LIQUEFACTION SUSCEPTIBILITY ASSESSMENT OF A SOIL DEPOSIT

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ABSTRACT

It is important for civil engineers to know whether the soil at the site is liquefiable or not under any seismic conditions, so that suitable methods can be adopted, if required before construction of any building or any other project. Recently a lot of research has been done in this regard. In the past, number of investigators made their investigations in this field and developed various methods to assess the proneness of soil deposit to liquefaction at various depths. Out of these methods the cyclic stress approach is most commonly used. In this paper the cyclic stress approach has been discussed.

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INTRODUCTION

In common usage liquefaction refers to a condition of soil when it start behaving like a liquid such that there is transformation from a solid state of soil to liquefied state as a result of increased pore water pressure and reduced effective stress. Liquefaction occurs during an earthquake, when the pore water pressure in saturated cohessionless soil becomes so great that the particles of soil become suspended in the water. More precisely liquefaction is defined as a state of temporary loss of shear strength in cohesion less, saturated soil that results from instantaneous increase in its pore water pressure during heavy ground shaking such as during an earthquake. The concise proper definition for liquefaction of soil has been the subject of continuing debate among the geotechnical profession.

THEORY

When the soil deposit is subjected to vibration or shaking during an earthquake, it tend to decrease and compact in volume. Propagation of shear stress causes the cohesion less loose soil to contract. As water in the pore spaces is forced out so soil particles tend to tend to rearrange themselves into a dense packing, with reduced space in the voids. However, if the drainage of water in the pore spaces is impeded then this tendency to compact in volume results in instantaneous and progressive increase in pore water pressure and so loss of shear strength occurs. The condition of liquefaction occurs after loss of shear strength due to transfer of stress from soil to pore water pressure during dynamic loading. After transfer of stress the shear strength is controlled by resulting effective stress. If there is complete transfer of stress then total liquefaction occurs but if only partial stress is transferred, then partial loss of shear strength takes place, which results in partial liquefaction. In this paper the cyclic stress approach of assessing liquefaction susceptibility has been discussed.

LIQUEFACTION SUSCEPTIBILITY ASSESSMENT BY CYCLIC STRESS APPROACH

Liquefaction susceptibility of soil is a measure of its inherent resistance to liquefaction, and can vary from non susceptible to highly susceptible, regardless of seismic loading, which means very small seismic energy is required to induce liquefaction. Liquefaction susceptibility is evaluated using primary soil properties such as fine content, grain size, degree of saturation, density, age of soil deposit and SPT-N values in each of the bore hole. Common methods for evaluating the liquefaction potential during an earthquake have been given by Seed and Idriss(1971), Ishihara(1977), Seed method(1979), Iwasaki et.al.(1984), Seed et.al.(1983,1984), Robertson Campanella(1985) and Youd et.at.(2001). These methods use laboratory test data to evaluate the stress condition necessary to cause liquefaction and in-situ penetration test data. Most of these methods use cyclic stress approach, which involve three main steps:

1. Estimation of CSR, where CSR is the cyclic stress ratio caused by anticipated earthquake.
2. Estimation of CRR, where CRR is the cyclic resistance ratio that represents the liquefaction resistance of in-situ soil.
3. Determining the factor of safety (FS) against liquefaction, which may be defined as FS = CRR/CSR.

Liquefaction would occur if FS is less than unity. Generally a minimum FS of 1.25 to 1.5 is specified. The cyclic stress ratio (CSR) produced by the earthquake can be estimated as (Seed et.al.(1983))

$$\frac{\tau_h}{\sigma_0'} \cong 0.65\left(\frac{a_{max}}{g}\frac{\sigma_0}{\sigma_0'}r_d\right) \qquad \ldots(1.1)$$

where

g is acceleration due to gravity.

α_{max} is peak ground acceleration.

σ_0 is total overburden pressure at the depth under consideration.

σ'_o is the effective overburden pressure at the depth under consideration.

r_d is the stress reduction factor.

r_d can be approximated as (Seed and Idriss, 1971)

r_d = 1- 0.008 x depth in meters.

Seed(1979) and Seed et.al.(1983) suggested that CRR i.e. cyclic stress ratio to induce liquefaction could be estimated from a modified penetration resistance N_1 = NCN, and the magnitude of earthquake M. Seed et.al.(1985) proposed a modified correlation, in which the stress ratio to induce liquefaction was related to corrected and modified value of N_1 , $(N_1)_{60}$. The corrected SPT number indicated as $(N_1)_{60}$ is obtained from SPT number $(N)_{60}$ measured in the field.

$$(N_1)_{60} = N_{60} \sqrt{(100/\sigma'_z)} \qquad \ldots(1.2)$$

where

$(N_1)_{60}$ is SPT number corrected for overburden pressure.

$(N)_{60}$ is measured SPT number (duly corrected for field procedures)

σ'_z is vertical effective stress at test section (kPa)

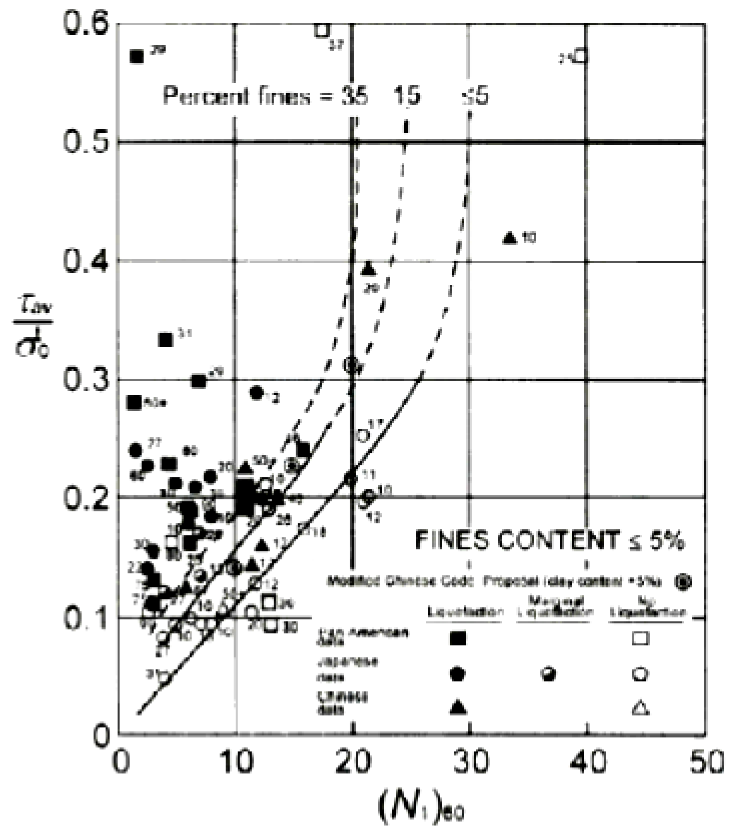

Figure 1: Cyclic stress ratio to cause liquefaction as a function of corrected SPT $(N_1)_{60}$.

Figure1 gives the relationship between the SPT number $(N_1)_{60}$ and the cyclic stress ratio (CRR) to cause liquefaction for different values of percentage of fines for an earthquake of magnitude 7.5. The value of CRR can be corrected for magnitude of earthquake other than 7.5 using the relation

$$(\tau/\sigma'_o)_M = \psi\ (\tau/\sigma'_o)_{7.5} \qquad \text{…(1.3)}$$

Where $(\tau/\sigma'_o)_M$ is the cyclic stress ratio for magnitude other than 7.5 i.e. for magnitude M and $(\tau/\sigma'_o)_{7.5}$ is that for the magnitude 7.5 obtained from fig.1. Various investigators gave different value of ψ for different magnitudes; it decreases with increase in the magnitude of the earthquake. Iwasaki *et al.* (1984) have extended the approach of Seed *et al.* (1983). They define the liquefaction resistance factor *F*L as:

$$F_L = \frac{R}{S_S} \qquad \text{…(1.4)}$$

where *S*s is the cyclic shear stress ratio due to earthquake and *R* is the in-situ cyclic undrained normalized shear strength of the soil and is determined as follows:

(a) For 0.04 mm ~ D_{50} ~ 0.6 mm

$$R = 0.0822\left(\frac{N}{\sigma_v'+0.7}\right)^{0.5} + 0.225\log_{10}\frac{0.35}{D_{50}}$$

…(1.5)

(b) For 0.6 mm ~ D_{50} ~ 1.5 mm

$$R = 0.0822\left(\frac{N}{\sigma_v'+0.7}\right)^{0.5} - 0.05$$

…(1.6)

where σv' is the effective overburden pressure (in kgf cm-2), D_{50} is the mean particle diameter (in mm) and *N* is the standard penetration test (SPT) number. The cyclic stress ratio *S*s is given by Equation 1.1. Iwasaki *et al.* (1984) propose the following simplified procedure based on onshore field observation for liquefaction risk assessment:

$I_L = 0$ very low risk

$0 < I_L < 5$ low risk

$5 < I_L < 15$ high ris

$15 < I_L$ very high risk

Where I_L is the liquefaction potential index and is defined as

$$I_L = \int_0^{20} FW(z)dz$$

…(1.7)

where $F = 1 - F$L for FL <= 1.0 and $F = 0$ for FL > 1.0

The liquefaction potential index I_L depends critically on the maximum ground acceleration.

CONCLUSION

Out of the methods discussed above the method suggested by Seed et.al.(1983,1984) for assessing the liquefaction susceptibility of soil by cyclic stress approach is mostly preferred because it requires comparatively less calculations and give reasonably reliable results.

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