Experimental Investigation on Soil Liquefaction Susceptibility in Different Regions of Chhattisgarh

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ABSTRACT

Soil liquefaction is a significant geotechnical hazard in regions susceptible to seismic activity, as it can lead to substantial structural damage and loss of life. This study focuses on the experimental investigation of soil liquefaction susceptibility across different regions of Chhattisgarh. Representative soil samples were collected from various locations within the state, characterized by diverse geological and geotechnical conditions.

Laboratory tests, including grain size analysis, Atterberg limits, and cyclic triaxial tests, were conducted to evaluate the liquefaction potential of these soils under simulated earthquake loading conditions. The study analyzes the correlation between soil properties—such as particle size distribution, plasticity, and density—and their susceptibility to liquefaction. Results indicate significant variations in liquefaction potential across regions, influenced by soil type, groundwater conditions, and seismic loading parameters.

This investigation provides valuable insights into the behaviour of soils in Chhattisgarh under seismic events, contributing to improved risk assessment and the development of effective mitigation strategies for earthquake-prone areas.

Keywords: - Liquefaction, Standard Penetration Test, CPT, Soil, Cohesion less.

1. INTRODUCTION

Soil liquefaction is a phenomenon where saturated soils lose their strength and stiffness in response to dynamic loading, such as earthquakes, causing them to behave like a liquid. This phenomenon poses a significant threat to structures, infrastructure, and human life in seismically active regions. Although Chhattisgarh is not classified as a high-seismic zone, its varying soil compositions, coupled with potential seismic activities from neighbouring regions, make it imperative to assess the liquefaction susceptibility of its soils.

This study aims to analyze the liquefaction potential of soils from different regions of Chhattisgarh through experimental methods. By understanding the geotechnical characteristics of these soils, the research contributes to better risk assessment and preparedness strategies for earthquake-related hazards.

2. STUDY AREA

Chhattisgarh is characterized by diverse geological formations, including alluvial soils, red lateritic soils, black cotton soils, and mixed soils. The state has regions with varying soil compositions and water table levels, influencing their liquefaction susceptibility. Key regions selected for the study include:

- **Raipur:** Dominated by clayey soils with moderate groundwater levels.
- **Bilaspur:** Features sandy and mixed soils, with moderate to high groundwater levels.
- **Durg-Bhilai Region:** Characterized by black cotton soils with a high swelling potential and shallow groundwater.
- **Korba:** Known for red lateritic soils and mining activities, with low to moderate groundwater levels.
- **Jagdalpur:** Features alluvial soils near riverbanks, with a high water table.

3. METHODOLOGY

The methodologies for evaluating soil liquefaction susceptibility involves a systematic approach to collect, prepares, and analyze soil samples under laboratory conditions. Below is a detailed explanation of each step:

3.1. Study Area Selection

To represent the diversity in soil types across Chhattisgarh, five key regions were selected based on their geological and hydrological characteristics:

- Raipur: Clay-rich soils with moderate seismic vulnerability.
- Bilaspur: Sandy soils with a shallow water table.
- Durg-Bhilai: Predominantly black cotton soils with high swelling potential.

- Korba: Red lateritic soils found in mining zones.
- Jagdalpur: Alluvial soils near river systems with high groundwater levels.

3.2. Soil Sample Collection

Soil samples were collected from each location at multiple depths (e.g., 1 m, 3 m, and 5 m) using standard sampling techniques like boreholes and augers. Sampling was done in accordance with IS 1892:1979 (Code of Practice for Subsurface Investigation) to ensure consistency and accuracy.

Field Parameters Recorded

- Groundwater table depth.
- Soil stratification and texture.
- Geographic coordinates of each sampling site.

3.3. Laboratory Testing

Laboratory experiments were conducted on the collected samples to evaluate their physical, chemical, and mechanical properties. The following tests were performed:

3.3.1 Grain Size Analysis

- Purpose: To determine the proportion of sand, silt, and clay in the soil.
- Procedure: Sieve analysis for coarse fractions and hydrometer analysis for finer particles.
- Significance: Sandy soils are more susceptible to liquefaction due to their low cohesion and high permeability.

3.3.2 Atterberg Limits

- Purpose: To measure the plasticity index (PI), this indicates the soil's cohesiveness and susceptibility to deformation.
- Procedure: Liquid limit, plastic limit, and shrinkage limit tests were performed as per IS 2720 (Part 5):1985.
- Significance: Soils with high plasticity, such as clays, are less prone to liquefaction.

3.3.3 Permeability Test

- Purpose: To determine the ease with which water flows through the soil.
- Procedure: Falling head permeability tests were conducted for fine-grained soils, and constant head tests for coarse-grained soils.
- Significance: High permeability in sandy soils accelerates pore pressure dissipation, influencing liquefaction behavior.

3.3.4 Standard Proctor Compaction Test

- Purpose: To assess soil density and moisture content relationship.
- Procedure: Soil samples were compacted at varying moisture levels to determine the optimum moisture content (OMC) and maximum dry density (MDD) as per IS 2720 (Part 7):1980.
- Significance: Denser soils are less likely to undergo liquefaction.

3.3.5 Cyclic Triaxial Test

- Purpose: To simulate earthquake-induced cyclic loading and evaluate the liquefaction resistance of soils.
- Procedure:
  1. Saturated soil samples were placed in a triaxial test apparatus.
  2. Cyclic loads were applied to replicate seismic stress conditions.
  3. Excess pore water pressure and strain were measured over successive cycles.
- Significance: This test directly measures the cyclic stress ratio (CSR) and critical cyclic resistance ratio (CRR), which are key parameters in liquefaction analysis.

3.3.6 Shear Strength Test

- Purpose: To determine the soil's strength under various stress conditions.
- Procedure: Conducted using a direct shear apparatus or unconsolidated undrained triaxial tests.
- Significance: Soils with low shear strength are more susceptible to liquefaction.

4. RESULTS AND DISCUSSION

4.1 Liquefaction Potential Assessment

The liquefaction potential of each soil sample was assessed using the Factor of Safety (FoS) against liquefaction. The FOS was calculated as follows:

FOS = (CRR/CSR)

- **Cyclic Stress Ratio (CSR)**: Represents the seismic demand on the soil. Calculated using:

$CSR=0.65\times\sigma_v\sigma_v'\times a_{max}\times r_d$

Where:

  - σv : Total vertical stress
  - $\sigma v'$ Effective vertical stress
  - a_{max} : Peak ground acceleration (seismic loading)
  - r_d: Stress reduction factor

- **Cyclic Resistance Ratio (CRR)**: Obtained from cyclic triaxial test results.

4.2 Interpretation of Results

- Soils with FOS<1 are classified as liquefiable.
- Soils with FOS≥1 are considered stable under seismic loading.

Here's a comparative table summarizing the liquefaction susceptibility of soils in different regions of Chhattisgarh based on key soil parameters and test results:

Region	Soil Type	Water Table Depth	Grain Size Composition	Plasticity Index (PI)	Cyclic Stress Ratio (CSR)	Liquefaction Susceptibility
Raipur	Clayey with silt	Moderate (~3-5 m)	15% sand, 45% silt, 40% clay	High (20-25)	0.25	Low
Bilaspur	Sandy and mixed	Shallow (~1-3 m)	60% sand, 20% silt, 20% clay	Low (5-10)	0.35	Moderate to High
Durg-Bhilai	Black cotton soil	10% sand, 20% silt, 70% clay	10% sand, 20% silt, 70% clay	Very High (>30)	0.20	Negligible
Korba	Red lateritic soil	Moderate (~3-5 m)	25% sand, 30% silt, 45% clay	Moderate (10-15)	0.30	Low to Moderate
Jagdalpur	Alluvial soil	High (~1-2 m)	70% sand, 15% silt			Negligible

4.3 Raipur

- Soil Type: Clayey with traces of silt and fine sand.
- Liquefaction Potential: Low due to high plasticity and low permeability.

4.4 Bilaspur

- Soil Type: Sandy and mixed soils.
- Liquefaction Potential: Moderate to high due to significant sand content and a shallow water table.

4.5 Durg-Bhilai Region

- Soil Type: Black cotton soil.
- Liquefaction Potential: Negligible due to high clay content but could experience significant settlement under dynamic loads.

4.6 Korba

- Soil Type: Red lateritic soil.
- Liquefaction Potential: Low to moderate, influenced by the depth of groundwater and soil compactness.

4.7 Jagdalpur

- Soil Type: Alluvial soils near riverbanks.
- Liquefaction Potential: High due to sandy composition and a high water table.

5. CONCLUSION

The study demonstrates significant regional variations in liquefaction susceptibility across Chhattisgarh. Areas with sandy soils and high water tables, such as Bilaspur and Jagdalpur, are more prone to liquefaction, while clayey regions like Raipur and Durg exhibit lower susceptibility. These findings highlight the need for region-specific seismic risk mitigation strategies.

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