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REVIEW ON 'ANALYSIS OF THE LIQUEFACTION POTENTIAL USING IN-SITU AND LABORATORY TESTS'

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ABSTRACT

This project aims to analyze the liquefaction susceptibility of some selected sites. The selected sites of specific data related to Standard Penetration Tests data are collected for determination of liquefaction susceptibility of these sites by using SPT test from these procedures, shear stresses due to earthquake or settlements of structures are evaluated using SPT test for liquefaction analysis of soils. Liquefaction which can be defined as a loss of strength and stiffness in soils is one of the major causes of damage to buildings and infrastructure during an earthquake. This report provides basic knowledge about the liquefaction of cohesionless soils under seismic loading. Presented also are the most widely accepted methods for evaluating the liquefaction potential of cohesionless soils in level ground, for estimating earthquake-induced settlements. Liquefied soil loses its density and strength and damages the structures. Analysis of soil liquefaction is essential for assessing and mitigating the risks associated with this geotechnical phenomenon, ensuring infrastructure safety, and contributing to earthquake-resistant construction practices.

Keywords: Liquefaction, SPT Test, Earthquake, CRR, CSR, FOS.

I. INTRODUCTION

Soil liquefaction is a major geotechnical hazard that occurs when soil loses its strength and stiffness due to earthquake-induced cyclic loading and behaves like a fluid. Liquefaction can cause severe damage to structures and infrastructures, such as settlement, tilting, cracking, and collapse. Therefore, it is essential to analyze the liquefaction potential of soil before designing and constructing any project in seismic-prone areas. Liquefaction of soil is a phenomenon in which saturated or partially saturated soil temporarily loses its strength and behaves like a liquid during seismic activity or other rapid loading conditions. This occurs when the water pressure within the soil pores increases to the point where it exceeds the soil's ability to support the weight or load on it, causing the soil particles to lose contact and allowing them to move freely, resembling a liquid-like state. Liquefaction can lead to ground instability, settlement, and potential damage to structures built on or in the affected. Analysis of soil liquefaction is essential for assessing and mitigating the risks associated with this geotechnical phenomenon, ensuring infrastructure safety, and contributing to earthquake-resistant construction practices. Various methods have been developed to evaluate the liquefaction potential of soil, such as laboratory tests, field tests, and numerical analysis. Some of the commonly used methods are the standard blasting test, ground response analysis, cone penetration test (CPT), and standard penetration test (SPT). These methods are based on different principles and assumptions and have their advantages and limitations.

One of the most widely used methods for evaluating the liquefaction potential of soil is based on the data obtained from the standard penetration test (SPT). The SPT is a field test that measures the resistance of soil to penetration by driving a split spoon sampler into the ground using a standard hammer and drop height. The number of blows required to drive the sampler for a certain distance is recorded as the SPT blow count (N). The SPT blow count reflects the relative density and shear strength of the soil and can be used to estimate its liquefaction resistance. However, the SPT data are affected by various factors such as overburden pressure, hammer efficiency, borehole diameter, rod length, and soil type. Therefore, the SPT data need to be corrected and normalized before using them for liquefaction analysis. Moreover, different procedures and criteria have been proposed to calculate the cyclic stress ratio (CSR) and the cyclic resistance ratio (CRR) of the soil based on the SPT data and to compare them with a factor of safety (FOS) against liquefaction. The soil is considered to be liquefiable if the FOS is less than 1.

II. LITERATURE REVIEW

According to our paper tile, we have reviewed nearly about nineteenth international research paper here enlisting the review :

1) **Sabih Ahmad, M.Z.Khan, Abdullah Anwar, and Syed Mohd, "Determination of Liquefaction Potential By Sub-Surface Exploration Using Standard Penetration Test", IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 10, October 2015.**

In this paper, the author discusses the estimation of liquefaction potential in soils, which is a critical concern in geotechnical engineering, especially in earthquake-prone areas. They highlight the significance of the Standard Penetration Test (SPT), which is a widely used method for subsurface geotechnical investigation, and its role in assessing liquefaction potential. The author acknowledges that the SPT procedure has evolved over a century and is commonly utilized in determining liquefaction potential. Liquefaction occurs when there is a loss of shear strength in saturated, cohesion-less soils due to increased pore water pressures and reduced effective stresses under dynamic loading, typically during earthquakes. In this study, the author aims to predict the liquefaction potential of soil at a site in Lucknow by conducting Standard Penetration Tests (SPTs) and analyzing four sets of boreholes (BH-1, BH-2, BH-3, and BH-4). Both field and laboratory tests were conducted to assess the liquefaction potential accurately. The author employs data from the borehole sets to determine liquefaction parameters such as the Cyclic Resistance Ratio (CRR) and Cyclic Stress Ratio (CSR) using the method proposed by Idriss and Boulanger. These parameters are essential indicators used to identify areas prone to liquefaction during seismic loading. By determining CRR and CSR values, the author aims to identify areas susceptible to liquefaction, providing valuable insights for earthquake risk assessment and geotechnical engineering in the region. However, the author acknowledges that there are cases where liquefaction has been observed even when FS is greater than 1, as mentioned in previous studies. This indicates uncertainties in the prediction process, attributed to various factors such as differing soil conditions, the reliability of case history data, and the chosen calculation methods. Consequently, the author suggests that further investigations are necessary to improve the accuracy of liquefaction assessments. These additional studies would help refine the understanding of liquefaction triggers and enhance the reliability of predictions in geotechnical engineering practice.

2) **Md. Shakhawat Hossain, A. S. M. Maksud Kamal, Md. Zillur Rahman and Atikul Haque Farazi, "Assessment of soil liquefaction potential: a case study for Moulvibazar town, Sylhet, Bangladesh", MIT Open Access Article, 30 Mar 2022.**

This paper discusses the assessment of seismic hazard potential in Moulvibazar, a small town located in northeast Bangladesh. The researcher's focus of the study is to evaluate the liquefaction potential, which can exacerbate the destruction caused by earthquakes. He studied the detailed description of the geomorphological characteristics and surface geological units present in Moulvibazar town. The researchers conducted standard penetration tests (SPT) at 25 borehole locations within that study area. Then he calculates the factor of safety against liquefaction. Before calculating of factor of safety, first of all, researchers calculate the cyclic stress ratio (CSR), cyclic resistance of ratio (CRR), and magnitude scaling factor(MSF). Then he calculates the liquefaction potential index (LPI). They utilized the liquefaction potential index (LPI), which is derived from the geotechnical properties of soil and groundwater depth, to evaluate the likelihood of liquefaction occurrence. They calculated the factor of safety for each soil layer encountered in the boreholes down to a depth of 20 meters using a simplified procedure. The sum of the factors of safety for all layers in a borehole was used to determine the LPI value for that borehole. The researcher also revealed cumulative percentages of LPI, indicating that 42% of the surface area in Zone 1 and 78% in Zone 2 would exhibit surface manifestation of liquefaction during the scenario earthquake described. The liquefaction hazard map produced in his study can serve as a valuable tool for seismic site characterization and micro zonation in Moulvibazar town.

3) **V.K. Dwivedi, R.K. Dubey, S. Thockhom, V. Pancholi, S. Chopra1 and B.K. Rastogi, " Assessment of Liquefaction potential of soil in Ahmedabad Region", Western India, J. Ind. Geophys. Union, V.21, no.2, pp: 116-123, March 2017.**

The author discusses the importance of estimating liquefaction resistance, known as the Cyclic Resistance Ratio (CRR), in geotechnical earthquake engineering. They focus on assessing the liquefaction potential of soil in the

Ahmedabad city area, which primarily comprises sandy to silty sediments and has experienced significant construction activities recently. The first step the researcher is going to conduct the geological investigation on the Ahmedabad region. He collected data from Standard Penetration Tests (SPT) conducted in 23 boreholes. Then the researcher calculated the factor of safety (FS) against liquefaction, with a focus on comparing earthquake-induced loading (characterized by the Cyclic Stress Ratio, CSR) with liquefaction resistance (represented by the Cyclic Resistance Ratio, CRR). Various empirical formulas and correction factors are used to estimate these parameters based on Standard Penetration Test (SPT) data. Results from the liquefaction assessment indicate that the majority of soil samples in the Ahmedabad city area are classified as non-liquefiable, with only a small percentage categorized as marginally liquefiable or liquefiable. He concludes that the different parameters analyzed in the present study indicate high compaction and low water table which give high SPT N-values. Hence it can be concluded that the study area is safe for construction.

4) **Sudhir K. Jain & Shashank Pathak, "Intensity Based Casualty Models, "Case Study Of Bhuj and Latur Earthquake in India", Journal 15, World Conference on Earthquake Engineering (WCEE),2012.**

It is a Case study the research collected casual data from Latur and Bhuj after the Earthquake. Latur in 1993 and another in Bhuj in 2001. People wanted to understand why the death rates were different even though the shaking intensity was similar. They found out that in Latur, more people died compared to Bhuj for the same level of shaking. This was because of how the buildings were made and when the earthquakes happened. In Latur, the buildings were more vulnerable, and the earthquake happened during the day when more people were inside the buildings. They found that for the same level of shaking, the expected death rates were much higher in Latur than in Bhuj. For example, when the shaking was at level VII, the expected death rate in Latur was about 0.31%, while in Bhuj it was only about 0.0029%. They found that the way buildings are made and the time of day the earthquake happens can affect the number of casualties. He concluded that In Latur, where buildings were poorly made and most people were inside sleeping when the earthquake hit, a lot more people died compared to Bhuj, where buildings were slightly better and more people were outside.

5) **B.K. Maheshwari, A.M. Kaynia and D K. Paul, " Liquefaction Susceptibility Of Soils In Himalayan Region, The 14th World Conference on Earthquake Engineering, October 12-17, 2008.**

In this paper, the author aims to analyze the liquefaction susceptibility of selected sites near Dehradun, the capital city of the northern state of Uttarakhand, India. The author highlights past earthquakes where liquefaction caused significant damage and emphasizes the importance of assessing liquefaction susceptibility in areas like Haridwar, where loose saturated sands are prevalent. As Haridwar is a city undergoing industrial and tourist development, understanding the liquefaction potential is crucial for future development and land use planning. The paper then provides details about the selected sites for the study: Dhanuari and Roshnabad. The tests were conducted in the Soil Dynamics Laboratory of the Department of Earthquake Engineering at IIT Roorkee, India, using a vibration table fabricated according to Gupta (1977). The author discusses the findings from field tests conducted at the Dhanuari and Roshnabad sites, indicating a clear threat of liquefaction in Dhanuari but not in Roshnabad for the earthquake magnitude considered. This conclusion holds significant practical significance, especially since Dhanuari is situated very close to Roorkee, where substantial industrial development is underway. The author emphasizes that further investigations are necessary to arrive at a concrete conclusion. They suggest conducting additional field tests at different locations, as well as laboratory tests such as cyclic triaxial tests. These additional tests would provide more comprehensive data and allow for a more thorough analysis of liquefaction susceptibility at both sites.

6) **Rohit Tumane, Ritesh Tandekar, Nikita Janbandhu, Rupali Ramteke and Sandhya Suryawanshi, "Review Paper on Soil Liquefaction and Earthquake", Journal of International Research Journal of Engineering and Technology (IRJET), Volume: 07,5 May 2020.**

This case study, Concludes that the soil liquefaction has occurred in saturated or partially saturated cohesive soil. Due to earthquake shaking or sudden changes in stresses the Pore water pressure increase by which the solid particles of soil behaves like viscous fluid. Liquefaction majority occurred in sandy and silt soil. Methods Used to reduce liquefaction 1. Avoid liquefaction susceptible soil, 2. Built liquefaction resistance structure, 3. Use vibro compaction, 4. Dynamic compaction, 5. Stone column, 6. Compaction grouting.

7) V. Sesov, K. Edip & J. Cvetanovska, " Evaluation of the Liquefaction Potential By In-situ Tests and Laboratory Experiments In Complex Geological Conditions", Journal 15, WCEE (2012).

This case study deals with the investigations and results of the evaluation of the potential of liquefiable soil layers at the location where a new industrial complex is planned to be built in the southern part of the Republic of Macedonia. The liquefaction potential is an important issue that should be considered in soil site investigation. In this work, two general types of approaches available for this exist Use of empirical relationship based on correlation of observed field behavior with various in-situ tests 2. Use of laboratory testing of samples. For the new industrial complex which is planned to be built at first preliminary evaluation of the liquefaction potential is done with SPT and CPT methods. Results indicated the soil layers whose cyclic resistance ratio is lower than the expected cyclic stress ratio and might behave as liquefiable. Soil samples were taken from the borehole of the site and cyclic undrained triaxial tests were done. The results of the undrained triaxial experiment reveal the fact that the soil can behave liquefiable considering the low cyclic stress ratio needed to initiate liquefaction.

8) Indranil Kongar, Tiziana Rossetto, and Sonia Giovinazzi, "Evaluating simplified methods for liquefaction Assessment for loss estimation", Journal of Natural Hazards and Earth System Sciences,1 June 2017.

In this case study, the recent earthquake in Haiti (2010), Canterbury, New Zealand (2010-2011), and Tihoku, Japan (2011), highlighted the significance of liquefaction as a secondary hazard of seismic events and the significant damage that it can cause to buildings and infrastructure. This study compares 11 unique models, each based on one of three principles of simplified liquefaction assessment methods: liquefaction potential index (LPI) calculated from share-wave velocity, the HAZUS software method, and a method created specifically to make use of USGS remote sensing data. Data from the September 2010 Darfied and February 2011 earthquake 5new Zealand are used to analysis shows that the best-performing model is the LPI calculated using known Shear-wave velocity profiles, which currently forecast 78% of sites where liquefaction occurred and 80% of sites where liquefaction did not occur, these data may not always available to insures. the HAZUS method for estimating liquefaction probabilities performs poorly irrespective of triggering thresholds. this paper also considers two models HAZUS AND EPOLLS for estimating the scale of liquefaction in terms of permanent ground deformation but finds that both models perform poorly. Existing models show a very low correlation with observation and strong estimation bias underestimation in the case of HAZUS and Overestimation in the case of regional EPOLLS. Based on this analysis the estimation from these simplified models is highly uncertain and any value to loss estimation analysis outside of the regions for which they have been developed.

9) Raghvendra Singh, Debasis Roy, and Sudhir K. Jain, "Investigation Of Liquefaction Failure In Earthen Dam During Bhuj Earthquake", Research Gate, January 2003.

In This case study A magnitude 7.6 earthquake occurred in Bhuj, India on January 26, 2001. A large number of water-retaining earthen dams were affected by the earthquake. This paper examines the nature of distress in several relatively severely affected dams. The damaging effects of the Bhuj earthquake on the embankment Dam have been considered in this paper with particular reference to Change Dam, Fatehgadh Dam, and Kaswati Dam. One of these dams, Change Dam, Distress Liquefactions in the foundation of upstream and downstream slopes, slumping, and cracking. And second Fatehgadh dam Distress in possible liquefaction in the foundation near the upstream toe, and shallow failure in the upstream slope, cracking. And third Possible liquefaction in the foundation near the upstream toe, shallow failure in upstream slope failure, cracking. The Data present in this paper indicated that liquefaction within the foundation soil would have been widespread underneath Chang Dam, while that underneath Fatehgadh Dam and Kaswati Dam was relatively localized. The sliding block method was used to estimate the magnitude of observed deformation.

10) Onur Selcukhan and Abdullah Ekinci, "Assessment of liquefaction Hazard and Mapping Based on Standard Penetration Test in the Long Beach and Tuzla Regions of Cyprus", Multidisciplinary Digital Publishing Institute (MDPI),(23 May 2023).

This research paper provides a detailed evaluation of the liquefaction potential in the northern part of Cyprus, utilizing an improved potential index to identify areas at risk. Cyprus is the third largest and most populated island in the Mediterranean Sea and is still rapidly expanding. Historically 15 destructive earthquakes were reported on Cyprus from 1896 to 2019 causing structural damage. In this study, the liquefaction potential of Tuzla Beach and Long Beach on the east coast of Cyprus is estimated using the standard penetration test (SPT) data collected from more than 200 boreholes that were along streamlined locations near the sites in both locations. The results are presented in a liquefaction potential index obtained from the factor of safety (F.S) coefficient, both study area are susceptible to liquefaction. And thus liquefaction potential maps are prepared to identify hazards in Tuzla and Long Beach. This paper also highlights the unique geological setting of the area and the challenges it poses to the applicability of current methods to assess the liquefaction potential in alluvial deposits. By comparing various methods, such as SPT, CPT, and surface geology aspects. Overall, the findings of this study provide valuable insight into improving our understanding of the risk association with liquefaction.

11) **Sahil Srivastava, Pravindra Singh Bhan, Sakshi Agarwal, Rishabh Kumar Singh, Himanshu Vimal, Pranav Sharma, Nandini Kaushik, Ishika Mittal, Hemant Nauhwar and Shantanu Upadhyay, "Analysis of Liquefaction Potential of Soil using SPT Data: Field Assessment (Case Study: Dayalbagh Area, Agra)", Journal Of Emerging Technologies And Innovative Research (Jetir), Volume 10, (2023).**

This study aimed to evaluate the risk of soil liquefaction in Dayalbagh, Agra, to ensure the safety of future construction projects. This site has been selected because the site is near to Yamuna River and the soil of that area is sandy. The selected area lies in zone III which is moderately affected by earthquake forces. In this test, a borehole is drilled to a specific depth, and a standard split spoon sampler is placed inside it. The split spoon sampler consists of a driving shoe, a drop hammer weighing 63.5kg is used to drive the sampler into the soil at a rate of 30 blows per minute. The number of blows needed to drive the sampler to a depth of 150mm is counted and recorded. This process is repeated three times, with the number of blows recorded for the first 150mm being ignored. The sum of the number of blows for the last two 150mm penetrations is recorded as the N value or the standard penetration number (N). This test is conducted as per the standard procedure given in the IS -2131:1981 code. After that overburden correction and water table correction factor is applied. They used calculations like the Cyclic Resistance Ratio (CRR) to assess soil resistance to liquefaction and compared it to the Cyclic Stress Ratio (CSR) to determine safety. The analysis confirmed that Dayalbagh is not at high risk of liquefaction, a crucial finding for construction in earthquake-prone areas. However there are possibilities of liquefaction to occur if a very large magnitude earthquake occurs or other dynamic loading with significant value takes place.

12) **Rupam Saikia and Malaya Chetia, "Soil Liquefaction Potential Studies of Guwahati City – A Critical Review", International Journal of Innovative Research in Science, Engineering, and Technology(IJIRSET),Vol. 3, Issue 5, May 2014.**

This study aims to provide a review of the various studies conducted on the liquefaction potential of Guwahati City. Guwahati situated along the bank of mighty Brahmaputra comes in Seismic Zone V of India. By understanding and assessing its vulnerability to soil liquefaction it is crucial for earthquake preparedness and risk mitigation. First study was carried out by Raghukanth and Dash. Standard Penetration Test (SPT) values of 100 borehole locations were than collected for the study. They used the Idriss and Boulanger method which is an Updated and better method for determining the liquefaction potential of a particular soil profile as compared to the Semi-empirical method originally developed by Seed and Idriss. Liquefaction Potential Index (LPI) as proposed by Iwasaki et al.Was also used to Illustrate the liquefaction vulnerability which takes into account the effect of thickness and depth along with the FOS Of the liquefiable layer. After the evaluation by Raghukanth and Dash it was Ayothiraman et all. made another effort to evaluate the liquefaction potential of Guwahati City. In their evaluation they too studied 100 borehole data, which they collected from the Guwahati Metropolitan Development Authority (GMDA). Recently Sharma and Hazarika gave an evaluation of the liquefaction Potential of Guwahati City.In their study, they used 200 boreholes data. As per the evaluation result of both Raghukanth ad Dash and Ayothiraman et al. FOS was found to be less than 1 in almost all the places under study which means almost entire Guwahati city is susceptible to liquefaction. But as per Sharma and Hazarika FOS for most of the places in Guwahati city was found to be greater than 1 which according to them was non-liquefiable. Despite various findings from different studies, there's a need for further research using probabilistic approaches to better understand the liquefaction potential. Advanced techniques like shear-wave velocity measurements are recommended for more reliable assessments. A comprehensive soil profile map and borehole data collection are also essential for future studies.

13) Neelima D. Satyam and Ikuo Towhata,"Site-specific ground response analysis and liquefaction assessment of Vijayawada city (India)", Springer Science Business Media Dordrecht,(2015).

This study concludes that the city is vulnerable to seismic risks due to its geological and geotechnical characteristics, including the presence of recent alluvium and higher groundwater levels. In this paper, the liquefaction potential of Vijayawada City is estimated using the ONDA program. The tool uses SPT data to determine dynamic soil properties, and then the peak ground acceleration (PGA) at the surface is calculated at each location which is used for the evaluation of the factor of safety against liquefaction. In this site, the thickness of the alluvium in some of the areas is estimated to be of the order of 150 m. Geological Survey of India (GSI) carried out deep drilling at some locations in the city and could not find the bedrock depth up to 140 m below the ground. The geotechnical data show that the study area has four major soil types, namely black cotton (58 %), sandy clay loams (23 %), red loams (17 %), and sandy soils (2 %). Most of the city is covered by alluvium, and sandy clay loams are formed along the river. Vijayawada city is located along the stream of Krishna River and is covered by dominant amounts of alluvium. Ground response analysis will be useful for the prediction of local site effects and for estimating the dynamic behavior of the soil during seismic loading. To assess the peak frequency and amplitude of vibration, microtremor testing was adopted in the area of study. From the study, it is observed that almost all the locations that are near the water bodies are within the risk. Vijayawada could experience a Peak Ground Acceleration (PGA) of up to 0.27 g and a Peak Ground Velocity (PGV) of up to 8 cm/s, indicating a moderate to high seismic hazard. A map with the comparison of the Liquefaction potential index and PGV was generated for further damage estimation.

14) M. K. Gupta. Professor of Soil Dynamics, University of Roorkee, India, "Liquefaction During 1988 Earthquakes and a Case Study", Journal of Missouri University of Science and Technology, Paper No. 14.19, June 1-4, 1993.

The study by M.K. Gupta discusses the phenomenon of liquefaction during earthquakes, with a focus on two significant earthquakes that occurred in northeastern India in 1988. Liquefaction, where saturated soil loses strength and behaves like a liquid, causes widespread damage. A case study of a road bridge near Tezpur, designed to withstand liquefaction, showed excellent performance during the earthquakes. The study highlights the importance of understanding and mitigating liquefaction risks in earthquake-prone regions. Widespread liquefaction of foundation soil has been observed during the earthquakes of August 6, 1988, and August 21, 1988. In the event of liquefaction of foundation soil, no extra safety in the design of structures is of any help. It is, therefore, extremely important to carry out the liquefaction investigations for foundation soils prone to liquefaction and provide the necessary remedial measures if necessary.

15) Prathamesh Gurme and Sangram Patil, "Latur - Killari Earthquake: An Overview Study", International Journal of Innovative Research and Advanced Studies (IJIRAS) ,Volume 4 Issue 7, July 2017.

The Latur earthquake in 1993 was a rare intraplate earthquake in Maharashtra, India, occurring in the early morning when most people were indoors, leading to high casualties. The earthquake's epicenter was far from any fault line, possibly caused by the continuous crumpling of the Indian plate against 30,000 injuries. The earthquake measured 6.2 on the moment magnitude scale and significantly impacted the region's densely populated areas. The focus of the quake, 12 kilometers deep, contributed to the extensive damage. The tragedy highlighted the importance of understanding earthquake magnitude and intensity for effective disaster preparedness and construction improvements. Earthquake's impact on the relatively small affected area underscores the importance of understanding local seismic hazards. Despite lacking modern infrastructure, the earthquake response efforts, including rescue, relief, and rehabilitation, were remarkable and even exemplary on an international scale. Latur has a very rare type of earthquake. It can be seen from the graph that on average about one earthquake of magnitude greater than 8.0 takes place every year as against about 96 events per year of magnitude range 6.0 to 8.0: a ratio of about 1 is to 100. If this trend were to apply to India, the Indian subcontinent should have had about 400 earthquakes of magnitude range 6.0 to 8.0 in the last 100 years since we had four events of magnitude greater than 8.0 in that period. We have had far a smaller number of moderate earthquakes. This illustrates an interesting aspect of Indian seismicity: India has a relatively high frequency of great earthquakes and a relatively low frequency of moderate earthquakes. Moderate earthquakes create awareness and lead to improvements in construction at relatively low human costs, which could be very effective in the long run. Due to rather infrequent moderate earthquakes, the Indian.

16) J Dixit, D. M. Dewaikar, and R. S. Jangid, "Assessment of liquefaction potential index for Mumbai city", Natural Hazards and Earth System Sciences,(2012).

The study evaluates factors of safety against liquefaction (FS) at 142 representative sites in the city, considering different earthquake scenarios with a 2% probability of exceedance in 50 years. The liquefaction potential index (LPI) is derived from FS values obtained from SPT-based empirical procedures. This index helps predict the likelihood of liquefaction-induced damage at the surface level of each site. Liquefaction occurs during seismic events due to rapid loading, causing excess pore-water pressures that transform granular materials into a liquefied state. Factors influencing liquefaction include earthquake magnitude, ground motion intensity, soil type, thickness, and groundwater levels. The liquefaction potential is evaluated using factors of safety (FS), where FS < 1 indicates liquefaction susceptibility. Various in-situ tests such as SPT, CPT, BPT, and Vs tests are used to assess FS. A threshold FS of 1.2 is considered non-liquefiable, but liquefaction can still occur even with FS > 1.0. Mitigation measures require an accurate evaluation of liquefaction potential in soils. Contour maps of LPI are generated for the city to predict the occurrence of damaging liquefaction for the earthquakes of magnitude Mw =6.0, Mw = 6.5, and Mw =7.0 of a max level 0.3 g corresponding to 2475-yr return period and are shown in Figs. 6 through 8, respectively. These contour maps show the liquefaction vulnerability at different sites in the city. Liquefaction susceptibility for sites with LPI > 15 is very high, and liquefaction is very unlikely at sites with LPI < 5. Some of the sites in the city: namely Sion, Wadala, Sewree, and Marine line, are highly vulnerable to severe liquefaction for Mw =6.0 and an amax value of 0.3 g. LPI is greater than 15 for Mw = 7.0 and a max value of 0.3 g at many sites in the city, namely Mahim, Wadala, Sion, Sewree, Trombay, JNPT, Goregaon, Bandra, Andheri, and Marine line.

17) Jagabandhu Dixit .D. M. Dewaikar R. S. Jangid, "Soil liquefaction studies at Mumbai city", Natural Hazards and Earth System Sciences,2012.

The study assesses soil liquefaction susceptibility in Mumbai, India, a major economic hub situated along the western coast. The city's reclaimed land predominantly consists of alluvium, sand, and recent conglomerate. Using standard penetration test data, the study quantifies liquefaction susceptibility based on factors such as earthquake-induced cyclic stress and soil resistance. The factor of safety against liquefaction is evaluated at various sites for two peak ground acceleration (PGA) levels, corresponding to different return periods. Contour maps illustrate liquefaction vulnerability across the city for a seismic event of magnitude Mw 6.5. These contour maps show the information vulnerability at different sites of the city. The seismic site classification is based on SPT N values complying with the International Building Code (IBC 2003) and provisions in the National Earthquake Hazards Reduction Program (NEHRP). Raghukanth and Iyengar (2006) for the analyses are 0.18 and 0.30 g corresponding to 10 and 2 % probability of exceedance in 50 years, respectively, for different magnitudes of earthquake

18) Manish Bawankule, Dr. Shantanu N. Pawar, "Evaluation of Liquefaction Potential of Nagpur Region Using SPT Data Field Assessment", IOP Conference Series: Earth and Environmental Science, 2022.

The study focuses on assessing liquefaction potential in Nagpur, Maharashtra, a rapidly growing city prone to seismic activity. Using the SPT-N method, soil liquefaction susceptibility is evaluated across 56 representative sites. Factors such as SPT blow count and peak ground acceleration influence liquefaction assessments. Corrections are made to SPT-N values to estimate the Cyclic Resistance Ratio (CRR), considering variations in soil composition and fluctuating water tables. The study aims to provide valuable data for further research and infrastructure planning in earthquakes. The study suggests that site-specific evaluations can be conducted using the provided graphs and tables to assess liquefaction potential based on soil types encountered in Nagpur. The area is in seismic zone II and faces mild earthquakes having 5.3 magnitudes also it has a rock development area. From research work and findings, it can be broadly concluded that Nagpur city is safe from liquefaction danger though some locations are susceptible to liquefaction. Site-specific evaluation of liquefaction potential should be possible by using the graphs and tables presented in this study for all encountered types of soil at a particular location in Nagpur.

19) K. SaiKiran, M. Sri Vidya and P. Dhanamma,"Analysis of Liquefaction of Soil using SPT Data", International conference on recent advances in civil engineering infrastructure(RACEI) 2016.

This paper provides a detailed analysis of soil liquefaction potential using Standard Penetration Test (SPT) data from ten sites across three regions in India: Visakhapatnam, Bangalore, and Delhi. The study's objective is to map liquefaction susceptibility across these regions to guide construction practices and mitigate risks. Soil liquefaction, a critical concern during seismic events, occurs when saturated or partially saturated loose cohesionless soils lose strength and stiffness under stress, behaving more like a liquid. They used the simplified procedure provided in Annexure-F of IS 1893-part1 (2016) for their analysis. This procedure involves determining the Cyclic Resistance Ratio, and Cyclic Stress Ratio at varying depths, considering factors like the soil's density, earthquake magnitude scaling, and the presence of fines. Then Factor of safety is Calculated from CRR and CSR. If the value of the Factor of safety is less than 1 then the soil has liquefaction potential. They also discuss several mitigation measures to enhance soil stability, including Deep Dynamic Compaction, Vibro-Compaction, and the use of Stone Columns. These methods aim to increase the density and shear strength of the soil, thus reducing its susceptibility to liquefaction from this study.

III. LITERATURE GAP

Earthquake vibrations have been felt in India before. SPT (Standard Penetration Test) tests are more common in megacities but fewer tests are done in rural areas. So in our paper, we are going to find the liquefaction potential by using SPT (Standard Penetration Test) Data.

IV. CONCLUSION

The above authors used SPT(Standard Penetration Test), cyclic triaxial undrained test, and Microtremor Testing for analysis of liquefaction potential in the Mumbai, Nagpur, Dayalbagh Agra, Vijayawada, Ahmedabad, Lucknow and Guwahati cities of India. From these studies, it was understood that Certain locations have high liquefaction risk and some are not at high risk and it highlights the need to conduct liquefaction tests in various locations.

V. REFERENCES

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