Comparison of different methods for evaluating the liquefaction potential of sandy soils in Bandar Abbas

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Abstract

Liquefaction is a phenomenon in which the shear strength of the soil dramatically is reduced or even eliminated in a short time. This phenomenon occures in non-cohesive , saturation and sleazy soils that have been subjected to ground motions and as a result earthquake occurs. Different methods are presented for evaluating liquefaction potential such as Seed et al, NCEER workshop, regulations of china and so on. This study compared the results of different methods for evaluating liquefaction potential (at least four methods) in the sandy soils of Bandar Abbas coastal city. Based on this , the results of standard penetration test from geotechnical data of two boreholes drilling machine have been used in the coastal city of Bandar Abbas.

Key words: Liquefaction Potential - The Standard Penetration - Cyclic Shear Stress – Cyclic Shear Resistance

1. Introduction

One of the biggest devastating phenomenon and main factor damage to structures and technical buildings during earthquake in areas that have been built on sandy soils is reduction or loss of shear strength at the occurrence of soil liquefaction. Thus, the evaluation of liquefaction potential is important. There are two main methods for evaluation of liquefaction potential. The goal of first method is that to model complex interactions in a non-linear site response analysis and by using an appropriate structural model explicitly, and it will be remembered as numerical methods. According to the complexity and the cost and required time, this method can be used more in research studies. The second method is based on the empirical solidarity between seismic loading (the stimulus) and soil resistance against liquefaction (capacity factor), and it is remembered as experimental methods. These methods are compared to numerical models have broader usage due to the simpler use and less expensive. In this method, stimulating factor evaluating ways in determining liquefaction potential are divided into three major groups based on cyclic stress, cyclic strain, and energy. (Figure 1)

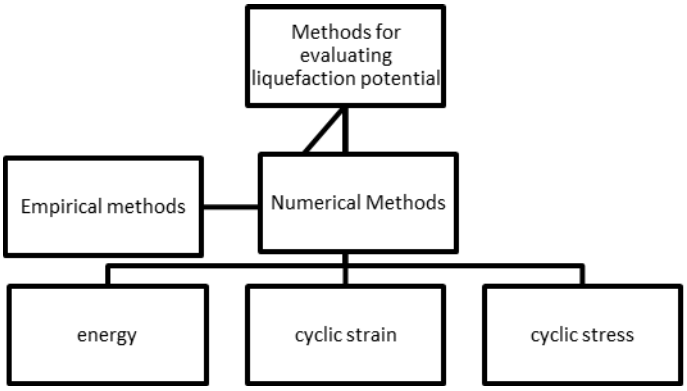

Figure 1: Methods of evaluating liquefaction potential

In recent years, several empirical methods are represented for evaluating soil liquefaction potential, including methods based on SPT tests, CPT tests or Geoseismic tests by measuring shear wave velocity. This study is paid attention to evaluating of liquefaction potential based on Soil aggregation and SPT number and with cyclic stress method. According to the goal of this paper is used laboratory and out-door data two boreholes drilled in the coastal city of Bandar Abbas for estimating liquefaction potential in different ways, and compares the results at the end of each method.

2. Report on geotechnical boreholes:

For this study, two borehole rings to a depth of 15 m are drilled in the coastal city of Bandar Abbas, and aggregation, hydrometer, Aterberg limits and moisture percent were performed on cheated examples. Outdoor tests of SPT type were performed in every 2 meters. Groundwater level is located at a depth of 2 meters in each borehole. Summary of the geotechnical results used in this study are listed in Tables 1 to 2.

Depth	Soil type	liquid limit	Plastic limit	Fine percent	D50	Wet density of soil kg/cm2	Spt
2	Silty Sand	NL	NP	18	0.092	1.56	9
4	Silty Sand	NL	NP	20	0.099	1.50	9
6	Silty Sand	NL	NP	20	0.132	1.56	13
8	Silty Sand	NL	NP	20	0.115	1.65	17
10	Silty Sand	NL	NP	31	0.115	1.70	22
12	Silty Sand	NL	NP	28	0.125	1.85	33
15	Silty Sand	NL	NP	33	0.136	1.85	37

Table 1 . Summary of geotechnical information on soil layers in borehole BH1

Depth	Soil type	liquid limit	Plastic limit	Fine percent	D50	Wet density of soil kg/cm2	number Spt
2	Silty Sand	NL	NP	21	0.119	1.56	9
4	Silty Sand	37.8	8.5	67	0.008	1.50	13
6	Silt	NL	NP	17	0.130	1.60	16
8	Silty Sand	NL	NP	19	0.146	1.60	19
10	Silty Sand	NL	NP	18	0.146	1.65	25
12	Silty Sand	NL	NP	18	0.165	1.87	30
15	Silty Sand	NL	NP	20	0.158	1.87	35

Table 2 . Summary of geotechnical information on soil layers in borehole BH2

3 . The theory:

In the cyclic stress method that is used to evaluate the liquefaction potential in this research, both stimulating factor (load) and the load (resistance) are expressed in terms of cyclic shear stress. By being tantamount the cyclic shear stress induced by loading to the initial vertical effective stress at the desired depth, the cyclic shear stress ration is defined as bellow:

$$CSR = \frac{\tau_{cyc}}{\sigma'_{v0}} \tag{1}$$

The cyclic shear resistance (CRR) is also defined as past cyclic stress being tantamount before start soil liquefaction. Therefore, the potential for soil liquefaction can be expressed in the form of factor of safety (FS) against liquefaction:

$$FS_L = \frac{CRR}{CSR} = \left(\frac{\text{resistance}}{\text{loading}} = \frac{\text{capacity}}{\text{demand}}\right) \tag{2}$$

3-1 Cyclic shear stress ratio:

Here, a simple method was introduced by Seed and Idriss [1] in 1984. It is used for estimating cyclic shear stress induced by earthquake at depth of Z as follow:

$$CSR = (\tau_{av} / \sigma'_0) = 0.65\left(\frac{a_{max}}{g}\right).\left(\frac{\sigma_v}{\sigma'_v}\right).r_d \tag{3}$$

Where amax, maximum horizontal acceleration is due to the earthquake on the ground, g acceleration of gravity, vσ total vertical stress, v'σ vertical effective stress and rd stress reduction coefficient in depth.

3-2 Cyclic shear resistance ratio:

As regard to obtaining undisturbed samples of deposits below the groundwater level is not very expensive and available in outdoor tested areas. Therefore, in this study is used simpler and more efficient method, standard penetration test. Several relations are presented for calculating the ratio of shear strength by using aggregation graph, Spt number, and sometimes paste limit of soils that are mentioned in this study in four methods:

1- Seed et al.(1983) [2]

2-Tokimatsu-Yoshimi(1983) [3]

3-NCEER Workshop(1997) [4]

4-Japan ' Bridge Code (1991) [5]

4 . Analysis of the results:

Assuming magnitude earthquake equal to 7.5 and maximum Acceleration at surface equal to 0.3, safety of factor against liquefaction is calculated and determined based on geotechnical data listed in Tables 1 and 2 at various depths. (In this paper the details of computational methods for determining the cyclic shear stress and cyclic shear strength is ignored) These results are presented in Tables 3 and 4.

Depth	soil type	FS Seed et al	FS Tokimatsu-Yoshimi	FS NCEER Workshop	FS Japan ' Bridge Code
2	Silty Sand	1.033	0.995	1.004	2.219
4	Silty Sand	0.778	0.768	0.729	1.654
6	Silty Sand	0.899	0.860	0.883	1.511
8	Silty Sand	1.072	1.006	1.031	1.583
10	Silty Sand	1.242	1.154	1.350	1.598
12	Silty Sand	1.997	1.736	2.822	1.747
15	Silty Sand	2.152	1.873	2.862	1.724

Table 3 . Summary of liquefaction calculation results in borehole BH1

Depth	soil type	FS Seed et al	FS Tokimatsu-Yoshimi	FS NCEER Workshop	FS Japan ' Bridge Code
2	Silty Sand	1.033	0.995	1.019	2.070
4	Silt	0.981	0.934	1.070	3.135
6	Silty Sand	1.056	0.993	0.986	1.618
8	Silty Sand	1.192	1.112	1.153	1.535
10	Silty Sand	1.432	1.307	1.766	1.570
12	Silty Sand	1.747	1.535	2.833	1.563
15	Silty Sand	1.979	1.721	2.864	1.615

Table 4 . Summary of liquefaction calculation results in borehole BH2

With regard to consideration of FS (factor of safety) equal one in this study, therefore it is observed that up to the depth of 6 meters from surface, soil layers are susceptible to liquefaction. Factor of safety against calculated liquefaction in each of the methods are shown different results, and also significant differences. Therefore, the point is determining the correct safety of factor against liquefaction that it should be chosen based on the introduction of earthquake levels and performance of structure. It is noted that if factor of safety is equal to 1.2 in depths of 10 m in borehole BH1 by Tokimatsu-Yoshimi method, soil layer is not liquefaction but soil layer in other methods is able to liquefaction.

5. Discussion and conclusion

This study compares study methods of evaluating the liquefaction potential for sandy soils in the coastal area of Bandar Abbas which results indicate that the liquefaction potential assessment methods is outlined each with its own strengths and weaknesses. For example, the results of Japan Bridge Code with other methods are considerable. On the other hand, the choice of FS (factor of safety) in the soil liquefaction potential is very important So that if not selected based on the performance of structures and earthquake levels correctly, can lead to wrong conclusions in determining liquefaction potential. Therefore it is recommended to evaluate the liquefaction potential beside the selection of appropriate confidence coefficient, check be done by various methods and do not comment definitely just by one method and particularly recommends for important structures to use cyclic triaxial tests.

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