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Geotechnical Risk Mapping For Earthquake-Prone Areas Using Remote Sensing Data

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Abstract

Earthquake-prone regions require precise geotechnical risk mapping to mitigate potential hazards effectively. This paper explores the integration of remote sensing data with Geographic Information Systems (GIS) to develop geotechnical risk maps that can identify vulnerable zones prone to seismic hazards. Satellite imagery, digital elevation models (DEMs), and radar data provide essential information about soil types, fault lines, landforms, and surface deformation. By combining these datasets with historical earthquake records and geological surveys, a comprehensive risk model is developed. The study emphasizes the use of multispectral remote sensing for land use classification, Interferometric Synthetic Aperture Radar (InSAR) for detecting ground displacement, and GIS for overlay analysis. A tabulated summary outlines key parameters influencing seismic risk. Limitations of remote sensing data, such as spatial resolution and temporal gaps, are discussed. The results highlight how remote sensing enhances

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traditional geotechnical assessments and supports disaster preparedness and planning in earthquake-sensitive areas.

***Keywords**: Geotechnical Risk, Earthquake-Prone Areas, Remote Sensing, GIS, InSAR, Digital Elevation Model, Seismic Hazard Mapping*

INTRODUCTION

Earthquakes pose significant risks to human life and infrastructure, particularly in seismically active zones. Geotechnical risk mapping involves evaluating soil and terrain conditions to predict areas susceptible to ground shaking, liquefaction, landslides, and structural failures during seismic events. Traditional ground surveys, while accurate, are time-consuming and spatially limited.

Remote sensing provides a synoptic and repeatable means to gather geospatial data over large areas, crucial for earthquake hazard analysis. This paper presents a methodology for integrating remote sensing datasets with GIS to create detailed geotechnical risk maps that assist in earthquake disaster mitigation and land-use planning.

ROLE OF REMOTE SENSING IN GEOTECHNICAL RISK MAPPING

Remote sensing technologies offer several advantages:

- **Multispectral Satellite Imagery** captures land cover and soil types, key factors affecting seismic ground response.
- **Synthetic Aperture Radar (SAR)** and **InSAR** detect subtle ground deformations indicative of fault activity and ground instability.
- **Digital Elevation Models (DEMs)** provide terrain slope and aspect data, influencing seismic shaking and landslide susceptibility.
- **Thermal and Hyperspectral Sensors** can identify soil moisture and composition variations affecting soil behavior during earthquakes.

Combining these datasets with GIS allows spatial correlation and risk quantification.

DATA COLLECTION AND METHODOLOGY

The geotechnical risk mapping process involves:

1. **Acquisition of Remote Sensing Data**
    - Landsat 8 OLI for land use/land cover classification
    - Sentinel-1 SAR data for ground displacement analysis
    - SRTM DEM for terrain modeling
2. **Preprocessing and Classification**
    - Image correction and enhancement

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   - Land use classification into categories: urban, agricultural, forest, bare soil
   - Identification of soft soil zones prone to liquefaction
3. **Integration with Geological and Seismic Data**
   - Fault line mapping from geological surveys
   - Historical earthquake epicenters and magnitudes from seismic databases
4. **GIS Overlay Analysis and Risk Zonation**
   - Weighted overlay of soil type, slope, fault proximity, and displacement data
   - Classification into low, medium, and high geotechnical risk zones

TABLE 1: Parameters Influencing Geotechnical Risk And Their Impact

Parameter	Description	Impact on Earthquake Risk	Risk Level
Soil Type	Soft clay, sand, rock	Soft soils amplify shaking, liquefaction	High
Land Use	Urban, forest, agricultural	Urban areas face higher damage potential	Medium to High
Fault Proximity	Distance from active faults	Closer proximity increases seismic hazard	High
Ground Displacement	Measured by InSAR	Indicates active deformation zones	High
Slope	Steepness of terrain	Influences landslide and structural risk	Medium to High
Historical Earthquakes	Frequency and magnitude	Recurrence indicates high hazard	High

Table 1: Summary of geotechnical risk factors affecting earthquake vulnerability.

APPLICATION EXAMPLES

- **Himalayan Foothills, Northern India**
  Remote sensing revealed extensive areas of soft alluvial soils with high liquefaction potential. InSAR detected ground movement along active fault lines, correlating with recent seismic events. GIS maps identified urban fringes with critical risk, informing land-use restrictions.
- **California Central Valley, USA**
  Integration of Sentinel-1 data with seismic records highlighted zones prone to ground subsidence and liquefaction during earthquakes. The approach supported emergency response planning and infrastructure reinforcement priorities.

DISCUSSION

Remote sensing enhances traditional geotechnical investigations by offering:

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- Large-scale and repetitive data coverage
- Early detection of subtle ground changes
- Integration of diverse datasets for comprehensive risk assessment

Limitations include sensor resolution constraints and the need for ground truthing. Additionally, temporal gaps in satellite data may delay rapid hazard assessments. Future improvements lie in combining UAV data and machine learning classification to refine risk maps.

CONCLUSION

This study demonstrates that remote sensing combined with GIS provides a robust framework for geotechnical risk mapping in earthquake-prone regions. By integrating satellite imagery, SAR-derived displacement data, and geological information, it is possible to delineate high-risk zones effectively. These maps support disaster preparedness, risk mitigation, and informed urban planning, ultimately reducing earthquake-related losses. Continuous advancements in remote sensing technologies promise more accurate and timely geotechnical assessments for seismic hazards.

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