STUDY ON THE IMPACTS OF RAIL VIBRATIONS IN SLOPE FAILURES

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The Up-Country Railway in Sri Lanka, essential for connecting the central highlands, is increasingly threatened by slope failures that endanger both infrastructure and passenger safety. These failures are suspected to be exacerbated by train-induced vibrations, particularly in areas where maintenance is inadequate. The combination of heavy rainfall and vibrations can destabilize slopes, leading to frequent collapses. This research aims to explore the relationship between train vibrations and slope stability along the Up-Country Railway, providing insights that could guide improved maintenance practices and reduce the risk of such failures.

To investigate the relationship between train-induced vibrations and slope stability, the study utilized numerical modeling with finite element software specialized for geotechnical applications. The models were designed to simulate the impacts of varying track maintenance levels, train speeds, and slope angles. Local material properties, such as lateritic soil for the subgrade and crushed stone for ballast, were integrated to ensure the models accurately reflected the actual conditions along the Up-Country Railway. The finite element modeling provided detailed simulations of the railway substructure, capturing interactions between the sleeper, ballast, and sub-ballast layers. The models considered both static and dynamic loads, representing the weight of the train and the vibrations induced by train movements, respectively, to evaluate their effects on slope stability. The accuracy of the simulations was ensured by accounting for boundary conditions, soil types, and track geometry specific to the railway, allowing for a comprehensive analysis of the factors influencing the Factor of Safety (FoS) under different conditions.

The analysis revealed that poor track maintenance, especially under dynamic conditions, significantly reduced the Factor of Safety (FoS). For train speeds exceeding 60 km/h with poor maintenance, the FoS dropped from 0.9054 in static conditions to 0.8438 in dynamic conditions, indicating a higher risk of slope failure. Steeper slopes were particularly vulnerable, with a 55° slope showing a FoS of 0.8438 under dynamic conditions, while a 30° slope remained stable at 1.464. Variations in soil properties, such as cohesion and friction angles, also had a significant impact. Increasing cohesion from 5 kPa to 20 kPa at a 30° slope raised the FoS from 0.7462 to 1.406, highlighting the importance of accurate geotechnical evaluations in ensuring slope stability.

The study concluded that train-induced vibrations, particularly when combined with inadequate track maintenance, are a key factor in slope failures along the Up-Country Railway. Improved maintenance practices are essential to maintaining a higher FoS and mitigating the risk of slope collapses. The findings highlight the importance of ongoing monitoring and targeted interventions to enhance the stability and safety of this critical railway network, ensuring its continued operation in a challenging environment.

Keywords: FEM modeling, Landslides, Pseudo–static analysis, Track maintenance

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https://doi.org/10.31705/CERS.2024.30

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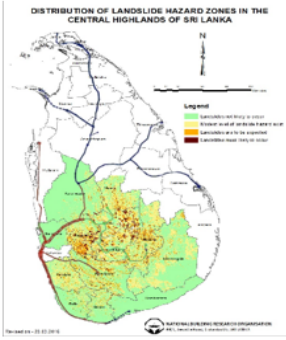
BACKGROUND

PROBLEM STATEMENT

Recurrent slope collapses threaten the Up-Country Railway.

Causes: train vibrations and poor maintenance.

Limited research hinders effective mitigation.



OBJECTIVES

Investigate train vibrations and slope failures.

Create models to analyze slope stability.

Assess maintenance and develop strategies to reduce collapses.

RESEARCH METHODOLOGY

Litreture Review → Familiarization of Finite Element Modelling → Create Finite Element (FE) models by adjusting key parameters. → Analysis and Interpretation of Results → Comparative analysis of the selected scenarios.

FINITE ELEMENT MODEL

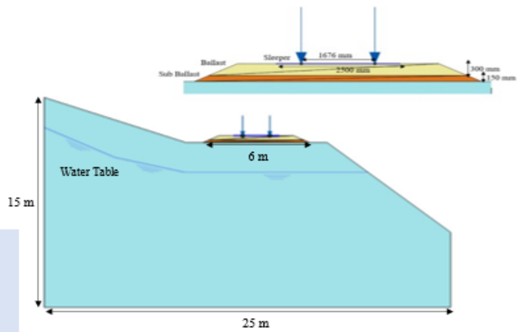
Finite Element Analysis

Plain Strain Idealization & Mohr-Coulomb Model

Static Load: 82.2 kN/m (Train axle load)

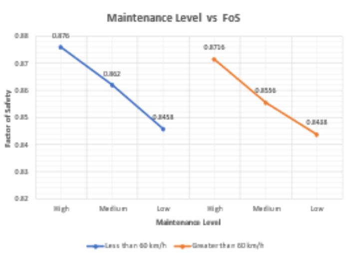
Dynamic Factor: Variable based on train speed and maintenance

- **Subgrade** - Lateritic soil
- **Ballast** - Crushed stone
- **Sub-ballast Material** -Sandy gravel
- **Sleeper Material** - Concrete (Elastic)

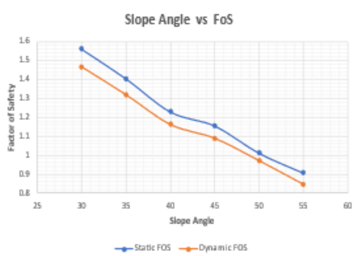


Geometrical Representation of Model Layout

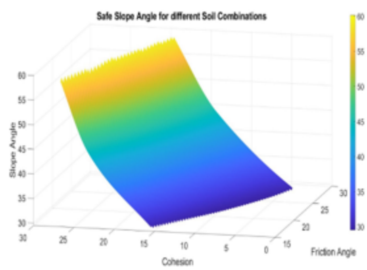
ANALYSIS



Fos vs Maintenance levels



FoS variation with various slope angles



Safe slope angles for different soil combinations