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Liquefaction Susceptibility: A Review

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ABSTRACT: In last few decades, development of liquefaction susceptibility evaluation is included. Due to the sensitivity of the fine soils and the actual liquefaction in previous earthquakes, the Modified Chinese Criteria can be ensured by reconsideration and modification. Modified Chinese Criteria, are world-recognized best-known indicator. After being disturbed by a cyclic load, there is a controversy and confusion of the fine-grained soils behavior is complex. In Modified Chinese Criteria, the plasticity index is the best suitable controlling parameter to replace the clay fraction. For the ease of assessment, plasticity index can confidently distinguish the fine-grained soils behavior. Fine-grained soil could be either like clay which expected to be cyclic softening or like sand, that susceptible to liquefaction phenomena. In this way, we can understand the cyclic behavior of fine-grained soils and which leads to a more accurate and confident output. Thus, the Chinese Criteria should replace fine percentage with the plasticity index in the assessment. This paper based on the previous related research on liquefaction susceptibility.

KEYWORDS: Liquefaction susceptibility; fine-grained soil; Chinese Criteria

I. INTRODUCTION

In the phenomenon of liquefaction, the strength and stiffness of a soil are reduced by earthquake shaking or other rapid loadings. By using laboratory testing program, liquefaction susceptibility is calculated and in these includes tests on a small shake table, by which the frequency and amplitude of harmonic excitation can be controlled. The number of cycles and porewater pressure at liquefaction is measured. After the several important earthquakes, extensive study of liquefaction was done by researchers around the world. Evaluation of earthquake-related soil liquefaction phenomena and related ground failures is one of the important aspects in geotechnical engineering. Researcher attempted to identify the type of soil highly susceptible to liquefaction based on both empirical and theoretical behavior. There is still no qualitative and quantitative parameters in the geotechnical field, the sensitive of liquefaction can be used as the evaluation tool. Although the researchers had tried to identify the type of soil highly susceptible to liquefaction based on both empirical and theoretical behavior, no qualitative and quantitative parameters can be used in the geotechnical field could be used as an evaluation tool on liquefaction susceptibility.

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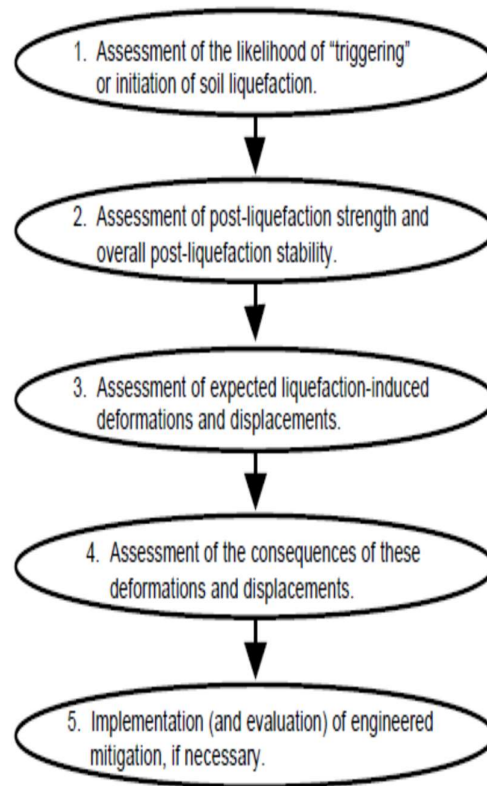


Fig. 1: Key Elements of Soil Liquefaction Engineering

II. LITERATURE REVIEW

- A. **H. B. Seed, and I. M. Idriss (1982):** Chinese Criteria is one of the best-known liquefaction susceptibility recognition established by Wang (1979). Seed and Idriss (1982), based on the reassessment of Wang's work, stated that three basic criteria by highly susceptible soil for liquefaction behavior must fulfill; (1) contains less than 15% clay fraction (finer than 0.005 mm); (2) liquid limit (LL) less than 35%; (3) water content (WC) higher than 90% LL. Although, this process is very conservative and less reliable, because it is different from the process of ASTM International on the determination of the soil index such as liquid limit.

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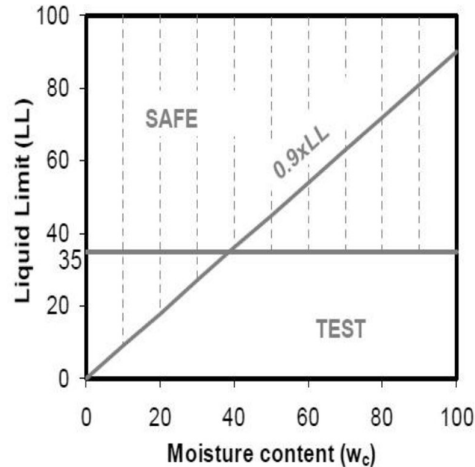


Fig 2: Chinese Criteria after Wang (Seed and Idriss, 1982)

B. Andrews and Martin (2000): In this paper, Andrews and Martin have prepared a refined empirical data and produced a new evaluation index as shown in table 1. It is a change of Chinese Criteria in according to the US standard. The main difference between Modified Chinese Criteria and original Chinese Criteria is 0.0002 mm was used as the limit between clay. And the silt particles and the liquid limit should be obtained by the Casagrande apparatus.

Table 1: Modified Chinese Criteria (Andrews and Martin, 2000)

Clay content	Liquid limit < 32%	Liquid limit ≥ 32%
< 10%	Susceptible	Further studies required (considering plastic non clay sized grain- mica)
>10%	Further studies required (considering non-plastic clay sized grain-mine and quarry tailings)	Not Susceptible

C. Guo and Prakash, (2000): Guo and Prakash discussed test on silt-clay mixtures. By analysis of the testing on the mixture of silt-clay, it was found that the value of threshold value of PI at around 4-5. The mixture of silt-clay is more susceptible to liquefaction. At lower plasticity range, PI is inversely proportional to the liquefaction resistant. While at higher plasticity range, PI is directly proportional to liquefaction resistant (Fig 3). Therefore, maximum details and comprehensive studies are warranted to prove that the lowest level of liquefaction resistance is PI = 4. They recommend that more research is needed to understand the seismic behavior of fine-grained soils.

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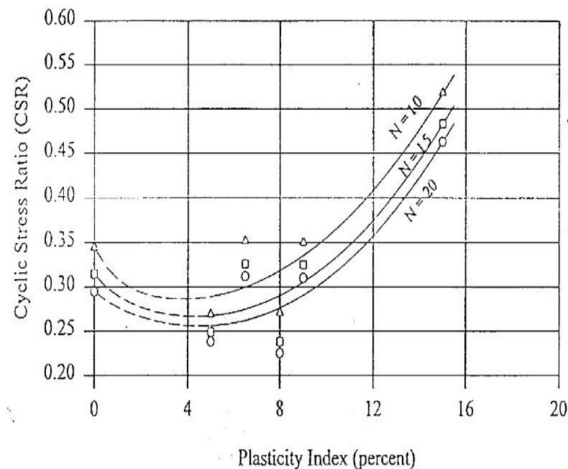


Fig 3: Normalized cyclic ratio vs plasticity index on undisturbed samples (Guo and Prakash, 2000)

- D. Seed et al (2003):** In this paper, Seed et al. recommended an assessment chart include Modified Chinese Criteria with the influences of fines contents in the assessment (fig 4). The soil laid in Zone A soil is likely to be liquefaction while in zone B it is potentially highly susceptible to liquefaction. Soils which are not out of the Zone A and Zone B are considered non-liquefiable.

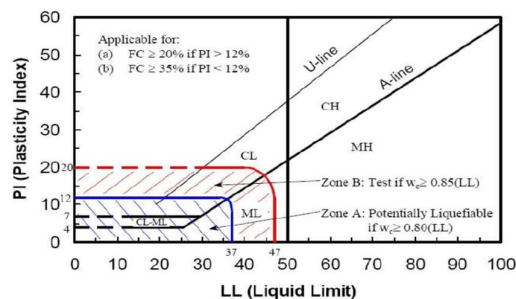


Fig 4: Recommendations Assessment of Liquefiable Soil Types (Seed et al., 2003)

- E. Sancio and Bray (2003):** In this paper, Sancio et al studied the investigation on the ground failure in Adapazali caused by 1999 Kocaeli Earthquake. The liquefaction phenomenon of Adapazali soil having the significant number of clay-size particles which is non-liquefiable, it is obtained from the result of tests on undisturbed soil samples from the sites. Apart from this, the properties of soil in liquefaction cases were tested in the Chi-Chi earthquakes in 1999, and found that the properties of soil are different from the Modified Chinese Criteria.
- F. Bray and Sancio (2006):** In this paper, Bray and Sancio discussed that PI. They say the PI is the best index of liquefaction susceptibility with WC / LL criterion. Liquefaction start to occur on loose dense soils of $PI < 12$ (low plasticity) at $WC / LL > 0.85$ while soils between PI of 12 to 18 were less liquefaction potential, this is based on field observation and cyclic tests result. $PI > 18$ shows that the soils are not susceptible to liquefaction. Although, based on the self-engineering decision, this proposed criterion should be used with caution. For liquefaction susceptibility, factors such as soil mineralogy void ratio and etc., PI is a good screening tool and it should be implicitly taken into consideration.

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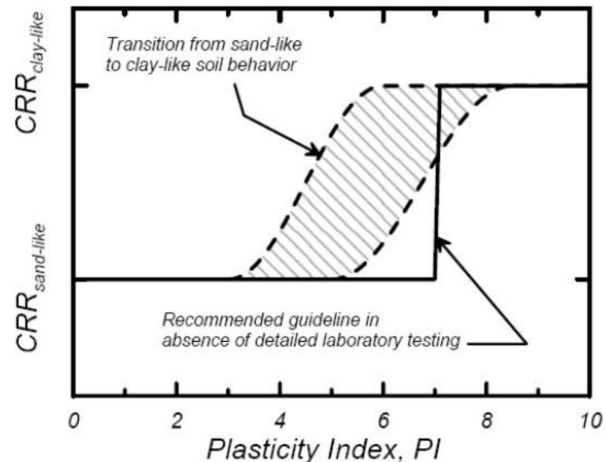


Fig 5: Transition of sand-like to clay-like behavior of fine-grained soils (Boulanger and Idriss, 2006)

- G. Gratchev et al (2006):** In this paper, Gratchev et al. check the validity of using PI as a screening parameter based on literature. Based on the results of undrained cyclic stress-controlled ring-shear tests, the value of the PI is increasing then liquefaction potential of soil decreasing and liquefaction will not happen to soil with $PI > 15$.
- H. Prakash and Puri (2010):** In this paper, Prakash and Puri discussed that how they extended their previous work and told that the use of fine percentages for liquefaction susceptibility determination should be discontinued. The plasticity index provides extra quality reviews and more research is required to fill the gap in the literature.

III. CONCLUSION

In this paper has been told about the development of susceptibility of liquefaction. Due to the disagreements in the index of soil testing, the basic Chinese Criteria was changed to Modified Chinese Criteria to fit the standards of use globally according to ASTM International. Although the revised Chinese Criteria are well known, the usefulness of the Chinese Criteria was in the doubt when it deviated from the real field observation of the previous earthquake. So, review on fine-grained soils which vulnerable to liquefaction must be study and more relevant research was required on this. Researchers found similarity and inquiries on the use of clay fraction as screening criteria in Chinese Criteria. In the study on liquefaction susceptibility by researchers, consider the plasticity index to control variable. According to the current literature reviews, it was believed that the clay fraction can get wrong results. The cyclic behavior of fine-grained soils is well understood then it produces to a more accurate and confident. So, in this way, the Chinese Criteria should be replaced with the fine percentage with the plasticity index in the criterion.

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