ASSESSMENT OF DISTRESSED RAILWAY EMBANKMENT IN BANGLADESH

Md Hamidur Rahman[1], Rokibul Hossain Titu*[2] and Mahabub Sadiq[3]

[1] *Additional Chief Engineer (Bridge), East, Bangladesh Railway, Bangladesh,*
e-mail: hrahman_2000@yahoo.com
[2] *Student, Khulna University of Engineering & Technology, Bangladesh, e-mail: titu2101505@stud.kuet.ac.bd*
[3] *Graduate Student, Khulna University of Engineering & Technology, Bangladesh,*
e-mail: iamsadiq6670@gmail.com

***Corresponding Author**

ABSTRACT

The embankment got distressed by Pachuria-Faridpur-Pukuria under the Bangladesh Railway West Zone Project in October 2015 during the reconstruction and rehabilitation of the existing track. Total 11Nos different distressed segments are identified along the alignment, and the segment length ranges from 30-548m. To identify the distressing problem, 93 boreholes were drilled at the distressed segment of the embankment. After that, disturbed and undisturbed samples were collected for detailed laboratory tests. The drilling depth ranged from 20-30m from the top of the embankment. This study has been focused on the stability of analysis of the distressed segments based on Bishop method and Low’s approach as well as the possible reasons for this distress. Through the analysis, it has been found that the property of fill material below the required limit. The slope is instable due to the fill material property.

Keywords: *Slope stability, Railway, Embankment Distress and Bangladesh.*

1. INTRODUCTION

Transportation is a crucial factor in the modernization of each country. During the construction of roads, railways, and airways, it may be necessary to establish a fixed path through soil that is unable to support the weight of traffic. Ground improvement is typically necessary in the majority of cases. Without proper ground improvement or faulty design of ground improvement, it could cause drastic structural failure.

The research focuses on the Kendrapara region in the state of Odisha, India (Deshpande et al., 2021). The objective of the study is to examine the development of an embankment for a new wide gauge railway line between Haridaspur and Paradeep. The track configuration at the designated investigation site stretches a distance of 1500 metres. One terminus of the connecting line is linked to the bridge abutment, while the opposite endpoint serves as a mainline. Table 1 provides the geometric specifications pertaining to the creation of embankments. The soil forming the foundation exhibits a high degree of softness, primarily composed of clay, and possesses undrained shear strength values ranging between 15 and 25 kilopascals (kPa). The groundwater level at the location's location is situated in close proximity to the ground surface, while the surrounding area adjacent to the embankment is currently utilised for agricultural purposes by local farmers. The soft clay layer has a thickness of 6 metres, which is situated beneath the natural ground surface. This soft clay layer is overlain by a 6-meter-thick layer of silty clay. Beneath the stratum of silty clay, a layer of sandy clay with a thickness of 8 metres is present.

The building of the embankment on silty clay was extended for a duration of six months throughout the calendar year of 2019. According to the guidelines set by the Research Designs and Standards Organisation (RDSO) (Kumar et al., 2020), the initial layer of untouched soil on the ground, extending to a depth of 2 metres, was substituted with sand. The replacement is expanded by a distance of 1 metre beyond the toe of the embankment in order to establish a drainage conduit from the upstream side to the downstream side. The failure of the embankment was observed during the construction process itself, namely when the ultimate height of the embankment reached the formation level, also known as the blanket layer. Upon conducting a physical examination, it was observed that the failure transpired throughout a stretch of 500 metres, primarily concentrated at the curved section of the embankment where the height measures around 9.851 metres. A segment of the embankment experienced lateral displacement, leading to the creation of a pronounced vertical incision. The soil that was removed from the embankment slid down and displaced the soil beneath it, resulting in an upward movement on the side of the embankment that experienced failure. The observed failure mode appears to be a fundamental failure.

This study encompasses a case analysis of the failure of a 91-meter long (300-foot) segment of an embankment connecting-ramp (referred to as Ramp ES) situated between the westbound lanes of Interstate-76 (I-76) and the southbound lanes of Interstate-71 (I-71) in Medina County, Ohio (Stark et al., 2018). The segment of 91 metres (300 feet) in length, located between Stations 202+00 and 205+00, experienced a failure during the construction process, specifically at a height of approximately 43% of the intended design height, which equates to 9.2 metres (30 feet). The project encompassed the expansion and refurbishment of the I-71 at the I-76 interchange, entailing the incorporation of an additional lane spanning 5.2 kilometres (3.2 miles) along I-71, the erection of new ramps and embankments, as well as the removal and subsequent reconstruction of 14 bridges. The designs and specifications pertaining to this project were finalised in the year 2004.

One crucial aspect of the Ramp ES design entailed the use of prefabricated vertical drains (PVDs) in order to expedite the consolidation process and enhance the shear strength of the underlying foundation soils, which were characterised by their weak and fine-grained nature, beneath the connected ramp embankment. The primary objective of the PVDs' design was to enhance the shear strength of the foundation soil by a range of 2.0-2.5 times, with the intention of achieving a sufficient element of safety during the placement process. This matter will be further elaborated upon in later discussions. Nevertheless, tension cracks emerged along the crest of the embankment after a mere 2.4

m (8 ft) of embankment fill placement, which accounts for slightly more than one-quarter of the total embankment height of 9.2 m (30 ft) at this specific site. In 2007, a segment of the embankment measuring 91 metres in length (300 feet) experienced failure after the embankment height had reached roughly 43% (4.0 metres; 13 feet) of its total height (9.2 metres; 30 feet).

A group of companies comprising both local and foreign contractors has been granted the contract for the construction of the Bhanga-Bhatiapara portion of the Dhaka-Khulna Road, as part of the Southwest Road Network Development Project (SRNDP), Contract No. 3. During the process of filling the embankment near the approaching point of a bridge at chainage 5+540 km, a slide failure in the embankment transpired (Siddique et al., 2005).

1.1 Project Description

At present, BR has initiated a project aimed at reopening the previously closed 'Pachuria-Faridpur-Pukuria' section. This involves the rehabilitation of the Pachuria-Faridpur section spanning 25.52 km, the reconstruction of the Faridpur-Pukuria section covering 25.8 km, and the construction of a new railway line extending up to Bhanga for a total length of 5 km (Faridpur-Bhanga Section of Bangladesh Railway (West), 2017). The objective of this work is to establish connectivity with the Trans-Padma rail corridor. The initiation of track operations was scheduled to occur in December 2015. The reprofiling and restoration efforts on the existing embankment were nearing completion; however, during the rainy season spanning from July to October 2015, particular sections of the embankment began to exhibit signs of damage (Figure 1). Total 11 Nos different segments having length of 30-548m were identified as significant distress.

Figure 1: Distressed segment of Railway Embankment

In this study, general condition of subsoil, stability analysis of the distressed segment of the embankments are presented.

2. METHODOLOGY

In March 2016, a total of 93 holes were bored along the Bhanga segment following the occurrence of an embankment failure. Standard Penetration Tests (SPT) were carried out in sandy soils at depths of up to 15 m in these holes, which were below 10 m in depth (Figure 2). Soil penetration tests (SPTs) were conducted at regular intervals of 1 meter depth. Auto-trip hammers were utilized to conduct SPTs. Undisturbed samples were collected from clay and silt layers in boreholes using a 100 mm diameter open-drive tube sampler.

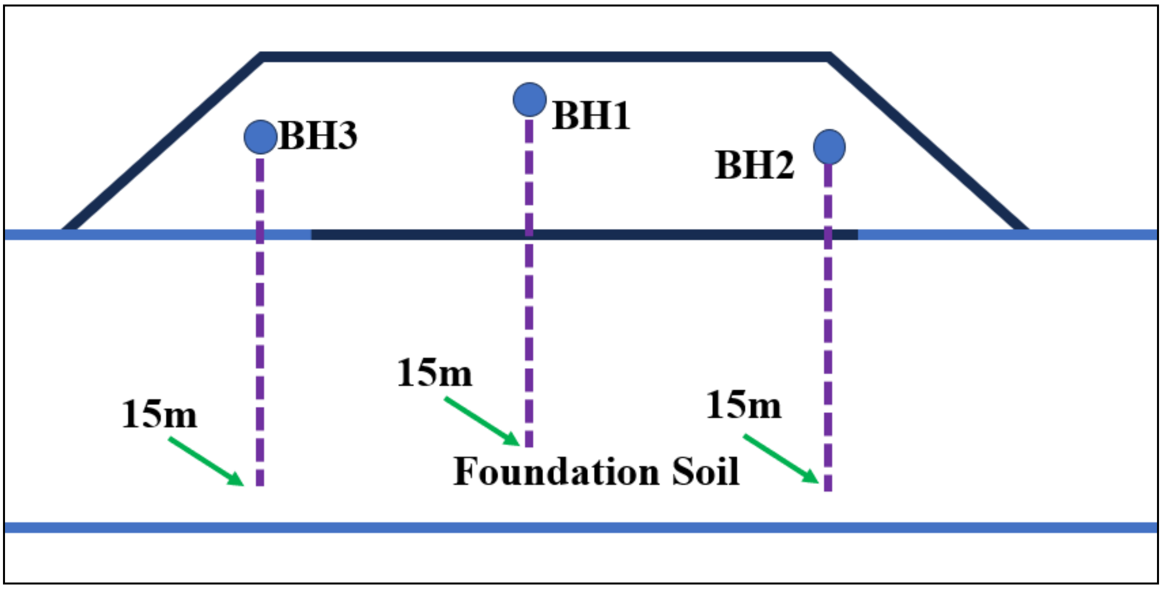

Figure 2:Layout of subsoil investigation

The evaluation of potential reasons for the failure of earth embankments often involves analyzing the geological and geotechnical soil properties at the location and applying limit equilibrium analyses, including slope stability analysis. This is a typical mechanics of soil stability problem. The presence of pre-existing slip planes in the soil, as well as the occurrence of lenses and bends in the cracker material, can greatly impact the stability of slopes. An assessment of stability was conducted to determine the factor of safety regarding sliding and bearing capacity failure of the embankment. The stability of these areas was assessed in short-term undrained conditions. Temporary unconsolidated behavior is anticipated until excessive pore pressures have decreased. The stability analysis was conducted using the SLOPE/W software. For this specific situation, the Bishop Method was chosen due to its effectiveness and appropriateness for the available data analysis.

The stability of the embankment has been analyzed using the methodology introduced by (Low, 1989). Embankments founded on soft clay the ground commonly face the risk of failure due to a circular slip surface that extends into the soft ground (Figure 3). A limitless number of tangent circles can be constructed, all tangential to a specified trial limiting tangent. Out of all the potential slip circles that pass along the soft foundation, the critical circle provides the lowest safety factor.

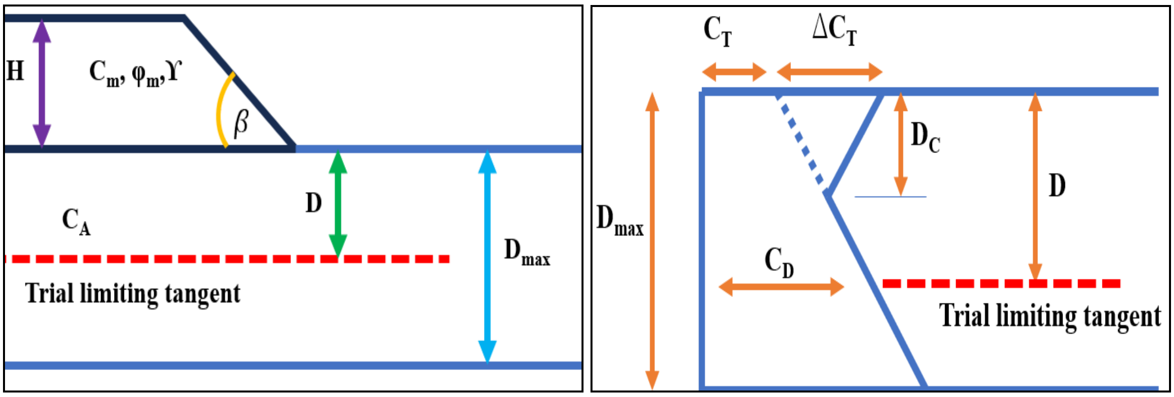

Figure 3: Description of embankment over soft ground

It is worth noting that this strategy considers the depth of the soft soil. The geotechnical qualities considered as illustrating the embankment portion inside the Bhanga-Faridpur stretch are as follows in Table 1.

Table 1: Parameters of the Stability Analysis for LOW Approach

SL No.	Properties	Magnitude
1	Height of embankment	5
2	fill ‘s shear strength of, C_m (kPa)	10
3	Fill’s angle of internal friction, φ_m (°)	0
4	Unit weight of fill, γ_m (kN/m^3)	20
5	Foundation Soil Layer thickness (m)	5
6	Foundation’s shear strength, C_D (kPa)	15
7	Foundation’s angle of internal friction, φ_m (°)	0

3. RESULTS AND DISCUSSION

3.1 Standard Penetration Test (SPT)

The borelogs display (Figure 4) the N-values acquired from the Standard Penetration Test conducted in the sandy soils found beneath the soft sub-soil composed of grey silty clay. The N-values obtained from Standard Penetration Test (SPT) in the sandy strata, below the soft sub-soil, at depths of 15 m in the boreholes BH1, BH2, and BH3 upto 15m. The N-values of the fill material recovered from boreholes BH1, BH2 and BH3 exhibited significant variation, ranging from 2 to 11. The N-values obtained via SPT in borehole BH1 varied between 0 and 5 for the soft clay beneath the fill. Nevertheless, the N-values obtained from borehole BH2 exhibited a range of 4 to 8. The N-values obtained from the Standard Penetration Test (SPT) in the sandy layers, located below the soft clay, of boreholes BH1 and BH2 varied from 28 to 40 up to a depth of 15 meters.

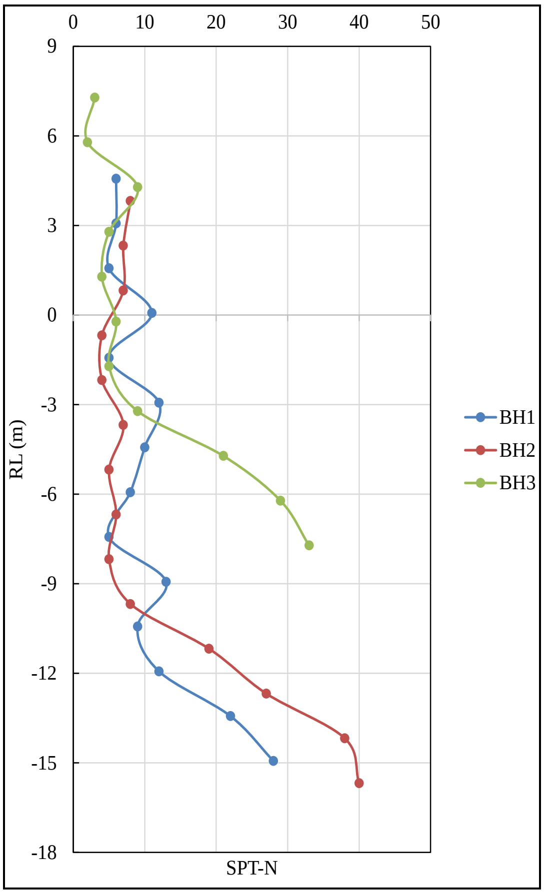

Figure 4: Variation of SPT-N with Depth

3.2 Index, Compressibility and Permeability Properties

In the Geotechnical Engineering Laboratory at BUET, experiments were conducted to identify and classify sub-soil using index properties. These tests included measuring moisture content, conducting liquid limit and plastic limit tests, and performing particle size analysis.

The liquid limit, plastic limit, and plasticity index of a soft silty clay material taken from a depth of 1.5 m to 7.5 m have been determined to be within the ranges of 40-72, 19-27, and 15-22, respectively. The embankment fill has a liquid limit (LL) of 50-51, a plastic limit (PL) of 23-24, a plasticity index (PI) of 25-28, a shrinkage limit (SL) of 18-22, and a linear shrinkage of 9-11% CH. The plasticity index for fill material as per RDSO is <12 (Kumar et al., 2020). Thus, the laboratory tests revealed that samples were highly plastic and didn't meet the fill material criteria. The dry unit weight (γ_d) of the embankment fill is 16.1 kN/m^3. The particle size distribution curve reveals that the percentage of clay particles (less than 0.002 mm) ranges from 43.7% to 49.6%, the percentage of silt particles (0.002 mm to 0.06 mm) ranges from 49.8% to 55.7%, and the percentage of sand particles (0.06 mm to 2 mm) is less than 1%.

3.3 Compressibility and Permeability Properties

Twelve consolidation tests were conducted at the BUET Geotechnical Engineering Laboratory using twelve undisturbed tube samples taken at depths ranging from 2.10 m to 5.6 m. The compressibility and permeability parameters of tweleves materials were investigated by one-dimensional consolidation tests with incremental loading.

Time-deformation curves were generated for each pressure increase. From these plots, the timings corresponding to 90% consolidation, referred to as t_{90}, were estimated employing Taylor's Curve Fitting Method. The coefficients of consolidation (C_v) for vertical flow and the coefficient of permeability (k_v) in the vertical direction were determined for each incremental increase in stress. The samples have C_c values of 0.15 and 0.44, and the initial void ratio (e_0) ranges from 0.78 to 1.1. According to Ameratunga et al. 2016, most of the subsoil samples were high compressible. The coefficient of consolidation for vertical flow (c_v) and the coefficient of vertical permeability (k_v) of the twelves soil samples have been determined to range from 0.62 to 12.15 m^2/year and from 0.03×10^{-7} to 2.5×10^{-7} cm/sec, respectively, depending on the stress range.

3.4 Stability Analyses of The Embankment

The embankment failure occurred when the height of the fill was gradually increased to around 5 meters. The slope stability assessments of the collapsed embankment section were conducted using the geotechnical data from the investigations. The actual embankment in the field had been considered based on the survey data. The research considered the strength of the fill and clay sub-soil to be 10 kPa and 15 kPa, respectively. The factor of safety calculated using the bishop Method is 0.942 (Figure 5). Soil strength ratings, although idealized, reveal that the soft sub-soil lacked the ability to support the fill soil above it. The slope experienced failure due to sliding (Nasvi & Krishnya, 2019).

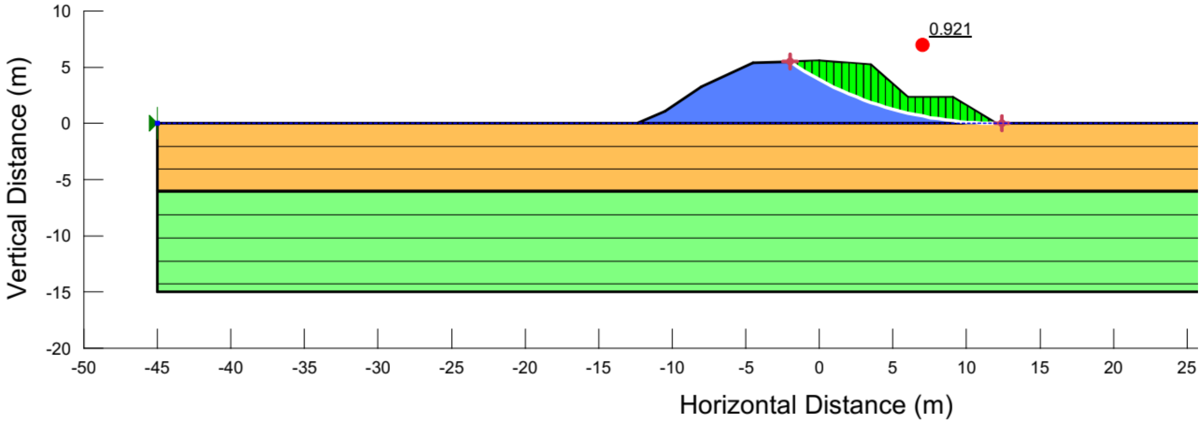

Figure 5: Lowest FOS and critical slip surface from Bishop method

The factor of safety by LOW approach has been determined to be 0.79 for a soft clay layer thickness of 5 m, and it decreases to 0.87 for a clay layer thickness of 5 m. It is evident that the clay layer's strength was insufficient to bear the weight of the soil above it, even with a slope ratio of 1:2 (vertical: horizontal). The embankment slope experienced a breakdown. Two additional analyses were conducted to examine the impact of fills and sub-soil shear strength on the stability of the exact same embankment section. In one analysis, the strength of the fill and clay sub-soil was deemed to be 15 kPa each, whereas in the other analysis, they were considered to be 20 kPa each. In the former scenario, the factor of safety achieved is 1.03, while in the latter situation it is determined to be 1.1. These findings indicate that as long as the clay layer possessed an undrained shear strength over 20 kPa, the embankment segment would not have experienced failure when the level of the filling was limited to 5m. Based on the stability analyses conducted, it is clear that the failure of the embankment might be related to the presence of a highly compressible sub-soil layer on which the fill was laid. The soft clay beneath is insufficient to sustain the complete embankment height without enhancing the ground conditions.

4. CONCLUSIONS

A study was conducted to investigate the factors contributing to the failure of the embankment along the Bhanga-Faridpur stretch of the West Zone of Bangladesh Railway. A series of stability evaluations were performed on the failed part of the embankment using soil investigations and survey data.

The investigation yields the following conclusions.

i. The subsoils from the distressed zone’s failed to meet the fill material specified criteria and high plastic in nature.
ii. The subsoils beneath the embankment were high compressible.
iii. Stability calculations by Bishop method and Low Approach indicate that it is not feasible to put or fill at the same time.

REFERENCES

Deshpande, T. D., Kumar, S., Begum, G., Basha, S. A. K., & Rao, B. H. (2021). Analysis of Railway Embankment Supported with Geosynthetic-Encased Stone Columns in Soft Clays: A Case Study. *International Journal of Geosynthetics and Ground Engineering*, *7*(2), 43. https://doi.org/10.1007/s40891-021-00288-5

Geotechnical Investigations, Soil Treatment and Reconstruction of Embankment by Earthwork including Turfing in Faridpur-Bhanga section of Bangladesh Railway (West). (2017).

J. Ameratunga, N. Sivakugan, and B. M. Das, “Correlations for Laboratory Test Parameters,” in *Correlations of Soil and Rock Properties in Geotechnical Engineering*, J. Ameratunga, N. Sivakugan, and B. M. Das, Eds., New Delhi: Springer India, 2016, pp. 51–86. doi: 10.1007/978-81-322-2629-1_3.

Kumar, A., Singh, S., Awashti, S. K., Ojha, S. K., & Shekhawat, R. K. (2020). *COMPREHENSIVE GUIDELINES AND SPECIFICATIONS FOR RAILWAY FORMATION*.

Low, B. (1989). Stability Analysis of Embankments on Soft Ground. *Journal of Geotechnical Engineering*, *115*(2), 211–227. https://doi.org/10.1061/(ASCE)0733-9410(1989)115:2(211)

Nasvi, M. C. M., & Krishnya, S. (2019). Stability Analysis of Colombo–Katunayake Expressway (CKE) Using Finite Element and Limit Equilibrium Methods. *Indian Geotechnical Journal*, *49*(6), 620–634. https://doi.org/10.1007/s40098-019-00357-7

Siddique, A., Safiullah, A. M. M., & Ansary, M. A. (2005). An investigation into embankment failure along a section of a major highway. *INTERNATIONAL SOCIETY FOR SOIL MECHANICS AND GEOTECHNICAL ENGINEERING*. https://doi.org/10.3233/978-1-61499-656-9-979

Stark, T. D., Ricciardi, P. J., & Sisk, R. D. (2018). Case Study: Vertical Drain and Stability Analyses for a Compacted Embankment on Soft Soils. *Journal of Geotechnical and Geoenvironmental Engineering*, *144*(2), 5017007. https://doi.org/10.1061/(ASCE)GT.1943-5606.0001786