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Resilience Modelling for Climate-Exposed Geotechnical Infrastructure

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Extended Abstract

Geotechnical infrastructure is increasingly exposed to climate-driven hazards, ageing, resource constraints and growing expectations for reliable service. Roads, buried pipelines, slopes, embankments and bridge approaches are ground-infrastructure systems whose performance is governed by environmental loading, soil and material behaviour, groundwater conditions, construction quality, deterioration, monitoring and maintenance. Climate change intensifies these challenges through more frequent extreme rainfall, flooding, drought, heatwaves and wetting-drying cycles, which can accelerate pavement deterioration, induce pipeline distress and trigger slope instability.

Core concept

This keynote introduces resilience modelling as an extension to conventional geotechnical design. Traditional design has generally focused on preventing failure under specified loads. While this remains essential, climate-exposed infrastructure also requires an understanding of how much performance remains during disturbance, how quickly functionality can be restored, and how systems can adapt over their service life. The framework therefore shifts attention from failure prevention alone to performance retention, recovery and sustainability. It is framed around residual performance, extent of recovery, and speed of recovery, and is illustrated through roads, pipelines, and landslides.

Road pavements

For road pavements, resilience modelling requires integration of material characterisation, moisture variation, traffic loading, construction quality, condition assessment and asset management. Thin-sealed unbound pavements are particularly sensitive to climate because their performance depends strongly on water ingress, suction, degree of saturation, stiffness and rutting resistance. A resilience perspective asks not only whether the pavement is initially adequate, but whether it can maintain trafficability, limit deterioration and recover after wet-weather or flooding events.

Buried pipelines

For buried pipelines, resilience modelling considers pipe deterioration, corrosion, leakage, soil-pipe interaction, ground movement and service continuity. Pipeline failure can cause direct loss of water supply, but it can also trigger geotechnical consequences such as erosion, ground softening or slope instability. A resilient system, therefore, requires condition assessment, leak detection, redundancy, emergency isolation, soil support assessment, and recovery planning.

Rainfall-induced landslides

For landslides, resilience modelling must connect climate forcing, antecedent moisture, infiltration, pore-water pressure, suction loss, slope deformation, drainage and early warning. Conventional slope stability assessment provides an important safety measure, but resilience requires a broader view: identifying vulnerable slopes, monitoring precursors, maintaining drainage, designing ductile mitigation systems and planning recovery of access and functionality after failure.

Central message

Climate-exposed geotechnical infrastructure must be designed and managed not only to resist failure, but to remain functional, recoverable and adaptable under uncertain future conditions. Resilience modelling provides a practical framework for linking geotechnical behaviour, climate hazards, monitoring data, recovery pathways and sustainable asset management into a unified engineering approach.