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Geotechnical Challenges and Potential for Innovative Solutions in Saudi Arabia

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ABSTRACT

This presentation explores a few of the key geotechnical challenges in Saudi Arabia, focusing on rock strength, escarpment stability, ground improvement verification, groundwater variability, and seismic parameters. Due to unique geological conditions, the potential for innovative approaches is presented for safe, efficient infrastructure construction. Techniques such as advanced site investigations and automated monitoring systems are highlighted for their critical role in addressing these issues. Additionally, the use of site-specific seismic assessments and specialized laboratory testing are discussed. These methodologies enhance the precision and safety of geotechnical designs, contributing to the economic and sustainable development of the Kingdom's infrastructure, and setting a benchmark for similar geological settings regionally.

1. INTRODUCTION

Geotechnical engineering plays a crucial role in the development of infrastructure in any country. In Saudi Arabia, the country's unique geological conditions present a variety of challenges that must be overcome to ensure the safe and efficient construction of buildings, roads, ports and harbors and other critical infrastructure on native as well as on reclaimed lands. This presentation will explore few of the key geotechnical challenges AECOM faced in Saudi Arabia and shed light on the potential for innovative ideas that can lead to economic solutions. The key challenges included in the presentation, among many others, are rock strength and bearing capacity, stability issues related to rock escarpments, ground improvement verification strategies, variable and rapid rise in groundwater conditions and seismic design parameters.

2. ROCK STRENGTH AND BEARING CAPACITY

In Saudi Arabia, geotechnical engineers frequently encounter significant challenges pertaining to accurately determining rock strength associated with bearing capacity and foundation design on the prevalent rock formations such as limestone and other igneous rock formations, particularly in regions like Riyadh. The prevailing industry practice often underestimates the rock bearing capacities leading to uneconomical design. Generally, conservative approaches are adopted in rock characterization resulting into lower bearing capacities for shallow foundations following empirical, semi-empirical correlations or based on permissible settlement criterion. An innovative solution to this challenge is improvement in quality and the adoption of advanced site investigation techniques, such as in-situ testing methods including pressuremeter and dilatometer tests, combined with sophisticated surface or down-hole geophysical surveys like MASW or PS-Logging. These technologies allow for a more precise mapping of subsurface conditions and variability in rock properties, accurate rock characterization and leading to optimized foundation designs that are both safe and cost-effective.

3. STABILITY OF ROCK ESCARPMENTS

Jebels are natural assets in Saudi Arabia and is of significant geoheritage value. However, the stability of rock escarpments in the country represents a critical geotechnical challenge for the planned developments close to steep slopes, especially in the mountainous regions. Natural erosion, flash floods, seismic activity, and human interventions contribute to the destabilization of steep slopes. These rock escarpments are susceptible to rockfalls and slope failures, which can pose serious risks to human life and infrastructure. Innovative solutions to enhance efficiency and comprehensiveness of the study includes the integration of remote sensing technologies with traditional rock slope stabilization techniques. The use of Unmanned Aerial Vehicles (UAVs) equipped with high-resolution cameras and LiDAR (Light Detection and Ranging) technology can perform detailed aerial surveys of inaccessible escarpments, providing accurate 3D models of the rock faces and identifying critical weaknesses such as fractures, voids, and overhangs. Additionally, an ArcGIS-based field data collection workflow would render a centralized and georeferenced database for field observations. The combination of high-tech monitoring and versatile stabilization techniques offers a robust framework for assessing and managing the risks associated with rock escarpments in challenging environments.

4. GROUND IMPROVEMENT VERIFICATION STRATEGIES

In this region, verifying the effectiveness of ground improvement works for most of the projects, especially involving newly reclaimed lands and artificial island, traditionally rely on simplified methods and empirical correlations developed for siliceous sands. Generally, the ground improvement verification strategies involve simplified liquefaction assessment methods and empirical densification correlations with intrusive (SPT, CPT) or non-intrusive (Vs) input parameters. The sands in Saudi Arabia and the region around it are predominantly of calcareous nature. Carbonate sands are well known and documented to behave differently from silica sands with very low penetration resistance, however, they possess higher cyclic resistance and low liquefaction potential. An innovative solution to enhance verification strategies involves the integration of site-specific specialized laboratory testing, such as calibration chamber testing, laboratory triaxial and simple shear testing, etc. Developing empirical correlations from these laboratory results to actual field performance is a crucial step. This approach not only ensures the reliability of ground improvement techniques but also optimizes the efforts required to achieve target performance, leading to more effective and economically viable construction practices.

5. VARIABLE AND RAPID RISE IN GROUNDWATER CONDITIONS

The variability and rapid rise in groundwater levels due to urbanization and climate change present a significant geotechnical challenge, particularly in urban areas like Riyadh and Jeddah. Such fluctuations in groundwater conditions can lead to hydrostatic pressure fluctuations that destabilize foundations and underground structures, complicating both design and construction processes. The rapid rise in groundwater levels, mostly linked to increased groundwater recharge from urbanization and from intense rainfall due to climate change. An innovative solution to manage these risks involves the implementation of automated groundwater monitoring systems combined with real-time data analytics. Additionally, the adoption of adaptive systems, which can process real-time monitoring data, ensures effective water management and mitigation of groundwater-related risks.

6. SEISMIC DESIGN PARAMETERS

In Saudi Arabia, addressing seismic design parameters accurately poses a significant geotechnical challenge due to the region's wide-ranging seismic activity and geological diversity. Conventional seismic design methods often rely on generalized hazard maps, which may overlook local seismic nuances, potentially resulting in over-engineered structures. An innovative approach to tackle this challenge involves employing site-specific Probabilistic Seismic Hazard Assessment (PSHA) in conjunction with ground response analysis for major projects. This methodology customizes seismic design parameters to site-specific conditions by integrating geological, seismological, and geotechnical data to probabilistically evaluate various seismic scenarios. Ground response analysis further enhances these parameters by simulating how local soil conditions influence seismic wave behavior, amplification, and potential ground failure mechanisms. By leveraging advanced numerical modeling techniques and historical seismic data, this approach offers a more accurate foundation for designing earthquake-resistant structures. Tailored seismic design parameters bolster structural safety and resilience, mitigating the risk of seismic damage across the region's diverse built environment.

7. CONCLUSION

In Saudi Arabia, the unique geotechnical challenges stemming from the region's diverse geological and environmental conditions necessitate innovative engineering solutions to ensure the safety, efficiency, and cost-effectiveness of infrastructure projects. Advanced site investigation techniques and real-time monitoring systems are crucial for accurately assessing rock strength, managing variable groundwater levels, and ensuring the stability of rock escarpments. Specifically, technologies such as in situ tests, UAVs equipped with LiDAR, and automated groundwater monitoring not only enhance the precision of foundational engineering practices but also enable proactive management of geotechnical risks. Furthermore, adopting site-specific probabilistic seismic hazard assessments (PSHA) and tailored ground improvement verification strategies cater to the distinct characteristics of local seismic activity and soil properties, respectively. These integrated approaches not only mitigate potential risks but also optimize construction practices, contributing significantly to the region's infrastructure resilience and sustainability. Apart from site-specific studies, knowledge sharing across various projects through research and publishing existing data and studies can play a pivotal role in achieving common of safety, efficiency, cost-effectiveness and sustainability of infrastructure projects across the Kingdom.

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