A REVIEW ON ASSESSMENT OF LIQUEFACTION OF SOILS WITH EMPHASIS SPT AND CPT BASED METHOD

Qamre Hasan[1], Sabih Ahmad[2]
M. Tech (Research scholar) [1,] Civil Engineering Department, Integral university, Lucknow (U.P), India
Dr. Sabih Ahmad[2], Civil Engineering Department, Integral University, (U.P), India

Abstract-The geotechnical characteristic of soil layer is one of the main factors influencing liquefaction potential of the ground. Liquefaction refers to the loss of strength in saturated, cohesion less soils due to build-up of pore water pressure during dynamic loading. The geotechnical characteristic of the soil has been measured both from standard penetration test and cone penetration test method for the same seismic condition. In order to compare the liquefaction potential evaluated based on site the spt data and cpt data, a specific site in Lucknow, have been selected and studies. At the end some correlation was derived between the obtain results and their validities were discussed.

Keyword. **Liquefaction potential, spt and cpt, dynamic loading**

I. INTRODUCTION

Most destructive liquefaction is the phenomena when there is loss of strength in saturated and cohesion less soils because of increased pore water pressure and reduced effective stress due to dynamic loading. It is a phenomenon in which the strength and stiffness of a soil is reduced by earthquake shaking or other rapid loading

Using the standard penetration test data for evaluating liquefaction of the soil layer was first recognized during 1966 Niigata earthquake, seed and Idriss 1971 developed the first experimental method based on the spt data to evaluation the liquefaction potential of the ground during heavy earthquake.

There is some liquefaction evaluation method based on the cone penetration test, in which the geotechnical characteristic of soil obtain from tip resistance and skin friction of the device can be used more accurately. In this study a specific site has been selected to compare the liquefaction potential estimate by standard penetration test and cone penetration test data.

II. REVIEWS ARTICLES

Seed and Idriss (1971) developed a simplified procedure for evaluating soil liquefaction potential bySignificant factors affecting the liquefaction (or cyclic mobility) potential of sands during earthquakes are identified, Available field data concerning the liquefaction or non liquefactionbehaviour of sands during earthquakes is assembled and compared with evaluations of performance using the simplified procedure. It is suggested that even the limited available field data can provide a useful guide to the probable performance of other sand deposits, that the proposed method of presenting the data provides a useful framework for evaluating past experiences of sand liquefaction during earthquakes and that the simplified evaluation procedure provides a reasonably good means for extending previous field observations to new situations. When greater accuracy is justified, the simplified liquefaction evaluation procedure can readily be supplemented by test data on particular soils or by ground response analyses to provide more definitive evaluations. [1]

Robertson and Wride (1997) provided modified method to evaluate cyclic liquefaction using cone penetration test (CPT). To evaluate liquefaction resistance of soils, a method was proposed to determine grain characteristics from the CPT data. This modified procedure of evaluating soil liquefaction potential using CPT test was validated by application of the proposed method on the sites affected by 1989 Loma Prieta earthquake. Also, the proposed method was compared with the methods presented by others researchers such as: Olsen (1988), Olsen and Koester (1995) and Suzuki et al. (1995). In this thesis, the above-mentioned method has been used to determine the factor of safety of soils against liquefaction, to find the liquefaction potential of soils for CPT-based sitesIn this method the values of tip resistance of the CPT and also the number of SPT blows, are corrected in terms of the tine content according to one of the two following ways:

$(N1)_{60cs}=ks(N_1)_{60}$

In the second way which has been developed in 1997, the following equations can be used to correct the SPT numbers and also the CPT tip resistance, respectively:

$(N_1)_{60cs}=\alpha+\beta(N_1)_{60}$

In which: Where AFC is the Apparent Fine Content, to be calculated by the following equation (Robertson &Wride, 1997):

Ic 1.26 AFc = 0

1.26 <Ic≤ 3.5 AFC (%)=1.75

Ic>3.5 AFC (%)=100. [2]

Suzuki et al. Method (1997): This method is based on the CPT data, and has been developed according to instrumented data in four heavy earthquakes hitted about 68 regions in Japan. The recommended curve by Suzuki et.al. (1997) is a little more conservative than that suggested by the NCEER workshop. If the soil characteristics are defined in terms of soil behaviour type Index, Ic, the liquefiable and liquefiable boundary recommended by Suzuki et.al. can be used. [3]

Youd et al. (2001) developed a summary report on the 1996 and 1998 workshops on evaluation of liquefaction resistance of soils. This report listed the recommendations made in the workshops on evaluating liquefaction resistance using different tests such as: standard penetration test, cone penetration test, shear-wave velocity test, and Becker penetration test. In this workshop, probabilistic and seismic energy analyses were also reviewed. However, recommendations were not made on these analyses. [4]

Boulanger and Idriss (2004): Recommended the new criteria based on cyclic laboratory test results and an extensive engineering judgment. The deformation behaviour of fine-grained soils is grouped as “Sand Like” and “Clay-Like”, where soils within the sand-like behaviour region are judged to be susceptible to liquefaction and have substantially lower values of Cyclic Resistance Ratio (CRR). [8]

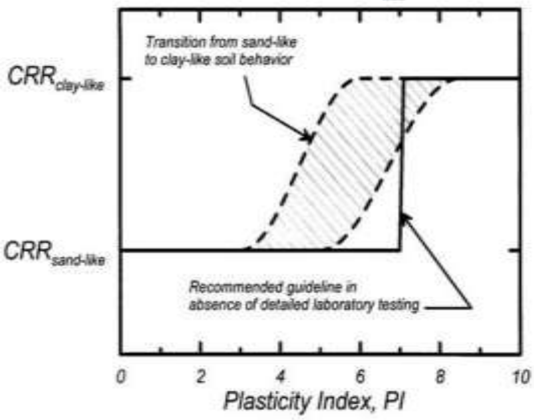

Fig.6 Criteria for differentiating between sand-like and clay-like sediment behaviour proposed by Boulanger and Idriss (2004).

Boulanger and Idriss (2004) [14] found that overburden stress effects on the Cyclic Resistance Ratio (CRR). The recommended K curves are expressed as follows:

$$K_\sigma = 1 - C_\sigma \ln\left(\frac{\sigma'_{vo}}{P_a}\right) \leq 1.0$$

The coefficient C is expressed in terms of $(N_1)_{60}$ or q_{c1N}

$$C_\sigma = \frac{1}{18.9-2.55\sqrt{(N_1)_{60}}}$$

$$C_\sigma = \frac{1}{37.3-8.27\,(q_{c1N})^{0.264}}$$

where, $(N_1)_{60}$ and q_{c1N} are limited to maximum value of 37 and 211 respectively (i.e., keeping C less than eq**).** [5]

By H. Bolton Seed et al.(2017) The purpose of this paper is to clarify the meaning of the values of standard penetration resistance used in correlations of field observations of soil liquefaction with values of N, measured in SPT tests. The field data are reinterpreted and plotted in terms of a newly recommended standard, (Nj)60, determined in SPT tests where the driving energy in the drill rods is 60% of the theoretical free-fall energy. Energies associated with different methods of performing SPT tests in different countries and with different equipment are summarized and can readily be used to convert any measured N-value to the standard (NJaj value. Liquefaction resistance curves for sands with different (Ni)6o values and with different fines contents are proposed. It is believed that these curves are more reliable than previous curves expressed in terms of mean grain size. The results presented are in good accord with recommended practice in Japan and China and should, thus, provide a useful basis for liquefaction evaluations in other parts of the world. Finally, suggestions are made concerning the significance of the term "liquefaction" as it is often used in conjunction with field evidence of this phenomenon. [6]

P. Villamor at al. (2016) Liquefaction features and the geologic environment in which they formed were carefully studied at two sites near Lincoln in southwest Christchurch. We undertook geomorphic mapping, excavated trenches, and obtained hand cores in areas with surficial evidence for liquefaction and areas where no surficial evidence for liquefaction was present at two sites (Hardwick and Marchand). The liquefaction features identified include (1) sand blows (singular and aligned along linear fissures), (2) blisters or injections of sub horizontal dikes into the topsoil, (3) dikes related to the blows and blisters, and (4) a collapse structure. The spatial distribution of these surface liquefaction features correlates strongly with the ridges of scroll bars in meander settings. In addition, we discovered paleo liquefaction features, including several dikes and a sand blow, in excavations at the sites of modern liquefaction. The paleo liquefaction event at the Hardwick site is dated at A.D. 908–1336, and the one at the Marchand site is dated at A.D. 1017–1840 (95% confidence intervals of probability density functions obtained by Bayesian analysis). If both events are the same, given proximity of the sites, the time of the event is A.D. 1019–1337. If they are not, the one at the Marchand site could have been much younger. Taking into account a preliminary liquefaction-triggering threshold of equivalent peak ground acceleration for an Mw 7.5 event (PGA7:5) of 0:07g, existing magnitude-bounded relations for paleo liquefaction, and the timing of the paleo earthquakes and the potential PGA7:5 estimated for regional faults, we propose that the Porters Pass fault, Alpine fault, or the subduction zone faults are the most likely sources that could have triggered liquefaction at the study sites. [7]

Robertson et al. (1992) proposed a stress-based liquefaction assessment procedure using field performance data from sites in the Imperial Valley, California. These investigators normalized VS by:

$$V_{s1} = V_s (Pa/\sigma')^{1.25} \quad (1)$$

where Pa is a reference stress of 100 kPa, approximately atmospheric pressure, and $\sigma'$is effective overburden pressure in kPa. Robertson et al. chose to modify VS in terms of$\sigma'$to follow the traditional procedures for modifying standard and cone penetration test resistances. The liquefaction resistance bound (CRR curve) determined by these investigators for magnitude 7.5 earthquakes. The cyclic stress ratios were calculated using estimates of a max for the larger of two horizontal components of ground acceleration that would have occurred at the site in the absence of liquefaction.[8]

Sabih Ahmad et al. (2015). Liquefaction is one of the critical problems in the field of Geotechnical engineering. It is the phenomena when there is loss of shear strength in saturated and cohesion-less soils because of increased pore water pressures and hence reduced effective stresses due to dynamic loading. Semi-empirical field-based procedures for evaluating liquefaction potential during earthquakes have two essential components: (1) the development of an analytical framework to organize past case history experiences, and (2) the development of a suitable in-situ index to represent soil liquefaction characteristics. The strength of semi-empirical procedure is the use of both experimental findings together with the theoretical considerations for establishing the framework of the analysis procedure.[9]

Jamshaid A et al. (2012) This paper reviews the current status of knowledge regarding liquefaction of soils containing fines based on the theoretical and experiments studies conducted so far. It is well established that the criteria for assessment of liquefaction potential of coarse grained soil is entirely different than that of fine grained soils. However, fine grained soil viz. silt and clays also behave differently which is attributed to their individual plasticity index or the plasticity index of the mixture. It has been found that the liquefaction susceptibility of silts shows a noticeable change in its liquefaction with change in plasticity index. For a PI range of 2-4%, the liquefaction resistance of silt was found to decrease with an increase in plasticity. [10]

Maral Goharzay et al. (2017): In this context, two different approaches of soil liquefaction evaluation using a soft computing technique based on the worldwide standard penetration test (SPT) databases have been studied. Gene expression programming (GEP) as a grey-box modelling approach is used to develop different deterministic models in order to evaluate the occurrence of soil liquefaction in terms of liquefaction field performance indicator (LI) and factor of safety (Fs) in logistic regression and classification concepts. The comparative plots illustrate that the classification concept-based models show a better performance than those based on logistic regression. In the probabilistic approach, a calibrated mapping function is developed in the context of Bayes' theorem in order to capture the failure probabilities (PL) in the absence of the knowledge of parameter uncertainty. Consistent results obtained from the proposed probabilistic models, compared to the most well-known models, indicate the robustness of the methodology used in this study. [11]

Cetin et al. (2004) This data article provides a summary of seismic soil liquefaction triggering and non-triggering case histories, which were compiled, screened for data completeness and quality, and then processed for the development of triggering relationships proposed in "SPT-based probabilistic and deterministic assessment of seismic soil liquefaction triggering hazard.This paper provides details about the collection of the data, their interpretation and analyses for the seismic soil liquefaction triggering performance of soil sites shaken by different intensity and magnitude earthquake events. [12]

IkramGuettaya et .at (2013): This paper presents a case study of liquefaction potential assessment for the foundation of an earth dam in Tunisia. An emphasis was made on the exploration of geotechnical conditions and the interpretation of field tests (SPT and CPT) and the results were collected before and after soil densification using the vibro compaction technique. The SPT resistance values increased on average from 12 to 25 blow counts/0.3 m, and the CPT resistance increased on average from 8 MPa to 14 MPa. Before vibro compaction, the factor of safety (FS) against liquefaction fell below 1.0, which means that the soil is susceptible for liquefaction. After vibro compaction the values of FS exceed the unit which justified the liquefaction mitigation efforts in dam foundation. [13]

Pradyut Kumar Muduli[1] & Sarat Kumar Dasn[2] (2015): In this paper, the model uncertainty of the developed standard penetration test (SPT)-based model for evaluation of liquefaction potential of soil is estimated within the framework of the first-order reliability method (FORM). First, an empirical model to determine the cyclic resistance ratio (CRR) of the soil is developed, based on the post-liquefaction SPT data using an evolutionary artificial intelligence technique, multi-gene genetic programming (MGGP). The uncertainty of the developed limit state model is represented by a lognormal random variable, in terms of its mean and the coefficient of variation, estimated through an extensive reliability analysis following a trial and error approach using Bayesian mapping functions calibrated with a high quality post-liquefaction case history database. A deterministic model with a mapping function relating the probability of liquefaction (PL) and the factor of safety against liquefaction (Fs) is also developed for use in absence of parameter uncertainties. [14]

A.M. Hanna et .al (2014) : the literature, predictions for the occurrence of nonlinear soil liquefaction in soil deposits have been investigated through numerous empirical methods. These methods which are also known as 'conventional techniques' were derived from several in-situ tests, laboratory tests and case records. An alternative general regression neural network (GRNN) model that addresses the collective knowledge built in a simplified procedure is proposed. To meet this objective, a total of 3895 case records including twelve soil and seismic parameters driven mostly from the cone penetration test results are introduced into the model. The data includes the results of field tests from the two major earthquakes that took place in Turkey and Taiwan in 1999 and some of the desired input parameters are obtained from correlations existing in the literature. The soil liquefaction decision in terms of seismic demand and capacity is determined by a recognized simplified approach, namely a stress-based method and a strain-based method. Furthermore, the liquefaction probability of soils with significant fines is tested with the so-called Chinese Criteria. The proposed GRNN model is developed in four phases, mainly: the identification phase, collection phase, implementation phase, and verification phase. An iterative procedure followed to maximize the accuracy of the proposed model. The case records were divided randomly into testing, training, and validation datasets. The proposed GRNN model effectively explored the complex relationship between the introduced soil and seismic input parameters and validated the liquefaction decision. [15]

Abdullah Anwar at .al(2016): The Standard Penetration Test (SPT) is the most widely used in-situ test throughout the world for subsurface geotechnical investigation and this procedure have evolved over a period of 100 years. Estimation of the liquefaction potential of soils is often based on SPT test. Liquefaction is one of the critical problems in the field of Geotechnical engineering. It is the phenomena when there is loss of shear strength in saturated and cohesion-less soils because of increased pore water pressures and hence reduced effective stresses due to dynamic loading. In the present study, SPT based data were analysed to find out a suitable numerical procedure for establishing a Multilinear Regression Model using IBM-Statistical Package for the Social Sciences (IBM SPSS Statistics v20.0.0) and MATLAB(R2010a) in analysis of soil liquefaction for a particular location at a site in Lucknow City. A Multi-storeyed Residential Building Project site was considered for this study to collect 12 borehole datasets along 10 km stretch of IIM road, Lucknow, Uttar Pradesh (India). The 12 borehole datasets include 06 borehole data up to 22m depth and other 06 borehole data up to 30m depth to further analyse the behaviour of different soil properties and validity of the established Multi-Linear Regression Model. Disturbed soil sample were collected up to 22m and 30m depth in every1.5m interval to determine various soil parameters. [16]

III. CONCLUSIONS

In this paper recent studies for assessment of liquefaction in soil is presented with emphasis on spt and cpt based methods It can be concluded that

1. The semi – empirical field based procedures used to evaluate the liquefaction potential of cohesion less soil are widely accepted and used due to the fact that it is based on actual case histories. Due to the high sensitivity of residual shear strength to small variations of void ratio and difficulties in simulating field stress and loading conditions, laboratory-based techniques are not widely used in engineering analysis.
2. The not only the cohesion less soils but cohesive soils also have the tendency to liquefy but the assessment of cohesive soil should be different compared to that cohesion less soil. The liquefaction potential of the silts and the mixture of silt-clay also have the potential to liquefy but they behave differently.
3. There is large scale gap that needs to be filled by taking up more researches before coming to concrete conclusion. The research work is required to be carried out in the area as what would be the impact on the fall of the liquefaction in case the 5% criterion neglecting the fines is set aside.
4. The effect on liquefaction potential by the low plasticity fines (PI< 4) based on the variable void ratio needs to be clarified. Experimental research work is needed to be conducted for clearing the confusion once for all.

REFERANCES

[1] Seed H.B. and Idriss, I.M. and I. Arango (1983). "Evaluation of Liquefaction Potential using Field Performance data." Journal of Geotechnical Engg, ASCE, 109(3); 458-482.

[2] Robertson, P.K., and Wride, C.E. (1997). "Cyclic Liquefaction Potential and Its Evaluation Based on the SPT and CPT," Proceedings, Workshop on Evaluation of Liquefaction Resistance, NCEER97-0022, Buffalo, NY, 41-87.

[3] Suzuki., Tokimatsu,K.&Koyamada,K.(19971): Prediction of liquefaction resistance based on CPT tip resistance and sleeve friction@, Proc. X 1.V Intern. Conf soil Mech. and found. Eng. Hamburg, Germany.

[4] Youd et al., Liquefaction resistance of soils: summary report from the 1996 NCEER and 1998 NCEER/NSF workshops evaluation of liquefaction resistance of soils, 2001, J. Geotech. Engg. Div. ASCE, 127(10) (2001) pp817-833.

[5] Boulanger, R.W., Idriss, I.M. (2004), "State normalization of penetration resistances and the effect of overburden stress on liquefaction resistance", Proc., 11th International Conference on Soil Dynamics and Earthquake Engineering, and 3rd International Conference on Earthquake Geotechnical Engineering, D. Doolin et al., eds., Stallion Press, Vol. 2, 484-491.

[6] By H. Bolton Seed[1], F. ASCE, K. Tokimatsu[2], L. F. Harder[3], M. ASCE, and Riley M. Chung[4], "Influence of spt procedures in soil liquefaction resistance evaluations"

[7] Sabih A, Khan M. Z, Abdullah A, Ashraf S.M., (2015), "Assessment of Liquefaction Potential of Cohesion less Soil by Semi-Empirical: SPT- Based Procedure", International Journal of Recent Advances in Engineering & Technology (IJRAET), Vol.3, Issue 10, pp 53-59, 2015

[8] Jamshaid A. Khan[1]Sabih Ahmad[2]Meraj A. Khan[3] M. Z. Khan[4], "An Overview of the Liquefaction of Fine Grained Soils" International Journal of Engineering and Science ISBN: 2319-6483, ISSN: 2278-4721, Vol. 1, Issue 11 (December 2012), PP 01-02

[9] Pradyut Kumar Muduli[1], Sarat Kumar Dasn[2], "Model uncertainty of SPT-based method for evaluation of seismic soil liquefaction potential using multi-gene genetic programming" The Japanese Geotechnical Society.

[10] by P. Villamor, P. Almond, M. P. Tuttle, M. Giona-Bucci, R. M. Langridge, K. Clark, W. Ries, S. H. Bastin, A. Eger, M. Vandergoes, M. C. Quigley, P. Barker, F. Martin, and J. Howarth, "Liquefaction Features Produced by the 2010–2011 Canterbury Earthquake Sequence in Southwest Christchurch, New Zealand" Bulletin of the Seismological Society of America, Vol. 106, No. 4, pp. –, August 2016, doi: 10.1785/0120150223

[11] Robertson, P. K., and Campanella, R. G. (1998). "Liquefaction potential of sands using the CPT." J. Geotech. Engrg.111 (3), 384–403.

[12] Cetin, K. O., et al. (2004) "Standard penetration test-based probabilistic and deterministic assessment of seismic soil liquefaction potential." J.Geotech. Geoenviron. Eng., 130(12), 1314–1340

[13] Ikram Guettaya[1], Mohamed Ridha El Ouni[2], Robb Eric S. Moss[3], "Verifying liquefaction remediation beneath an earth dam using SPT and CPT based methods" Soil Dynamics and Earthquake Engineering 53 (2013) 130–144

[14] Maral Goharzay[1], Ali Noorzad[2], AhmadrezaMahboubi Ardakani[3], Mostafa Jalal[3]," A worldwide SPT-based soil liquefaction triggering analysis utilizing gene expression programming and Bayesian probabilistic method" Journal of Rock Mechanics and Geotechnical Engineering 9 (2017) 683e693

[15]A. M. Hanna[1], D. Ural[2]& G. Saygili[3], "Evaluation of the liquefaction potential of soil deposits based on SPT and CPT test results" Earthquake–Soil Interaction 191

[16]Abdullah Anwar and Yusuf Jamal[1], Sabih Ahmad[2], M.Z. Khan[3], "Assessment of liquefaction potential of soil using multilinear regression modelling" International Journal of Civil Engineering and Technology (IJCIET) Volume 7, Issue 1, Jan-Feb 2016, pp. 373-415, Article ID: IJCIET_07_01_030