Sheet Pile Reinforcement for Slope Stabilization under Rainfall Conditions

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Abstract - *Landslides are one of the major geotechnical hazards affecting hilly regions, especially under heavy rainfall conditions. This study focuses on the experimental investigation of slope stabilization using sheet piles as a preventive measure. A laboratory-scale model was developed using lateritic soil obtained from the Nilgiris region, and tests were conducted under simulated rainfall conditions. The performance of slopes with and without sheet pile reinforcement was analyzed based on displacement and time to failure. The results indicate that the inclusion of sheet piles significantly reduces soil displacement and delays slope failure. The reinforced slope exhibited nearly 60–70% reduction in displacement compared to the unreinforced slope. The study highlights the importance of embedment depth and material stiffness in improving slope stability. The findings suggest that sheet piles can be effectively used as an economical and practical solution for landslide mitigation in vulnerable regions. A laboratory-scale experimental model was used to simulate rainfall-induced slope failure.*

***Key Words*: Sheet pile, slope stability, landslide mitigation, rainfall infiltration, soil displacement, embedment depth**

1. INTRODUCTION

Landslides are common in hilly terrains and are primarily triggered by factors such as heavy rainfall, soil erosion, and human activities. The stability of slopes depends on the balance between driving forces and resisting forces. When the shear stress exceeds the shear strength of soil, slope failure occurs.

Conventional stabilization techniques such as retaining walls and soil nailing are effective but often require high cost and space. In contrast, sheet piles provide a simple and efficient method for slope stabilization. Sheet piles act as vertical barriers that resist lateral soil movement and increase the factor of safety of slopes.

This study aims to experimentally evaluate the effectiveness of sheet piles in reducing soil displacement and improving slope stability under rainfall conditions.

2 .METHODOLOGIES

A laboratory-scale experimental model was developed to simulate slope conditions.

- Soil Type: Lateritic soil collected from Nilgiris region
- Slope Angle: 30°–45°
- Model Tank: Transparent acrylic flume
- Sheet Pile Material: Steel and PVC
- Embedment Depth: 8–12 cm

The soil was compacted in layers to ensure uniform density. Sheet piles were installed at the toe of the slope. A controlled water supply system was used to simulate rainfall conditions.

Displacement of soil was recorded at regular time intervals for both reinforced and unreinforced slopes.

The soil was compacted at optimum moisture content to achieve uniform density. Care was taken to ensure proper installation of sheet piles without disturbing the soil structure.

2.1 MATERIAL PROPERTIES

The soil used in this study is lateritic soil obtained from the Nilgiris region. The engineering properties of the soil are as follows:

- Specific Gravity = 2.65
- Cohesion (c) = 22 kN/m^2
- Angle of Internal Friction (φ) = 26°
- Liquid Limit = 42%
- Plastic Limit = 24%

The sheet piles used in the study were made of steel . Steel sheet piles exhibit higher stiffness and strength compared to PVC, resulting in better resistance to lateral soil movement.

Fig. 1: Lateritic soil used in the experiment

Fig. 2: Model sheet pile used for reinforcement

3 RESULTS AND DISCUSSION

3.1 Displacement without Sheet Pile

Table -1: Soil Displacement Without Sheet Pile

Time (min)	Displacement (cm)
2	5
4	9
6	14
8	20
10	28

The unreinforced slope showed rapid increase in displacement due to lack of lateral support.

3.2 Displacement with Sheet Pile

Table -2: Soil Displacement With Sheet Pile

Time (min)	Displacement (cm)
2	2
4	3.5
6	5
8	7
10	9

The reinforced slope showed controlled displacement, indicating improved stability.

3.3 Comparison of Results

The comparison shows that:

- Displacement is significantly reduced with sheet pile
- Rate of failure is slower
- Stability is improved

The reduction in displacement is approximately **65–70%**, confirming the effectiveness of sheet piles.

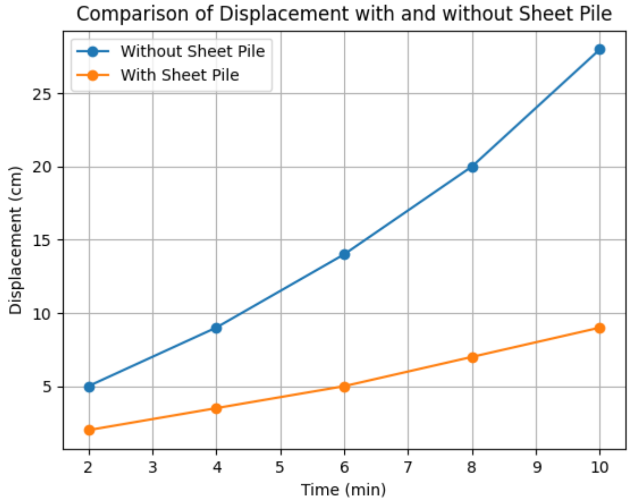

Chart -1: Comparison of Displacement with and without Sheet Pile

The percentage reduction in displacement due to sheet pile reinforcement ranges between 60% and 70%. This significant reduction demonstrates the efficiency of sheet piles in controlling soil movement and improving slope stability. This clearly indicates that sheet piles significantly improve the factor of safety of the slope.

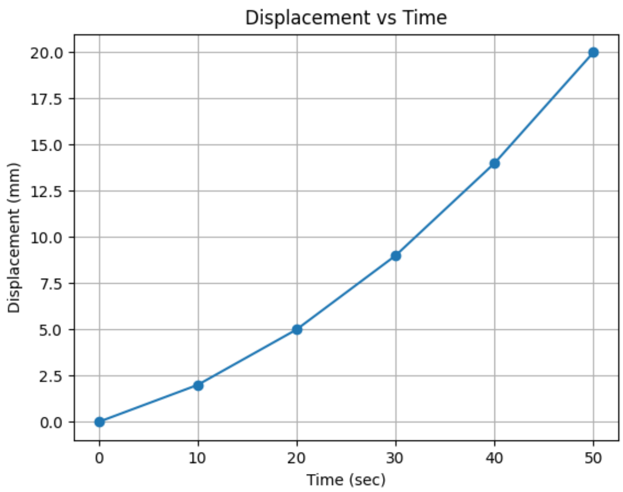

Chart -2: Displacement vs Time Graph

Fig. 2 shows the variation of displacement with time for both reinforced and unreinforced slopes.

3.4 Discussion

Sheet piles improve slope stability by providing passive resistance and intercepting potential failure surfaces. The effectiveness depends on embedment depth and material stiffness. Steel sheet piles perform better due to higher strength and rigidity.

Rainfall infiltration reduces soil strength by increasing pore water pressure. However, the presence of sheet piles limits soil movement and delays failure. The improvement in stability is attributed to the passive earth pressure developed below the embedment depth of the sheet pile. The increase in resisting force enhances the overall factor of safety of the slope.

Fig -3: Measuring displacement of soil with sheet pile

Fig -4: Measuring displacement of soil without sheet pile

The experimental setup used to measure soil displacement is shown in Fig. 3 & 4 Dial gauges were used to record displacement at regular intervals.

5. LIMITATIONS

The present study is based on a small-scale laboratory model, and the results may vary under actual field conditions due to soil heterogeneity and environmental factors. The rainfall simulation was controlled and may not fully represent natural rainfall patterns. Additionally, scale effects and boundary conditions of the model may influence the observed behavior. The study considers limited variations in embedment depth and material type, and further investigation is required for different soil conditions and field-scale applications. Long-term performance aspects such as durability and corrosion of sheet piles were not considered.

6. FUTURE SCOPE

Further studies can be carried out using full-scale field investigations to validate the experimental findings under real conditions. Numerical modeling techniques such as finite element analysis can be used to study soil–pile interaction in detail. Additionally, the performance of sheet piles under varying soil types, rainfall intensities, and long-term conditions can be explored for optimized design.

6. CONCLUSIONS

The experimental study confirms that sheet piles are effective in stabilizing slopes under rainfall conditions. The main conclusions are:

1. Sheet piles significantly reduce soil displacement.
2. Reinforced slopes show delayed failure compared to unreinforced slopes.
3. Embedment depth plays a crucial role in stability improvement.
4. Steel sheet piles perform better than PVC.
5. Sheet piles are an economical and practical solution for landslide mitigation.

The results of this study can be effectively applied in landslide-prone regions for practical slope stabilization.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to the Department of Civil Engineering of CSI College of Engineering , Ketti for providing the necessary facilities to carry out this research work. The authors also thank the project guide Mrs. Geetha Kumari for her valuable guidance and support throughout the study.

REFERENCES

[1] Das, B.M., Principles of Foundation Engineering, Cengage Learning.

[2] Terzaghi, K., Soil Mechanics in Engineering Practice, Wiley.

[3] Poulos, H.G., "Slope stabilization using piles," Canadian GeotechnicalJournal.

[4] Ito, T. and Matsui, T., "Lateral forces on stabilizing piles," SoilsandFoundations.

[5] Zhao, W. et al., "Sheet pile–soil interaction study," Applied Sciences.

[6] Kim, S.H. and Lee, D.Y., “Slope stabilization under rainfall,” Geotechnical Engineering.

[7] Coduto, D.P., Geotechnical Engineering: Principles and Practices, Pearson