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Assessment of the liquefaction susceptibility of Al-Nasiriya city soil based on plasticity properties

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ABSTRACT

The present paper is focused on using some of the geotechnical properties to assessment of liquefaction of Al-Nasiriya city soil. Four sites have been selected along both sides of Euphrates river. The geotechnical properties were used to separate soils that may be classified as susceptible to liquefiable from those non liquefiable. The criteria which are used in this study included effect of plasticity, natural moisture content, clay content, and voids ratio on the liquefaction susceptibility of soil. This study shows that 91% of soil samples lie within cyclic mobility zone depending on plasticity chart while according to natural moisture content and clay content, 100% and 81% of soil samples were classified as non-liquefiable soils.

Keywords: Al-Nasiriya Soil; Atterberg Limits; Clay Content: Liquefaction; Moisture Content; Plasticity Properties

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1. Introduction

The study of the geotechnical and dynamic parameters of the soil is of great importance in solving problems related to earthquakes engineering thus this phenomenon is one of the most important engineering problems that occurs during and after earthquakes or by strong ground motions. Soil liquefaction phenomenon represents the loss of soil strength and stiffness under the influence of rapid dynamic loads such as earthquakes, vibroflotation, blasting, and pile driving. This phenomenon makes the mass of soil behave like a liquid mass and soil can be deformed easily under the influence of this state and it can lead to deform and damage of structures constructed above this soil. Soil liquefaction may lead to decrease in bearing capacity and an increase in the rate of settlement in addition to horizontal movement due to lateral spreads of liquefied soils and it can be observed the effect of soil liquefaction damage on engineering structures such as schools, roads and bridges, drinking waters and energy resources [1].

During the ground shaking or ground movement, the phenomenon of soil liquefaction occurs as a result of the dynamic loading that increases the pore water pressure suddenly and then reduces the effective stresses of the soil.
There are a number of conditions for which their presence is suitable for occurrence of liquefaction phenomenon [2]. These include the following:

- Presence of deposits of sandy or silty soils,
- Saturated soil below the underground water table level,
- Loose or medium compact soil,
- Low value of soil permeability test,
- Soil subjected to seismic activities such as blast, earthquake, etc…

Therefore, the soils which have loose to moderately saturated granular with low drainage are the best often for occur the phenomenon of liquefaction. One of the most sediments subjected to this phenomenon is belong to Holocene age sediments (recent sediments) represented by silty sands, sands and gravels which composed of similar particles sizes, thus the well sorted soil (uniformity graded soil) is more susceptible to soil liquefaction than a poorly sorted (well graded soil).

Soil susceptibility and response to earthquakes are assessed and determined through field studied by determining the dynamic properties of the soil or by theoretical methods based on geotechnical criteria [3-6].

One of the most important criteria used to determine susceptibility soil liquefaction is Chinese criteria [7]. According to these criteria, the phenomenon of soil liquefaction occurs if the following conditions are met: particles of soil finer than (0.005 mm) should be lesser than or equal to (15%), liquid limit (LL) smaller than or equal to 35%, and natural moisture content greater than or equal to (90%) of liquid limit (LL). Many researchers have modified Chinese criteria based on field experiences in addition to differences in testing methodologies [8-12].

Although the study area is located within the Mesopotamian plain (Mesopotamian zone), which is considered safe from seismic activities. Moreover it is this area classified as no damage zone III [13]. However, the increase in seismic activities in last recent years and the exposure of the study area to the frequent hits of earthquakes in addition to that the Mesopotamian plain contains a thick of quaternary deposits.

All of this requires reconsidering the probability that to be this area is eligible for seismic risk. Therefore, this study was come to determine the susceptibility to soil liquefaction if exposed to any kind of sudden ground movements.

2. Location and geological setting

The study area is the city of Nasiriya, the center of Thi-Qar province which is located in southern Iraq within a flat plain (Mesopotamian plain). Holocene age sediments cover surface of the city comprising flood plains deposits, fluvial deposits, marshes deposits, and Aeolian deposits which are considered a part of the Mesopotamian sediments [14].
The study area represents selected four sites from Nasiriya city distributed on both sides of the Euphrates river as shown in Fig.1.

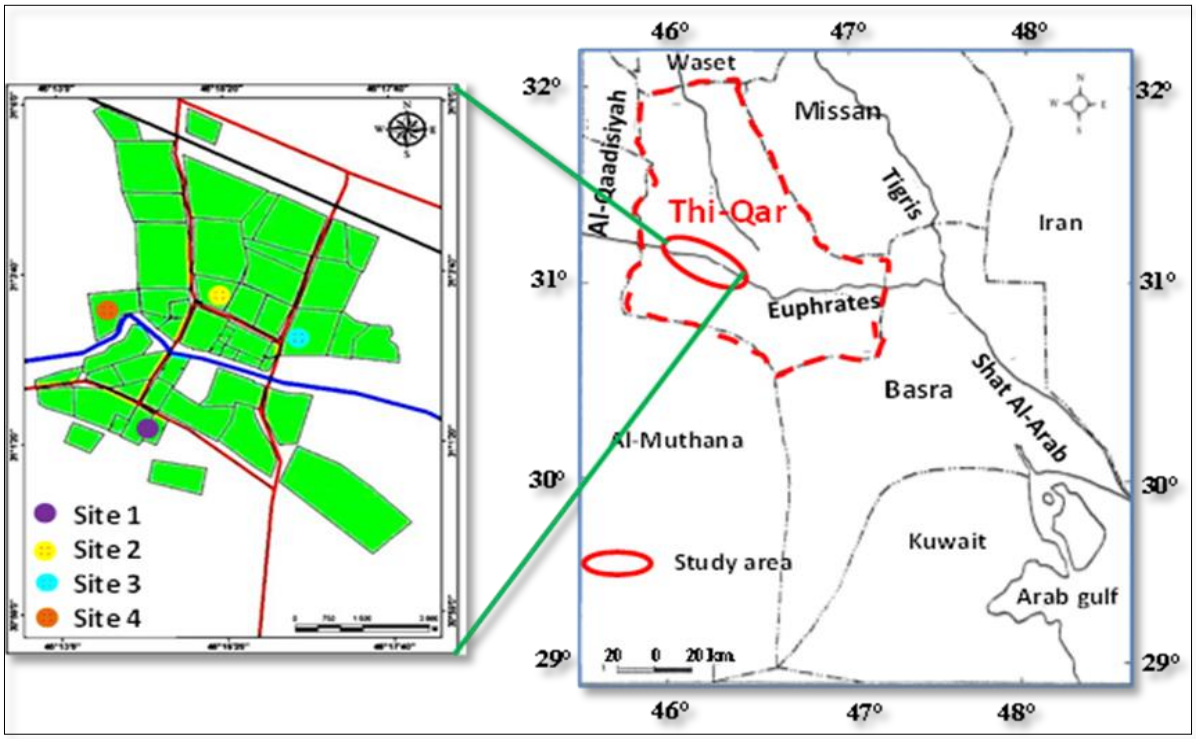


Figure 1. Sites distribution on Al-Nasiriya map

2.1. Seismicity of the studied area

Iraq is located in a relatively active seismic geographical location on the northeastern border of the Arabian plate. The seismic history of Iraq refers to seismic activities with various forces in the northern and northeastern regions as well as some southern and southwestern regions of Iraq witnessed seismic events, but less effectively than in the north and northeast of Iraq [15].

Tectonically, the city of Nasiriya lies within the Euphrates subzone which is considered as part of Mesopotamian zone of unstable shelf [16, 17] while Jassim and Goff have considered the Mesopotamian zone as a portion of the stable shelf [13,18]. As shown in Fig.2, Al-Nasiriya city lies within the no damage zone according to the map of seismic zoning [13].

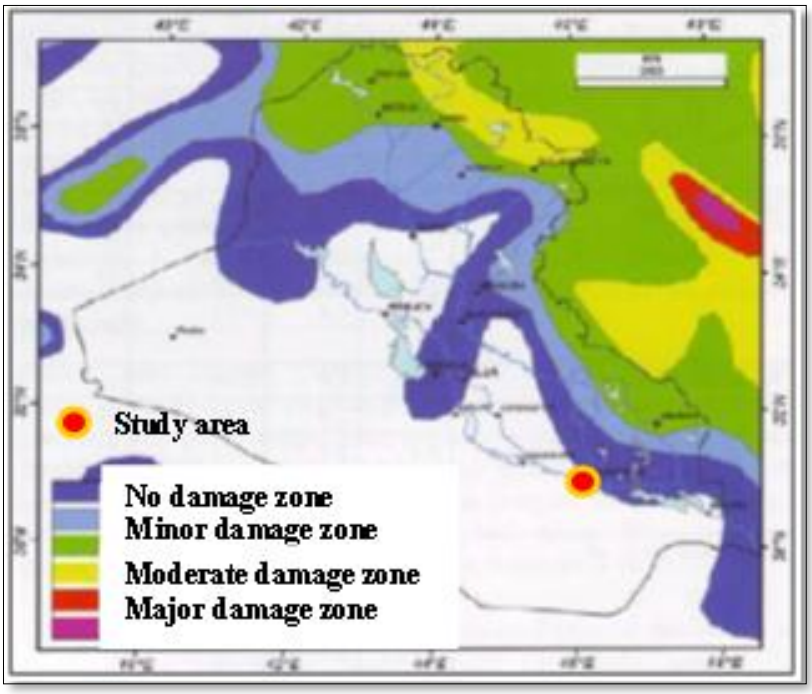


Figure 2. Isointensity Map of Iraq (Jassim and Goff, 2006).

3. Materials and methods

To achieve the objective of the study, soil investigation reports completed by the national center for construction laboratories were used for four projects distributed in the city center on both sides of Euphrates river as shown in Fig.1

Dependence on the American international standards (American society for testing and materials ASTM) for laboratory tests, the laboratory tests were carried out on samples of the study area for the purpose of obtaining the required physical properties.

The results of the particle size analysis, atterberg limits, natural moisture content, and clay content were subjected for analysis and discussion in this study. Table.1 and Fig.3 present descriptive statistics of variables (parameters) used in this research and their frequency distributions.

Table 1. Statistical values of physical properties of Al-Nasiriya city soil

Count	SD	Average	Min	Max	Parameter
43	10.58	48.44	30	74	LL (%)
43	3.989	27.6	21	37	PL (%)
43	8.692	21.07	3	38	PI
43	5.371	28.43	19	39	W_n (%)
43	15.19	31.65	4	61	C (%)

LL liquid limit, PL plastic limit, PI plasticity index, Wn natural moisture content, C clay content, Max maximum, Min minimum , SD standard deviation

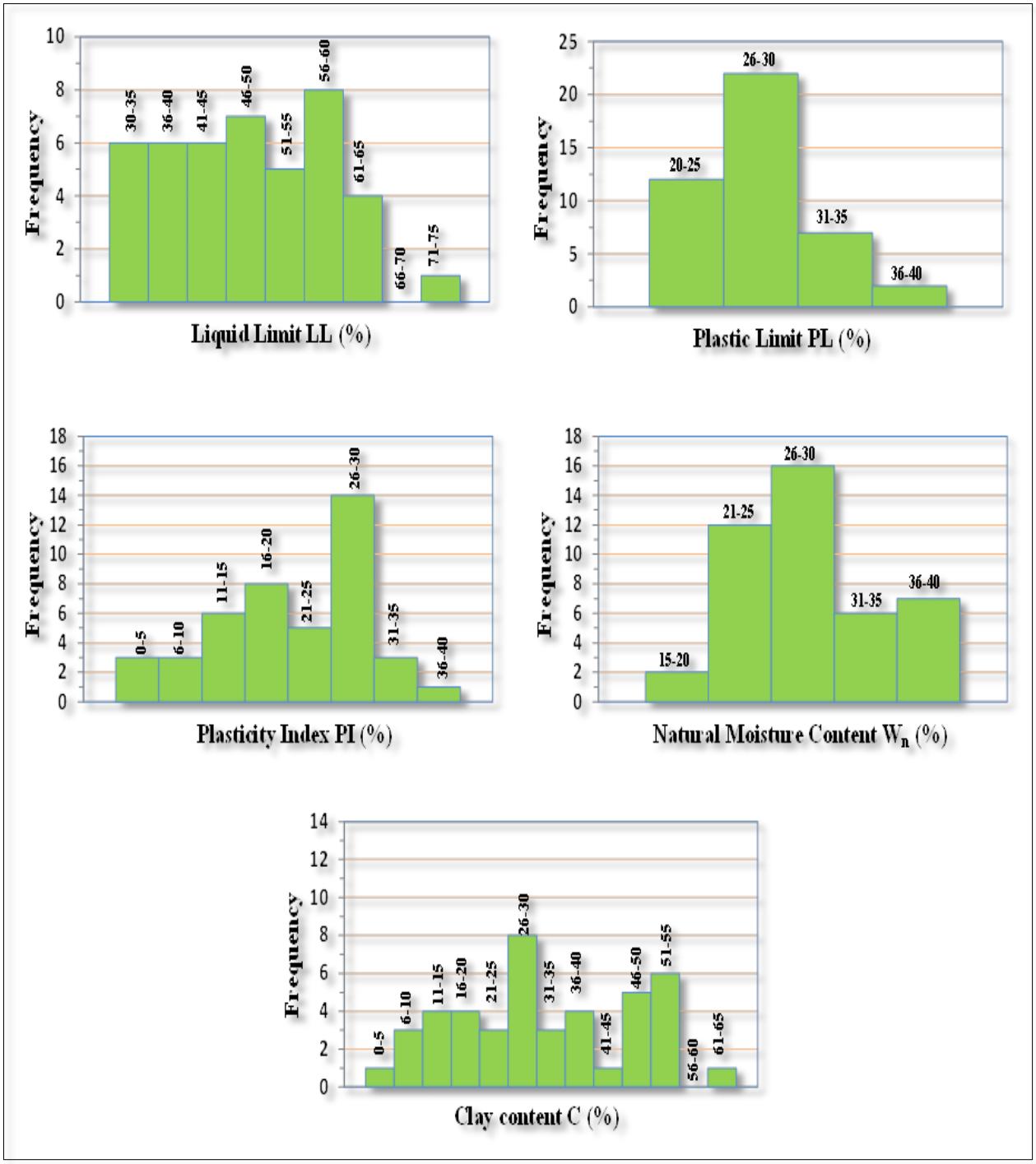


Figure 3. Histogram of data – studied area (Al-Nasiriya city)

4. Results and discussion

The particle size analyses were conducted according to [19], the percentages of clay, silt, sand, and gravel of soil samples are plotted against depth in Fig.4. It can be seen that Nasiriya soil is predominantly silt and clay with low percentages of sand but with the depths there is tendency for increasing sand content as observed in site 3.

Atterberg limits (consistency limits) tests were performed according to [20], Fig.5 shows the variations of liquid limit, plastic limit, and plasticity index with different depths. In general, the values of liquid limits range between (30-74%) while the values of plastic limits range between (21-37%) also, the plasticity indices values range between (3-38%).

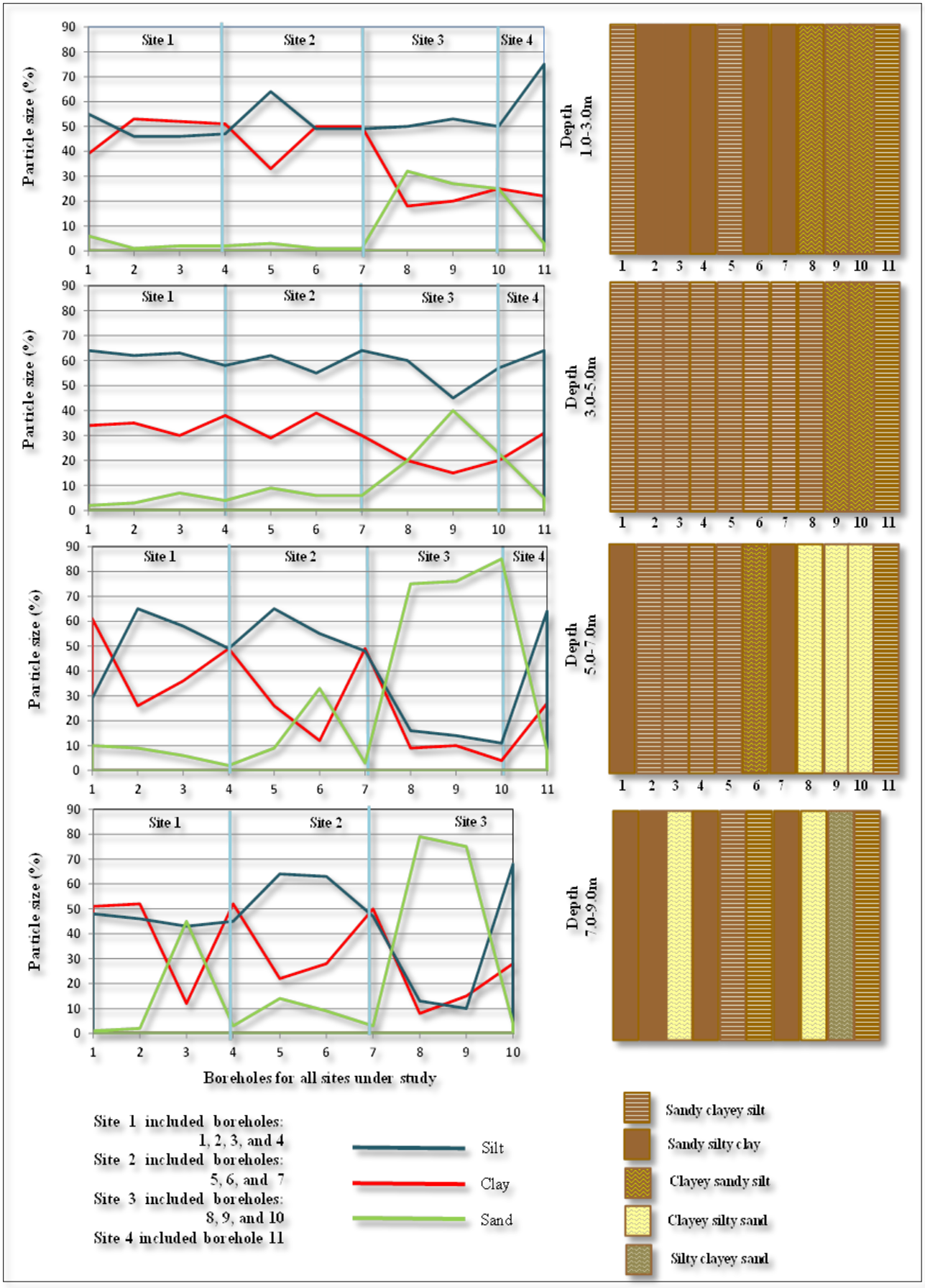


Figure 4. Variations of particles size percentages of Nasiriya city soil

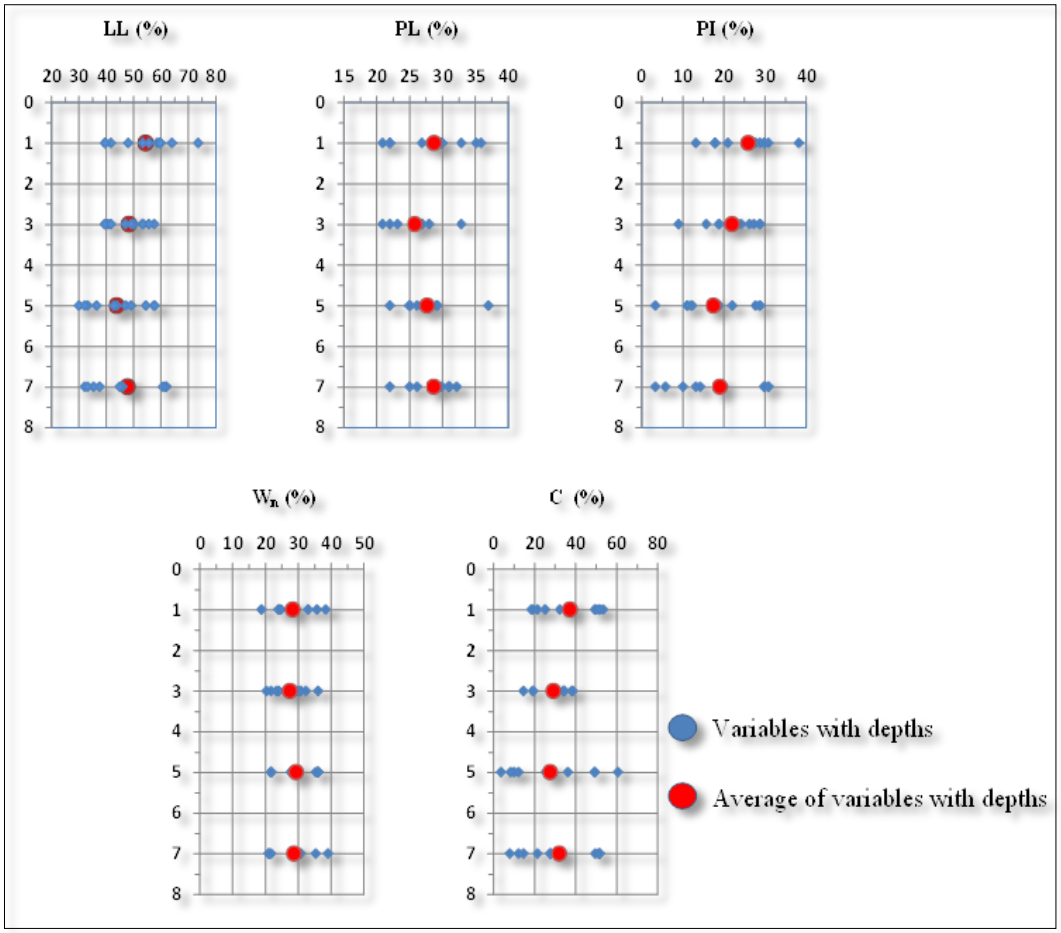


Figure 5. Variation of liquid limit, plastic limit, plasticity index, natural moisture content, and clay content

The unified soil classification system (USCS) were used to classify soil of Nasiriya city, it was found that 42% of data fall in the classification clay of high plasticity (CH) and 40% of data indicates clay of low plasticity (CL) while (18%) of data indicates silts of low plasticity (ML) on the plasticity chart as shown in Fig.6.

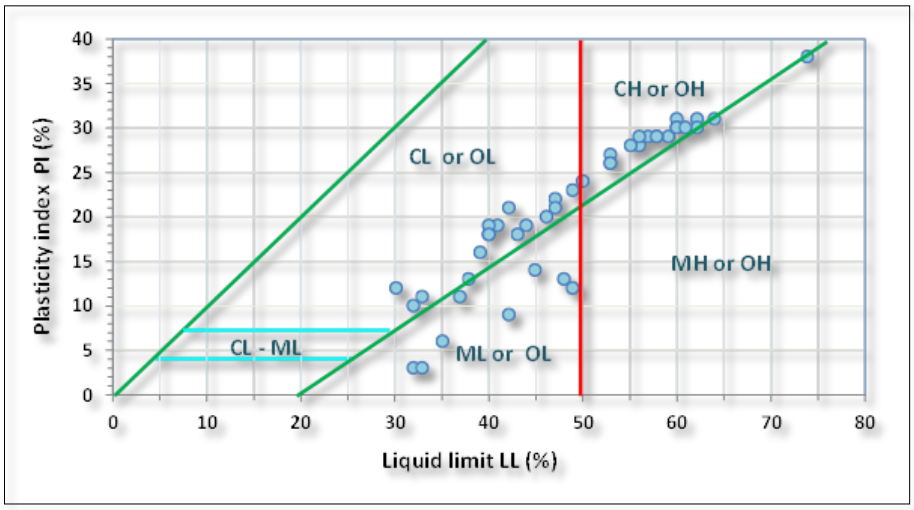


Figure 6. Plasticity ccharacteristics and soil classification

The factors were used in this paper to evaluation the soil liquefaction include soil plasticity (liquid limit, and plasticity index), water content, and clay content.

Assessment of soil liquefaction is on a basis of their response to flow susceptible or cyclic mobility. In both cases, effective confining stress is approximately equal to zero but behaviors of these soils are quite different. Soils susceptible to cyclic mobility undergo small deformations with only temporary strength losses while soils that susceptible to flow liquefiable undergo large displacement with sudden strength loss [21].

According to criteria proposed by[8-10] the soil with liquid limit greater than 36% may be considered as non-liquefiable soil while the soil with liquid limit between (34-36%) a threshold between non-liquefiable soil and soil of liquefiable. There are 38 soil samples with liquid limits greater than 36% therefore, Fig.7 indicates that 88% of the soils tested would be declared non liquefiable according to requirement.

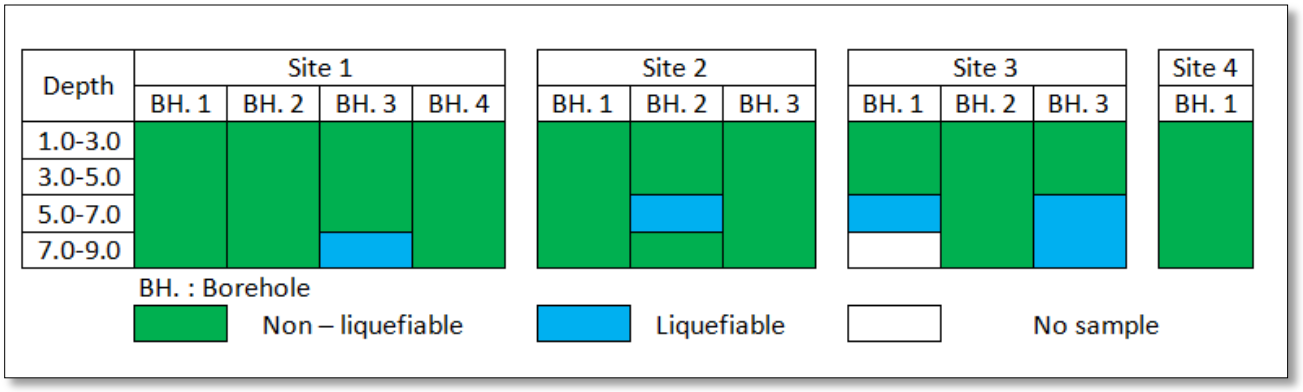


Figure 7. Variation of soil liquefaction with depth for all sites based on liquid limit

According to Chinese criteria the soil with plasticity index greater than 10% to be considered non liquefiable, of 43 soil samples tested, 37 of them had plasticity index greater than 10% therefore 86% of the soils tested would be considered non liquefiable according to requirement as observed in Figure-8. The plasticity index is one of the most important and best criteria in describing soil susceptibility to liquefaction compared to other criteria such as clay content, liquid limit, plastic limit, and activity [22].

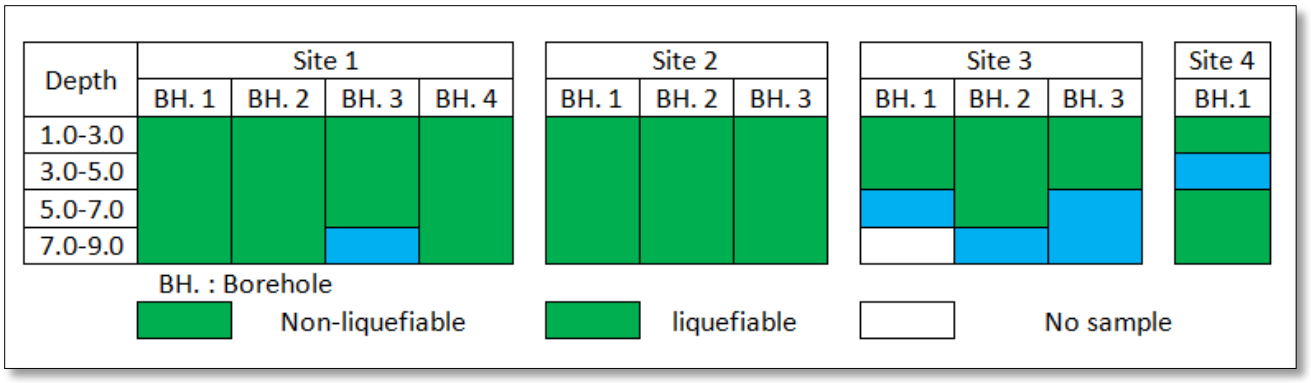


Figure 8. Variation of soil liquefaction with depth for all sites based on plasticity index

Based upon plasticity chart as shown in Fig.9 the soils with liquid limits less than (25%) and plasticity indexes less than (7%) would be considered susceptible to flow liquefaction therefore it can be observed there is no soil within liquefiable zone. While soils with liquid limits between (25-35%) and plasticity indexes between (7-10%) tend to be safe against flow liquefaction thus there are (9%) of soil samples within potentially liquefaction zone. Moreover, it is found that (91%) of soil samples with liquid limits greater than 35% and plasticity indices greater than 10% within the cyclic mobility zone.

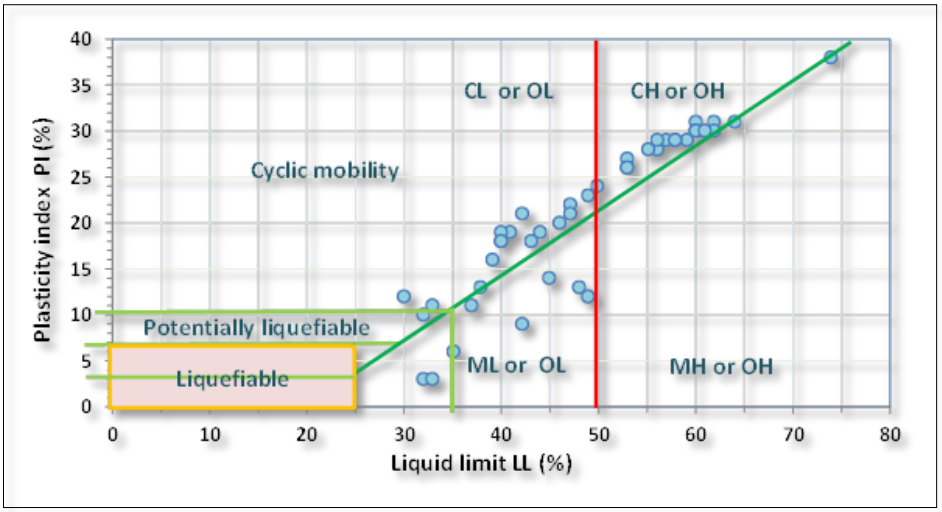
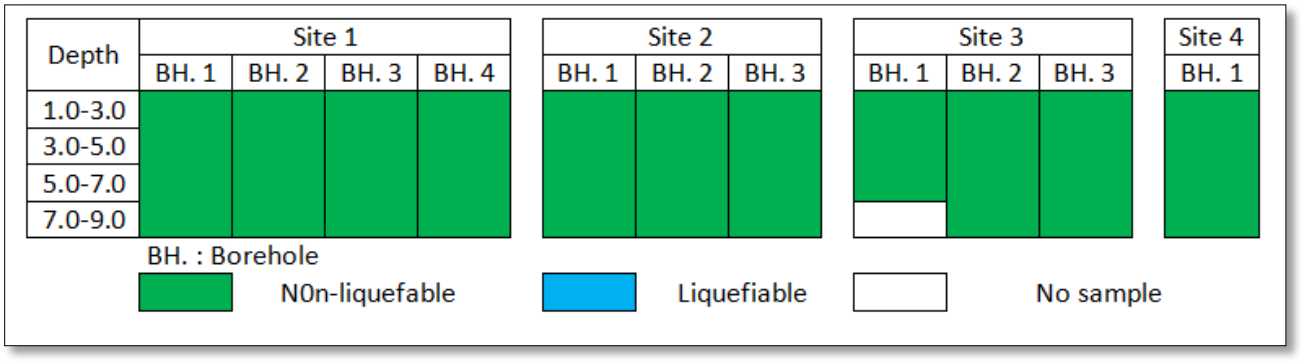


Figure 9. Liquefaction behavior on plasticity chart

The natural moisture content tests were performed according to [23]. It is clear that the values of natural moisture content varies from (19%) to (39%) with an average value of (28.43%) as observed in Fig.5. Seed et al. 1983 [8] proposed that soils with natural moisture content more than (90%) of their liquid limits would be considered as liquefiable soils, thus all of forty three samples (100%) would be considered non- liquefiable as shown in Fig.10.



Fgure 10. Variation of soil liquefaction with depth for all sites based on natural moisture content

Also, it has been noticed that there is variation of percentage of clay content (<0.002mm) with depths as shown in Figure-5 , thus, it can be observed that the range of clay particles is approximately from (4%) to (61%) with an average value of (31.65%). According to Seed et al. 1983 [8] and Esraa 2011 and 2014 [24] [25] [26] and Demir et al 2018 [27], soils with clay contents greater than 15% be considered non-liquefiable. Of the forty three soils tested, 81% would be considered non-liquefiable based upon this requirement as shown in Fig.11.

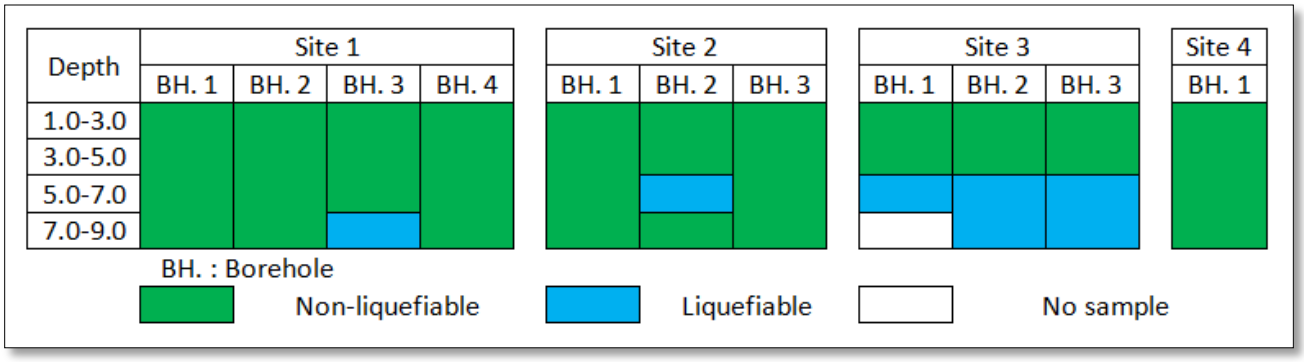


Figure 11. Variation of soil liquefaction with depth for all sites based on clay content

5. Conclusions

The main conclusions could be concluded from this research as follows:

- Al-Nasiriya city soil is predominantly composed of silt and clay with low percentage of sand but with the depth there is tendency for increasing sand content.
- According to unified soil classification system, Al-Nasiriya soil is predominately classified as clays of high plasticity (CH) to clays of low plasticity (CL) with presence of silts of low plasticity (ML) in a few amounts.
- Based on the seismic zoning map, Al-Nasiriya city soils lie within the no damage zone.
- It has been observed that by plasticity chart, soils are mainly susceptible to cyclic mobility (91%) and potentially susceptible to flow liquefaction (9%).
- The soils in the four sites were classified as non –liquefaction based on all criteria were used in this paper, but in the lower section of some sites studied, the soil exhibited susceptibility to liquefaction.
- All the criteria used in the present study showed similar resultsn.

Availability of data

The study findings which are supported by the data are obtainable by the corresponding's writer upon requests.

Interest conflicts

The writers affirmed that they hadn't interest conflicts.

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