JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

ASSESSMENT OF LIQUEFACTION POTENTIAL IN SOUTH INDIA USING AI AND ML

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Abstract : The work describes a Python-based technique for evaluating liquefaction potential. Infrastructure may suffer significant harm as a result of liquefaction, a phenomena that happens in saturated soils during earthquakes. For the purpose of creating robust buildings and reducing hazards, an accurate estimate of the potential for liquefaction is essential.The suggested approach uses a Python framework to integrate machine learning concepts, empirical correlations, and geotechnical principles. Obtaining input data, such as soil qualities, seismic parameters, and geotechnical site features, is the first step in the evaluation process. To guarantee compatibility and consistency, these data are preprocessed and standardised.Based on predetermined standards like the standard penetration test (SPT) blow count, shear wave velocity, and effective stress analysis, the liquefaction potential is assessed. Python is used to create empirical correlations and prediction models to calculate liquefaction susceptibility, liquefaction triggering potential**.**

***IndexTerms* - Liquefaction, SPT, Python Program.**

I. INTRODUCTION

The language of Buildings and the subsoil are both subjected to significant vibrations as a result of the ground shaking brought on by an earthquake. Differential settling of building foundations, pavement sinking, railway tracks, etc. are all effects of subsurface shaking. Loss of the soil's in-situ shear strength is often the cause of failure of the soil during an earthquake. When compared to shear loads brought on by an earthquake, this phenomena is known as liquefaction, when the soil's shear resistance is dramatically lowered. Due to this decrease in shear strength, the soil acts practically viscous. Furthermore, such subsoil is incapable of withstanding any overwhelming load, leading to enormous settlements, failures of building foundations and bridge abutments, and the emergence of slope liquefaction as a result.

These problems first appeared after the 1964 Good Friday earthquake in Alaska with a moment Richter magnitude of 9.2, followed by the Nigata earthquake in the nation of Japan with a moment magnitude of 7.5. This pair of earthquakes led to slope collapse, bridge pier sinking, home tilting, foundation failure, pavement failure, and the uncovering of buried infrastructure. There are several instances of liquefaction causing extensive devastation that occurred after 1964. These might include the Mw-6.6 San Fernando earthquake of 1971, the Mw-7.4 Argentina earthquake of 1977, the Mw-6.9 Loma Prieta earthquake of 1989, the Mw-6.8 Great Hanshin earthquake of 1995, the Mw-7.6 Chi-Chi earthquake of 1999, and the Mw-7.6 Bhuj earthquake of 2001, 2011 Sendia earthquake (Mw-8.9), 2011 Sikkim earthquake (Mw-6.8), and the 2004 Niigata-ken Chuetsu earthquake (Mw-6.8) are just a few examples. Large-scale liquefaction-related losses were seen in India as a result of the Bhuj earthquake (Mw- 7.6) on January 26, 2001. In the past, liquefaction-related ground collapse in India was not well recorded. A few case studies on paleo liquefaction, however, have revealed signs of liquefaction in India in the past. Sand blows and sand dykes at the Beltaghat site were seen during the 1897 Shillong earthquake, respectively (Rajendran & Rajendran, 2001). Paleo-liquefaction research conducted in Assam (Sukhija et al., 2011) further supports liquefaction failures during the Assam earthquake. The case studies mentioned above are typical instances where liquefaction damage was documented far from the epicentre during earthquake. These illustrations unmistakably demonstrate how the presence of the softer medium at shallow depths made the situation more disastrous even in remote areas. The evaluation of Lucknow's potential for liquefaction is crucial for the seismic microzonation discussed in this chapter because of the city's potential seismic susceptibility. At certain places, boreholes are dug, and Standard Penetration Test N (N-SPT) values are measured. On the basis of this, the in-situ soil cyclic resistance ratio was calculated. A thorough investigation of the seismic hazard and site reaction was done, and the surface PGA was mapped for maximum amplification.The cyclic stress ratio has been estimated using the maximum amplified surfaces PGA. These numbers have been used to try to determine the safety factor for the region.

II. THE STUDY AREA

Bengaluru-The Greater Bangalore metropolitan region has a total area of around 696.17 square kilometres. The study is only focused on the Bangalore Metropolis (Bangalore Mahanagar Palike) region. Andhrapradesh -A state in India's southern coastline area. With a total area of 162,970 km2 (62,920 sq m), it ranks seventh in terms of size. With 49,577,103 people, it ranks tenth in terms of population. Kerala-Kerala, a state on India's southwest coast. It is a tiny state, making up only a little more than 1% of the entire nation. Kerala runs along the Malabar Coast for around 360 miles (580 km), with widths ranging from about 20 to 75 miles (30 to 120 km).

2.1 Geomorphologic and geologic setting

Bengaluru-Bengaluru is located in the southeast of Karnataka, a South Indian state. It is located at an average elevation of 920 m (3,020 ft) in the centre of the Mysore Plateau, which is a part of the greater Precambrian Deccan Plateau. It has a geographic coordinate of 12.97°N 77.56°E and a total size of 1741 km2 (673 mi2). The Bangalore Urban district in the Indian state of Karnataka contains the majority of Bangalore, while the Bangalore Rural district includes the surrounding rural areas. The Bangalore (region) includes both the urban and rural districts of Bangalore. There are a few freshwater lakes and water tanks in Bangalore, however the Madivala tank, Hebbal Lake, Ulsoor Lake, and Sankey Tank are the biggest. In the silty to sandy layers of the alluvial deposits, there is groundwater. The Peninsular Gneissic Complex (PGC), which consists of granites, gneisses, and migmatites, is the area's most important geological unit. Bangalore's soils are made up of red laterite and red, fine loamy to clayey soils.[3]

The North Bangalore Taluk and the South Bangalore Taluk are two distinctive topographic terrains in Bangalore. An average of 839 to 962 metres above sea level, the North Bangalore taluk is a reasonably level plateau. A noticeable ridge that runs NNE-SSW runs across the centre of the taluk. On this ridge stands Doddabettahalli, the city's highest peak (962m). Both sides of this ridge have low valleys and moderate slopes. A succession of shallow water tanks, ranging in size from a tiny pond to those of substantial extent, mark the low-lying terrain.

Andhrapradesh-The State is one of the oldest land masses on earth and is a part of peninsular India. The oldest to most recent geological formations may be found in Andhra Pradesh. Formations that are igneous, sedimentary, and metamorphic make up the State. The Archaean group is covered by a complicated collection of Gneisses and Schists in the Peninsular Gneissic complicated. The Kurnool Group and Kadapa Super Group are Precambrian sedimentary formations that may be found in the Kurnool, Kadapa, Ananthapur, Chittoor, Guntur, Prakasam, and Krishna districts. The East and West Godavari districts are where you may find Deccan traps. Outcrops In the East and West Godavari and Visakhapatnam districts, Tertiary formations may be seen, while in river valleys, deltas, and along the East Coast, Quaternary sediments can be found as thick alluvial blankets.

Kerala is located between the Lakshadweep Sea to the west and the Western Ghats to the east, covering 38,863 km2 (1.18% of India's total area). Kerala's coastline is around 580 km long, while the state's overall breadth ranges from 35 to 120 km. Pre-Cambrian and Pleistocene strata make up the majority of Kerala's landscape geologically. The Western Ghats' tall hills and mountains rise gradually from a humid, scorching coastal plain in the region's geography. Kerala is located between the latitudes of 8°.17'.30" and 12°.47'.40" in the north and 74°.27'.47" and 77°.37'.12" in the east.[2] Kerala's climate is mostly tropical wet and maritime,[3] with a strong effect from the monsoon's heavy rains that occur every few months. In the distant past, the plains of the middle belt and the western coastal lowlands, which make up the Malabar Coast, may have been submerged. The notion has been supported by the discovery of marine fossils in a region close to Changanassery.[9] Neolithic dolmens from the Marayur region of the Idukki district, which is located on the eastern highland created by the Western Ghats, are among the prehistoric archaeological finds. Wayanad's Edakkal Caves have rock carvings from the Neolithic period, circa 6000 BCE.

2.2 Seismotectonic setting and seismicity

Bengaluru-It is the capital of the Indian state of Karnataka and is situated in an area with little seismic activity. Low to moderate seismic activity has always been present in the city. The Bureau of Indian Standards (BIS) seismic zoning map places the Bengaluru region in Zone II, which is categorised as a low-seismicity zone.In Bengaluru, earthquakes often don't happen very often and are small in size. key seismic occurrences are less likely to occur because to the city's location away from key tectonic plate borders. Intraplate tectonics, which includes stress release inside the Indian Plate, is the main cause of earthquake activity in Bengaluru.Despite the city's relatively low seismicity, it's crucial to remember that even little earthquakes might affect its infrastructure and safety. Being a heavily populated urban region, Bengaluru should continue to be aware of and ready for future seismic occurrences. Local organisations and authorities continue to keep an eye on seismic activity and take the required safety measures to protect the local population.In conclusion, because Bengaluru is situated in an area with low seismic activity, it rarely or rarely encounters earthquakes. Major earthquakes are unlikely, but it is still important to be on guard and ready for any potential seismic occurrences.

Andhra Pradesh —The Bureau of Indian Standards (BIS) revised the seismic hazard map of India in 2000 (6). The state of Andhra Pradesh is located in Zones II and III of the new map. Zone III now includes the south-eastern districts of Chitoor, Cudappah, and Nellore. Zone II now include portions of the Anantapur district that were previously located in Zones II and III of the 1984 BIS map. Zone III includes the Godavari-Krishna delta area and the districts located in the Godavari and Krishna river basins. Hyderabad is a city in Zone II. Since the earthquake database in India is currently lacking, particularly for earthquakes that occurred during the historical period (before 1800 A.D.), these zones provide an approximate indication of the earthquake danger in any given location and should be updated often.

Kerala—There has been a noteworthy upsurge in the earthquake activity in Kerala recently. They are mostly linked to structural elements with a NW-SE tendency, which are thought to be beneficial for movement under the current stress conditions. The NW-SE trending Periyar lineament/fault demonstrates spatial relationship with the earthquakes in central Kerala. The earthquake in Idukki-Pala-Kottayam indicates that doublets frequently occur. A NW-SE and NE-SW trending nodal plane with a mostly strike slip component may be seen in composite fault plane solutions of the 2000–2001 events [33]. A NW-SE and NE-SW trending strike slip fault are indicated by the Idukki event, which took place not far from the southern terminus of the Periyar fault/lineament [35]. Another location with recent seismic activity is the Wadakkancheri-Trissur region, which is located on the northern end of Periyar lineament. In a compressive tectonic environment, the spatial relationship between these two source zones is of importance since the Periyar fault's direction (NW-SE) is thought to be one that is conducive to reactivation. Therefore, it is imperative that many disciplines and approaches be properly integrated in order to estimate the earthquake hazard of these areas. A suitable seismic network should be constructed to identify the nucleation and/or distant triggering and/or migratory character, if any, as a fundamental prerequisite for hazard assessment. The movement across the fault system may be monitored using a cutting-edge GPS Geodetic network, allowing one to calculate the strain buildup.[1]

III. LIQUEFACTION POSSIBILITY

Soils which satisfy the given below criteria are also susceptible to liquefaction:

- Clay fraction less than 20%;
- Liquid Limit (LL): 21-35%;
- Plasticity Index (PI): 4-14%;
- Moisture Content: 90% of LL;
- Liquidity Index: ⩽ 0.75. [2]

IV. ASSESSMENT OF LIQUEFACTION POTENTIAL INDEX

The liquefaction potential index (LPI), developed by Luna and Frost in 1998, measures the severity of liquefaction and forecasts its surface manifestations, damage from liquefaction, and potential for collapse. LPI is calculated at a given place by integrating one minus the safety liquefaction factors over the whole depth of the soil column, with depths restricted to those between 0 and 20 m below the surface. Table 1 lists the degree of liquefaction severity in relation to LPI according to Iwasaki et al. (1982), Luna and Frost (1998), and MERM (2003). By comparing the seismic demand expressed in terms of cyclic stress ratio (CSR) to the capacity of liquefaction resistance of the soil expressed in terms of cyclic resistance ratio (CRR), the factors of safety against liquefaction (FS) and the corresponding liquefaction potential index (LPI) are calculated.

Table 1: The level of liquefaction severity.

LPI	**Iwasaki et al. (1982)**	**Luna and Frost (1998)**	**MERM (2003)**
LPI=0	Very low	Little to none	None
0<LPI<5	Low	Minor	Low
5<LPI<15	High	Moderate	Medium
15<LPI	Very high	Major	High

4.1 Determination of cyclic stress ratio

Cyclic stress Ratio (CSR) is a measurement of the stresses due to external loading of the earthquake. Following equation has been used to estimate the CSR values(Idriss and Boulanger 2006):

$$CSR = 0.65(\frac{a_{max}}{g}(\frac{\sigma_{vo}}{\sigma'_{vo}}) \times r_d)$$

Where,amax is the peak ground acceleration (PGA) at the surface obtained from site response study in terms of acceleration due to gravity, g is acceleration due to gravity, σ^1 is effective vertical stress, σvo is the total vertical stress, rd is the stress reduction co efficient. The value of rd has been determined using the empirical formula by Liao an Whitman (1986) as given below:

1. rd=1.0-0.00765z for z ≤ 9.15
2. rd= 1.174-0.026z for 9.15 ≥ z ≤23

where, z in equation is the depth of interest below ground level in meter. Once the value of rd is known , using the effective stress.

4.2 Determination of cyclic resistance ratio

$$CRR = e^{[\frac{(N_1)60cs}{14.1}\left[\frac{(N_1)60cs}{126}\right]^2+\left[\frac{(N_1)60cs}{23.6}\right]^3+\left[\frac{(N_1)60cs}{25.4}\right]^4-2.8]}$$

Cyclic Resistance Ratio (CRR) can be estimated as per Seed et al. (1985), Youd et al. (2001), Cetin et al. (2004). CRR is the Cyclic Resistance Ratio, (N1) 60CS is the corrected N-SPT. CRR is the Cyclic Resistance Ratio, (N1) 60CS is the corrected N-SPT. The above equation yields the value of CRR for an earthquake magnitude of 7.5(Idriss and Boulanger 2006)[2]

4.3 Factor of safety

These CRR values with depth have been used to estimate the Factor of Safety against liquefaction by considering the following equation (Idriss and Boulanger 2006)

$$FOS = \frac{CRR}{CSR}$$

The values of CSR and CRR with depth for each borehole have been used to estimate the FOS at different depths. Based on the depth of each layer, the stress reduction coefficient 'rd ' value has been calculated. The values of CSR have been calculated using amax value obtained from surface PGA map based on maximum amplification. The Once, the value of CSR, CRR and MSF are known, the FOS at various depths can be determined.

V. PYTHON CODE WORKING

5.1 Inputs of python program

The SPT number, soil depth, water depth below the level, The programme will receive inputs from users on a district, state, and the size of the planet. For CRR (cycle resistance ratio), CSR (cyclic seismeic ratio), and zone type (zone1, zone2, zone3, zone4), mathematical formulas have been introduced to the programme.Depending on the district and status of the area, the programme might determine the type of zone.Programme uses the district and state names in the area to inadvertently retrieve the

PGA(amax/g) value. The programme includes all districts and states in south India that fall under the different zones programme. It can quickly determine the maximum magnitude of the earth in that area by using the district and state names, making analysis is much easier for researchers.

5.2 Visualisation of result of program

By utilising Matplotlib, which aids in the geographical depiction of the liquefaction safety factor, the data may be seen more clearly.The percentage of safety against liquefaction is shown in green on the result pie chart. It is possible to determine the soil factor safety by combining the percentage of safety codes. Using the "date" module, the code may retrieve the timely data and time on the result graph. The programme may also create a bar graph with the matching factor of safety against liquefaction for magnitudes (1–10).The python code may automatically transmit the findings to the respective WhatsApp groups when the results have been generated in the form of graphs. The software can advise the user on precautions to take to enhance safety against liquefaction.

VI. RESULTS AND DISCUSSION

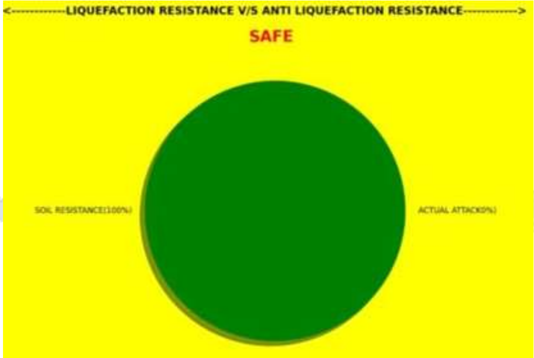

Fig. 1: Program output for soil which is safe forliquefaction

Fig. 2:Program output for soil which is unsafe forliquefaction

As a result of our Python analysis of liquefaction, it is now possible to analyse and comprehend the liquefaction potential of soils with useful tools and insights. We collected and interpreted seismic data, computed significant liquefaction-related metrics, and produced relevant visualisations for improved comprehension by utilising the strength of Python's data analysis and visualisation modules.Through this evaluation, we have shown how Python is capable of handling enormous datasets, carrying out intricate computations, and automating tedious activities. We were able to effectively edit and analyse soil and seismic data thanks to Python's versatility and its numerous scientific modules, including NumPy and pandas.Additionally, we were able to produce instructive plots and charts that assisted in the analysis of the data thanks to Python's visualisation capabilities, particularly when combined with the Matplotlib and Seaborn packages.

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