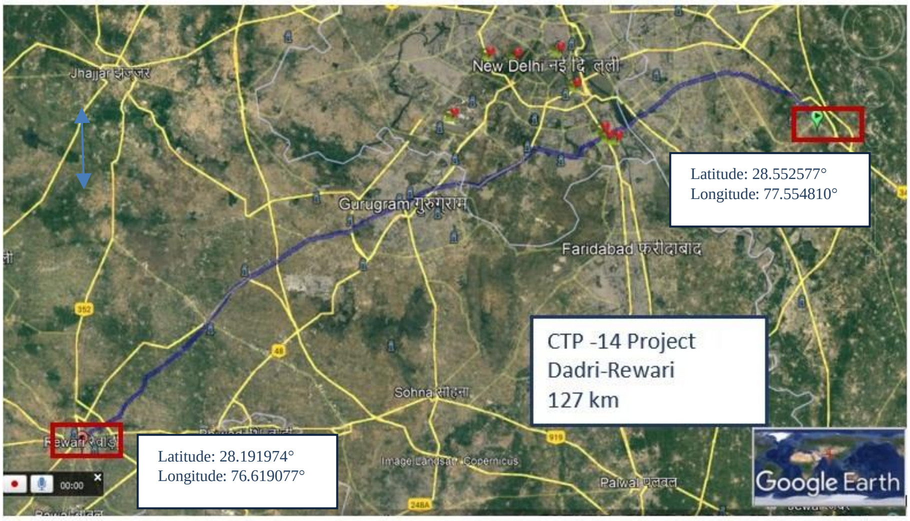


Fig. 2. Location of project site, CTP -14.

3 Identified Problems

Based on the observations and site visit to above locations following problems have been identified:

1. Edges of track platform has been damaged due to heavy rains (as shown in **Fig. 3**)
2. Slope area embankments are facing soil erosion.
3. Vegetation survival at slope areas of embankment is very poor.
4. Poor drainage around embankments.

(a) Rain-cut in track platform **(b)** Side slopes erosion in embankment

(c) Insufficient growth of vegetation

(d) Poor drainages around embankment

Fig. 3. Different problems identified in railway formation (a) rain-cut problems in track platform, (b) side slopes erosion, (c) insufficient growth of vegetation, and (d) poor drainage.

The collectively all of the above issues lead to the heavy erosion and rain-cut problems in all the railway formation. The objectives of the present study are to

1. Suggest measures for preventing soil erosion in the whole stretch
2. Suggest measures for stabilizing embankments in the whole stretch.

4 Fills Conditions

The entire stretch of 127 km from Rewari to Dadri has been affected by soil erosion. The observations have been reported in the Table.

Table 1. Details of field investigation and observations in selective chainages.

S. No.	District	Chainage No.	Observation	Vegetation Scope
1	Rewari	20+100	Soil: Sandy and sandy loam Edge of embankment's top has been run off and slope of embankment has faced soil erosion	Poor
2	Rewari	25+200	Soil: Sandy and Sandy loam Slope is damaged due to soil erosion	Poor
3	Mewat	65+300	Soil: sandy loam Embankment is around 30 m height and slope has been damaged due to soil erosion	Very poor
4	Dadri	133+800	Soil: sandy mixed with Yamuna sand Run off at top of the embankment due to soil erosion	Very poor
5	Dadri	130+200	Soil: sandy and sandy loam Run off at top of embankment and slope is damaged due to soil erosion	Very Poor

S. No.	District	Chainage No.	Observation	Vegetation Scope
6	Faridabad	114+75	Soil: sandy loam Soil run off due to rain	Poor

Following general observations have been reported from the changes:

- At the top edge no drainage system has been provided.
- The rate of soil erosion is extensive.
- The significant soil has been lost from the embankments which causes slope instability.
- The erosion protection measures have not been taken properly which results in cuts, rills and gully formation.
- Most of the structures used for railway embankment has been made with 40-78% sand fractions.
- The soil compaction has not been done properly which enhances the chance of erosion.

5 Methodology Adopted

Based on the field observations of various site locations and the sub-soil investigation reports the following problems have been identified.

1. Protecting the edge of track and slope from damage due to rainwater has been proposed in all the changes. The non-existence of drainage system leads to excess flow of rainwater which is contributing to rainwater and further contributing factor to soil erosion.
2. To stabilize the damaged slope due to sandy nature of the soil. Since granular soil has poor water holding capacity and low density the damages are expected in the side slopes. All the embankments have been constructed on a high gradient. The side slopes must be stabilized with protection methodology.
3. The suitable vegetation has been proposed to stabilize the soil in slopes, edges and at the bottom of the slopes. The reported soil has very less growth of the vegetation. The seeds of vegetation must be chosen carefully to makesure about the growth inside the slopes.
4. Bio-technical solutions must be employed to control the erosion.
5. The application of trees, grass and other plants for the protection of soil from water/wind erosion must be employed. The soil must be treated using amenders to make suitable environment for the growth of vegetation.

Due to very high percentage of sand fraction ranging from 40% to 70% at various section the proper compaction of dumped soil has not been possible. Thus, the favorable situation of vegetation growth is not there, it would need treatment in form of engineering solutions along with vegetation models with use of amenders, suitable species if grasses, herbs, bushes and other woody species.

Rain cuts are more prominent at the locations where blanket layer is completed. Velocity of rainwater increase on blanket surface and damage the formation even when rain fall is not heavy. Locally available soil is of Silty sandy nature which quickly loses its shear strength and gets converted into liquid state in presence of water. The soil used in the formation is not suitable for conventional turfing.

6 Suggested Solutions

The solutions for stabilizing the soils on slopes, mounds and the base of the mounds is required a combination of engineering as well as vegetative approaches. The choice of solution has to be decided on the sand percentage in the soil at the site. topography to tackle soil erosion and management of water drainage. Based on the field investigation report following solutions have been proposed and employed with trial sections.

- The concrete kerb on both sides of formation top (blanket top) along with chute drain has to be provided at every 40-meter interval. First trial section of 250 m has been proposed nearby Faridabad section. After successful performance in terms of run off the solutions have been employed for rest of the whole stretch. The detailing of kerbs has been designed based on M25 grade concrete as shown in Fig. 4. The proposed formation has been shown in Fig. 5. The significant reduction in the soil erosion has been observed in the next monsoon.

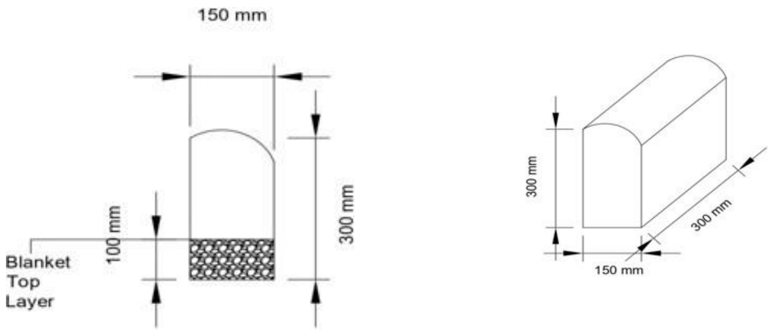


Fig. 4. Detailing of the proposed kerb.

(a) **(b)**

Fig. 5 (a)-(b). Kerbs with chute drains at the top of the formation.

- In critical places where gradient is higher, like location of the riverbank and soil with more than 70% sand fraction dry stone apron (stone pitching) has been proposed at the bottom. Use of jute/ coir mat/ geocell between the drains and covering with amender mixed soil for propagation of vegetation at the slope would be useful. At the bottom of embankment track slope toe wall construction has been suggested either by stone or affordable low-cost gunny bags with earth fill structure toe wall to control the soil erosion and for avoiding angle of repose made by erosion. Coir mats, with their high tensile strength and extreme durability, are suitable for the most severe erosion control problems and can have a lifespan of three to six years, allowing for vegetation to become fully established.

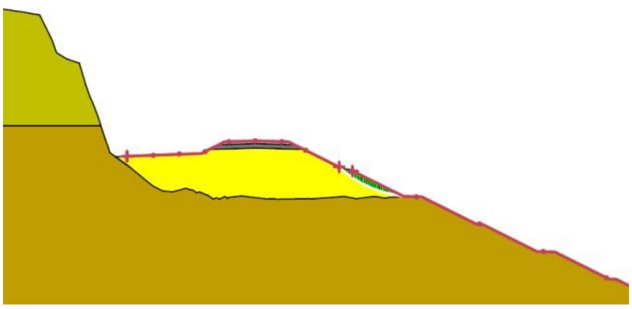
7 Slope Stability Analysis

Slope stability analyses have been conducted to check the Factor of safety for already existing slopes. The analysis has been performed using Slope/W software for different height of the slopes at different location of whole stretch. The drained properties of the fill have been considered to check the effect of water infiltration. The properties of different layer can be found in Table 2. The Mohr-Coulomb constitutive model has been assumed for fill materials.

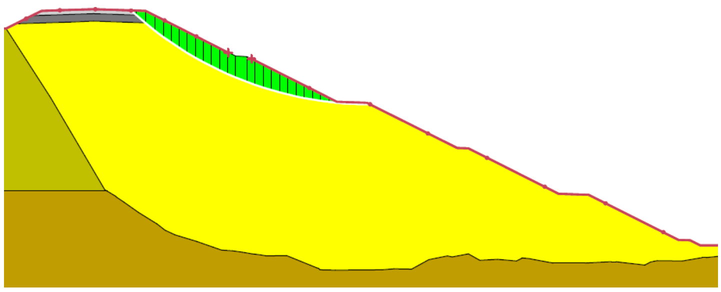
Table 2. properties of the different layers for slope stability analysis.

Layers	Unit Weight	Cohesion	Angle of Internal Friction
	kN/m^3	kPa	°
Blanket Layer	18.5	2	34
Subgrade	16.7	2	31
Embankment Fill	17	2	29.5
Rock Layer-1	26	184	35.2
Rock Layer-2	26	148	31

The slope stability analysis for different height of slopes have been shown in Fig. 6. The different height of the slopes has been shown the changes in the factor of safety. The reduction in factor safety with larger height of slopes shows the importance of consideration of protection methodology for larger height of slopes, which is very common for railway formation. In the RDSO guidelines it has been recommended to provide only turfing if the slope height is 4 m, coir mat with turfing for 4 to 6 m height and above 6 m height of slope Geocell with grass turfing has to be provided. Although no information has been provided about the rainfall based design and steady-state seepage coupled with stability analysis an inferences can be drawn about the types of protection methodology to be adopted from static slope stability analysis.



(a)



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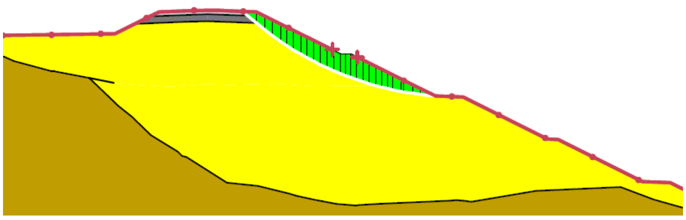

(c)

Fig. 6. Slope stability analysis for height a) 2.1 m , b) 4.2 m and c) 5.6 m height slope.

The variation of the factor of safety with the different slope height has been shown in Fig. 7. It has been seen the larger height is not safer for slope to be stable. The protection methodology to be designed in such a way in the larger soil slopes.

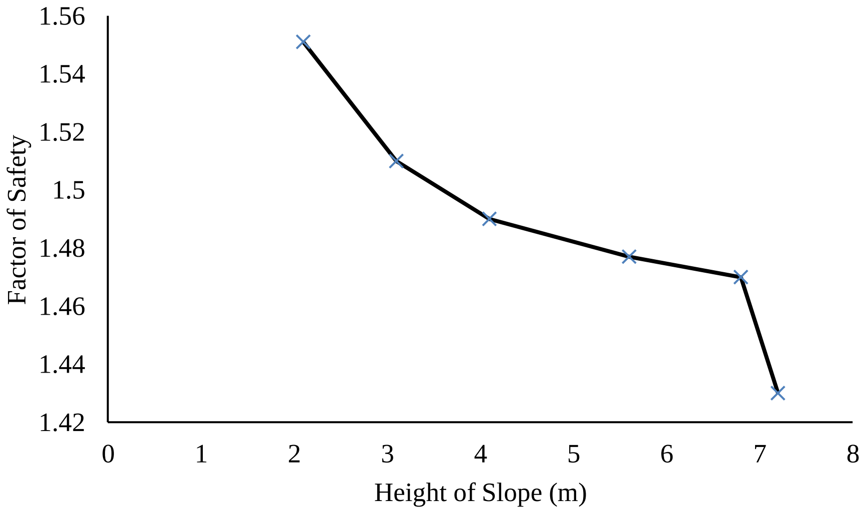

Fig. 7. The variation of static factor of safety with different slope height.

8 Suggestive Measures on Vegetations

It has been found that grass tufting is very economical, requires very little water once it has grown. The deep roots of the grass prevent water from tunneling underneath the surface of ground. For this purpose, a research has been conducted on various available grasses and has been proposed for different locations based on the sand fractions. In Table 3 it has been shown in detail with species name.

Table 3. The name of grass species.

	Sand Fraction (%)		
	Sandy Loam (>70%)	Sand and Gravel (61-70%)	Sand and Gravel (40-60%)
Grasses	Saccharam Bengalense, Seymour Grass, Panicum Maximum	Cenchrus Prieuri, Seymour Grass	Cenchrus Prieurii, Lasiurus Sindicus, Cenchrus Cilliaris

9 Conclusions

In the present study, the possible scope of slope protection methodology has been explored based on the field investigation. The challenges in the railway embankment are prominent due to larger height of formation and unavailability of the fill material. The available fill materials unsuitable for the vegetation growth and in many locations the drainage systems have not been maintained properly. Further slope stability analysis has been done to check the possibility of slope protection methodology in the existing formations. For protecting the track both work engineering and propagation of vegetation are used to treat in all the embankment area.

- The kerb with chute drains have been proposed on the top of the formation to give passage for
- Soils presented must be treated due to very high percentage of sands at various location which ranges from 60-70%. The treatment has been proposed using organic manure to make it favorable for vegetation growth.
- There is a need of consistently treat the soil considering the rate of soil erosion.
- The severe erosion in many areas of formations has been observed, it has been proposed to use tufting, vegetative hedges or strip or brunch grass or shrubs which will help in reducing runoff velocity by planting them.
- The increase time for water to infiltrate into the soil as the roots of the grasses are deeper. The grasses are acting as the porous filters. The hedges can drastically reduce the loss of soil and gully formations.
- Simultaneously, seed growing can be used so as to enhance the vegetation on the treated soil. The areas of severe erosion with medium to less sand percentage where some vegetation growth is possible, that area need seed sowing after treatment of soils for enhancing the survival of the vegetation. The grass species have been suggested for locations with higher sand fraction.

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