Integrated Geophysical and Geotechnical Assessment of Subsurface Stability for Sustainable Infrastructure Development on Moheshkhali Island, Bangladesh

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Abstract: Rapid development in Moheshkhali Island demands a clear understanding of subsurface conditions to ensure resilient infrastructure. This study integrates Electrical Resistivity Tomography, seismic reflection interpretation, and geotechnical investigations (SPT and laboratory testing) to assess near-surface lithology, deep structural features, and soil engineering properties. The combined approach provides a comprehensive subsurface stability profile, identifying variations in soil strength and tectonic influences. Findings offer essential guidance for planners and engineers in designing safe, sustainable infrastructure for Moheshkhali Island's ongoing development.

Keywords: ***Geophysical, Geotechnical, Subsurface stability, Sustainable infrastructure, Moheshkhali Island.***

Introduction

Rapid urbanization and industrialization across South Asia underscore the pressing need for sustainable urban planning and the selection of safe and stable locations for major infrastructure projects. Moheshkhali Island, situated along the southeastern coast of Bangladesh, has emerged as a strategic hub due to its economic potential and environmentally sensitive setting. Recognizing this importance, the Government of Bangladesh has proposed an ambitious mid-term development plan for Moheshkhali Upazila, which includes 17 large-scale infrastructure projects such as power plants, gas pipelines, liquefied natural gas (LNG) terminals, and economic zones. These initiatives aim to stimulate national growth but require robust scientific assessment to ensure long-term resilience.

Geological and Environmental Complexity

Sustainable development on Moheshkhali Island is particularly challenging because of its intricate geological framework and active coastal processes. The island lies within a tectonically influenced region where subsurface conditions vary considerably over short distances. Dynamic coastal activities—such as erosion, tidal fluctuations, and sediment deposition—further complicate land stability. As a result, understanding the geological and geotechnical characteristics beneath the surface is critical for safe infrastructure development.

Need for Integrated Subsurface Investigation

Traditionally, subsurface assessments rely on either geophysical or geotechnical methods, each providing valuable but incomplete information. Geophysical techniques, for example, offer rapid and non-invasive insights into lithological variability, whereas geotechnical tests provide direct measurements of engineering properties such as bearing capacity and shear strength. However, relying on one approach alone often results in gaps in interpretation. Despite ongoing infrastructure expansion on Moheshkhali Island, no comprehensive study has yet integrated these methods to characterize subsurface stability. This gap limits the accuracy of engineering designs and increases the potential risks for future development.

Methodological Approach

This study addresses the knowledge gap by combining geophysical and geotechnical techniques to produce a holistic subsurface assessment. Electrical Resistivity Tomography (ERT) was conducted to examine lithological variations within the near-surface zone, extending to approximately 30 meters. ERT data helps identify contrasting materials such as sand, clay, gravel, and saline-affected zones, which influence foundation design.

In parallel, seismic reflection data were interpreted using the Petrel platform to map deep-seated faults, stratigraphic boundaries, and structural features. This analysis is crucial for evaluating the tectonic stability of the island, understanding fault activity, and recognizing deeper geological constraints that may influence surface engineering conditions.

Geotechnical investigations, including Standard Penetration Tests (SPT) and laboratory analyses of collected soil samples, provided quantitative measurements of soil density, shear strength, grain-size distribution, and bearing capacity. These data offer direct evidence of the engineering properties required for foundation design and hazard mitigation.

Integrated Interpretation and Implications

The integration of geophysical and geotechnical datasets produces a more detailed and reliable understanding of subsurface stability across Moheshkhali Island. The combined interpretation reveals spatial variations in lithology, identifies weak soil zones, and highlights areas influenced by faulting or dynamic coastal processes. These insights are essential for determining suitable locations for critical infrastructure and for designing foundations capable of withstanding geohazards.

Conclusion

The outcomes of this integrated study will support policymakers, engineers, and developers by providing a scientifically robust foundation for planning resilient infrastructure. Through improved subsurface characterization, the development initiatives on Moheshkhali Island can progress in a sustainable and risk-informed manner, contributing to the long-term economic and environmental security of Bangladesh.