Engineering and Technology Journal
Journal homepage: engtechjournal.org

Correlation of Soil Liquefaction Potential Index and Geotechnical Properties for Baghdad City, Iraq

Hussein H. Karim [a], **Zena W. Samueel** [b], **Dalia A. Abdul Hussein** [c*]

[a] Department of Civil Engineering, University of Technology-Iraq. 40062@uotechnology.edu.iq

[b] Department of Civil Engineering, University of Technology-Iraq. zinawaleed2004@yahoo.com

[c] Department of Civil Engineering, University of Technology-Iraq. dalia.ali670@yahoo.com

*Corresponding author.

Submitted: 09/04/2019 Accepted: 21/06/2019 Published: 25/06/2020

K E Y W O R D S

Baghdad soil, Liquefaction potential index, Geotechnical properties, Safety factor

A B S T R A C T

This paper comprises the study and analysis of Baghdad soil for eight geotechnical properties, which extract from field experiments of 630 boreholes with depth taken to 30m and representing 200 sites. Soil investigation reports are composed from altered laboratory tests. The soil layers Divided into each 2m, which means 15 studied layers and soil properties values were embraced and submitted in tables and charts which have been analysis-using excel2013 and check the charts using curve expert program to get the relationships between the properties values and the factor of safety against liquefaction. The correlations between liquefaction potential represented by the safety factor and soil properties for the available data of 200 sites in Baghdad have been studied and statistically studied 'to evaluate both of soil properties and liquefaction potential index. Eight factors affecting liquefaction have been correlated with factor of safety for all earthquake magnitudes (ML= 4to 6.5 with 0.5 interval). These factors are, groundwater table, fill layer depth, standard penetration test (SPT- N value), saturated unit weight (γ), Relative density (Dr %), soil fractions (clay silt and sand %), and total settlement (S_{tot}). For better correlations, the same factors have been correlated with safety factor but for each earthquake magnitude alone.

How to cite this article: H. H. Karim, Z. W. Samueel and D. A. Abdul Hussein"Correlation of soil liquefaction potential index and geotechnical properties for Baghdad City, Iraq," Vol. 38, Part A, No. 06, pp. 813-824, 2020.
DOI: https://doi.org/10.30684/etj.v38i6A.189

1. Introduction

In geotechnical engineering. Soil formation, physical, chemical and engineering properties- of soil layers must be known down to a required depth. In order to get the information . about the site soil properties in least possible time, there is a need arises. To employ modern. Means, which reduce the time, cost, .efforts and staff. Site investigations or subsurface studies are done to limit the in situ (field) and laboratory geotechnical properties of the soil underlying the site [1, 2].

Many altered soil investigation methods are used to determine the suitability. Of site locations and then to subject sufficient, safe. In addition, economic design for the projects depending upon suitable subsoil investigations. Primarily, the direct laboratory investigations for boreholes samples are the mainly used method to investigate and determine the physical, engineering and chemical Soil properties. These properties are sometimes entirely differentiates from site to site and even from depth to another in the same site location boreholes [2].
The soil properties specify the performance of the soil under static and dynamic types of loading. The water table is affected by the water fluctuation from season to another, that fluctuation changes the soil properties and the soil behavior under loading. It is necessary in civil engineering field to assess the geotechnical properties, which are obtained through site investigations. These properties are generally required for every engineering project, which serves as a basis for the establishment of that project and for many other practical applications.
Other related literature is that carried out by reference [3] who analyzed. The data of 44 sites located in Baghdad City area implying empirical approaches with their adapted software. It is found that only 8 sites show liquefaction zones, which are mainly* occurring in the first 15 m from ground surface, with total settlements ≤20 cm. Reference [4] evaluated some geotechnical properties and liquefaction potential from seismic parameters for 14 sites in Iraq. This paper presents an approach for estimating liquefaction based on shear wave velocity. To investigate the liquefaction potential of soils, two selected sites have been studied using the computer program. The application shows a total settlement for saturated and dry sand of 32 mm for the first site while no...Settlement has been specified for the second site. Reference [5] evaluated Baghdad soil liquefaction potential under earthquakes effect. Data for 630 boreholes represent 200 site location points. Only 121 points show susceptibility to liquefaction. Reference [2] studied and analyzed Baghdad soil for 23 geotechnical properties, which were mined from field tests of 630 Boreholes with depth taken to 30m and representing 200 sites.

2. Spatial Distribution of Studied Sites

The advantage of LPI is that it predicts the performance of the whole soil column as opposed to a single soil element [6]. LPI at a site is computed by summarizing the factor of safety for the soil profiles. Liquefaction potential Index (LPI) proposed by many researchers such as Iwasaki et al. and seven [7, 8], Luna and Frost [9] and Juang et al. [10].
LPI was used in Baghdad city Iraq to assess liquefaction severity at a specific location, combines depth, cumulative thickness of liquefiable intervals, and factor of safety of liquefiable intervals into a single parameter. Liquefaction hazard maps for the area were prepared by conducting 200 SPT soundings in the study area and computing values of LPI for earthquake magnitudes 4, 4.5, 5, 5.5, 6, and 6.5. The values of LPI are ranging between 0 to 200 (but mainly in the range ~1 –> 28), with higher values located near Tigris River. The LPI is inversely proportional to the F.S. and the depth of the saturated layer; the higher the index, the greater the potential of liquefaction.
The 200 site points are mapped using geographical information system (ArcGIS10.3.). The GIS Techniques Were used to show the first Map, which is spatial locations and distributions ‘of site point's location of Baghdad city as shown in Figure 1. In addition, these site points were used to produce eight liquefaction potential index maps as an indication for the risk of liquefaction of Baghdad city.
The depth Of the studied boreholes has been adopted to only 30 m, the soil layers were grouped into each 2m, where 15 layers studied. The factor of safety is taken according to Adriss and Seed with F.S. =1.5. Actually, eight digital maps have been constructed for liquidation potential index divided for 4 categories according to the magnitudes. Each category have two digital map, one of them was digital interpolation map and the other was digital combined contour-interpolation map.
Applying Excel software, six tables evaluated with six Different earthquake magnitudes’ have been constructed using specific two equations in order to show liquefaction potential index in different six magnitudes of soil for Baghdad city.

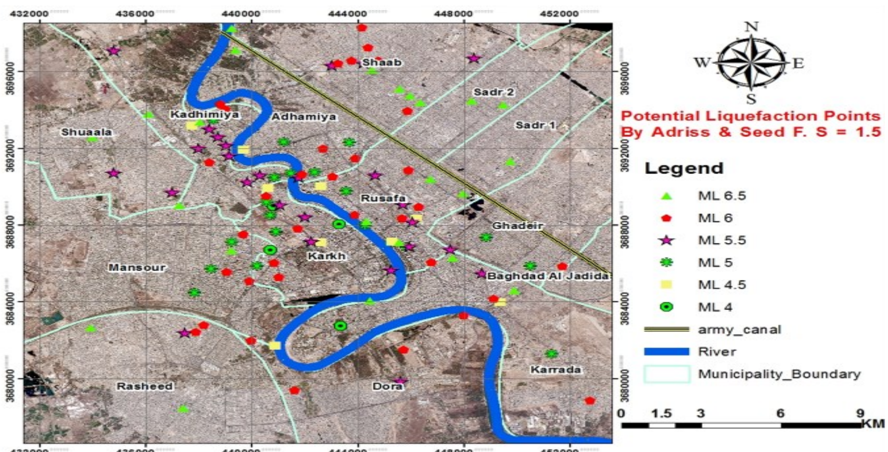

Figure1: Liquefaction potential site point's location according to the considered option.

I. Groundwater table

For Baghdad city, the groundwater level during a certain season especially in the winter is variable due to sewers networks defects and leakages as well as humans' activities. Therefore, it is affected directly on the soil liquefaction susceptibility.

The groundwater level data for 200 site points have relationships with liquefaction of soil represented by a factor of safety value. Figure ٢displays this relationship.

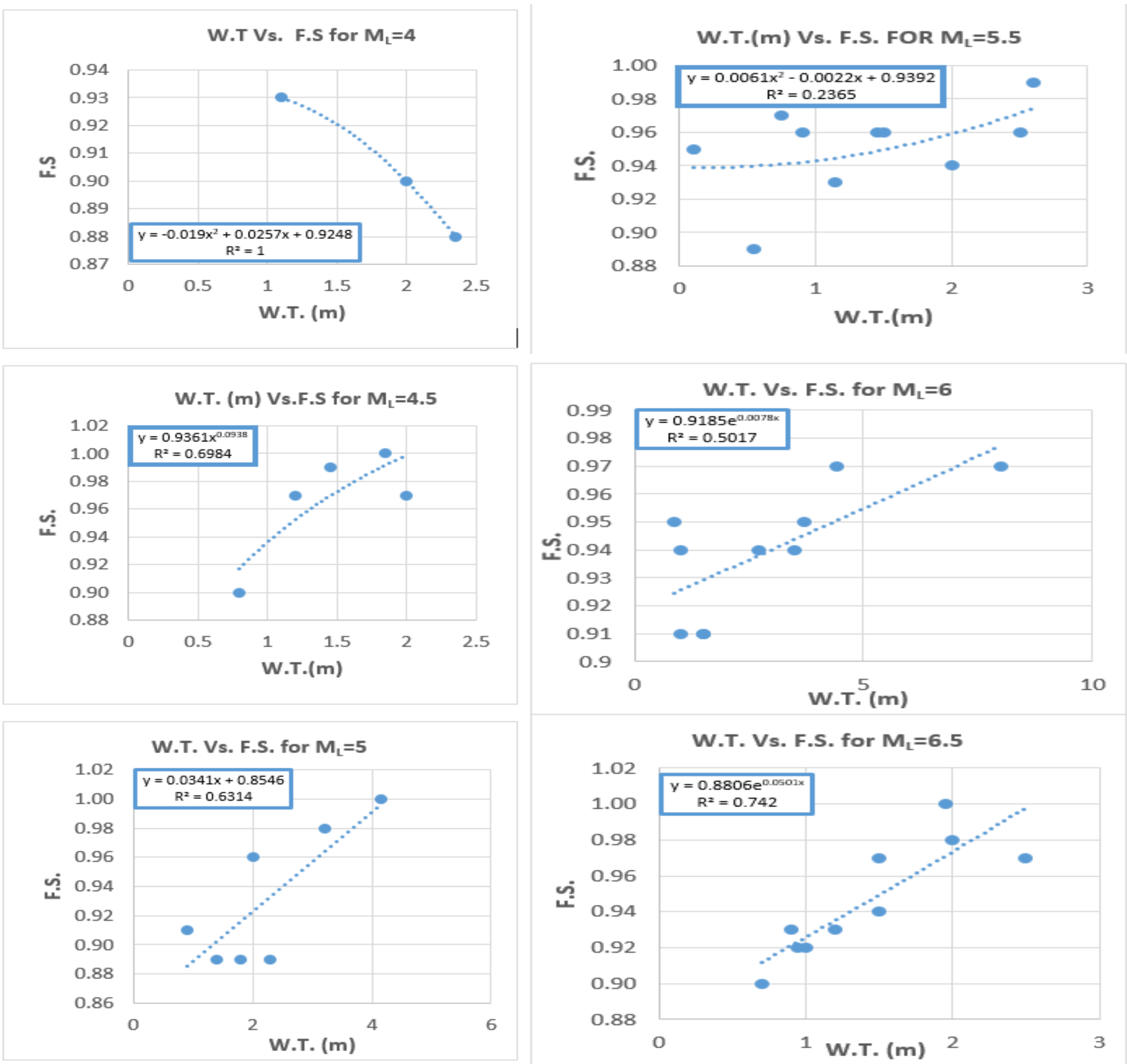

Figure 2: Relationship of safety factor˙ And groundwater˙ Depth for M_L= 4.5 - 6.5.

II. Depth of fill layer

There are several areas in Baghdad representing ancient historical civilization, besides the result of the development of the city and the evolution of its structure and life in which these areas were filled with soil, which was defined as a fill layers. In fact, most of the cases of liquefaction of soil occur in areas near the earth surface so that these layers can be considered as one of the main factor effecting the liquefaction of soil with different degree of impact.
Figure 3 show the mathematical relation between fill layers and factor of safety.

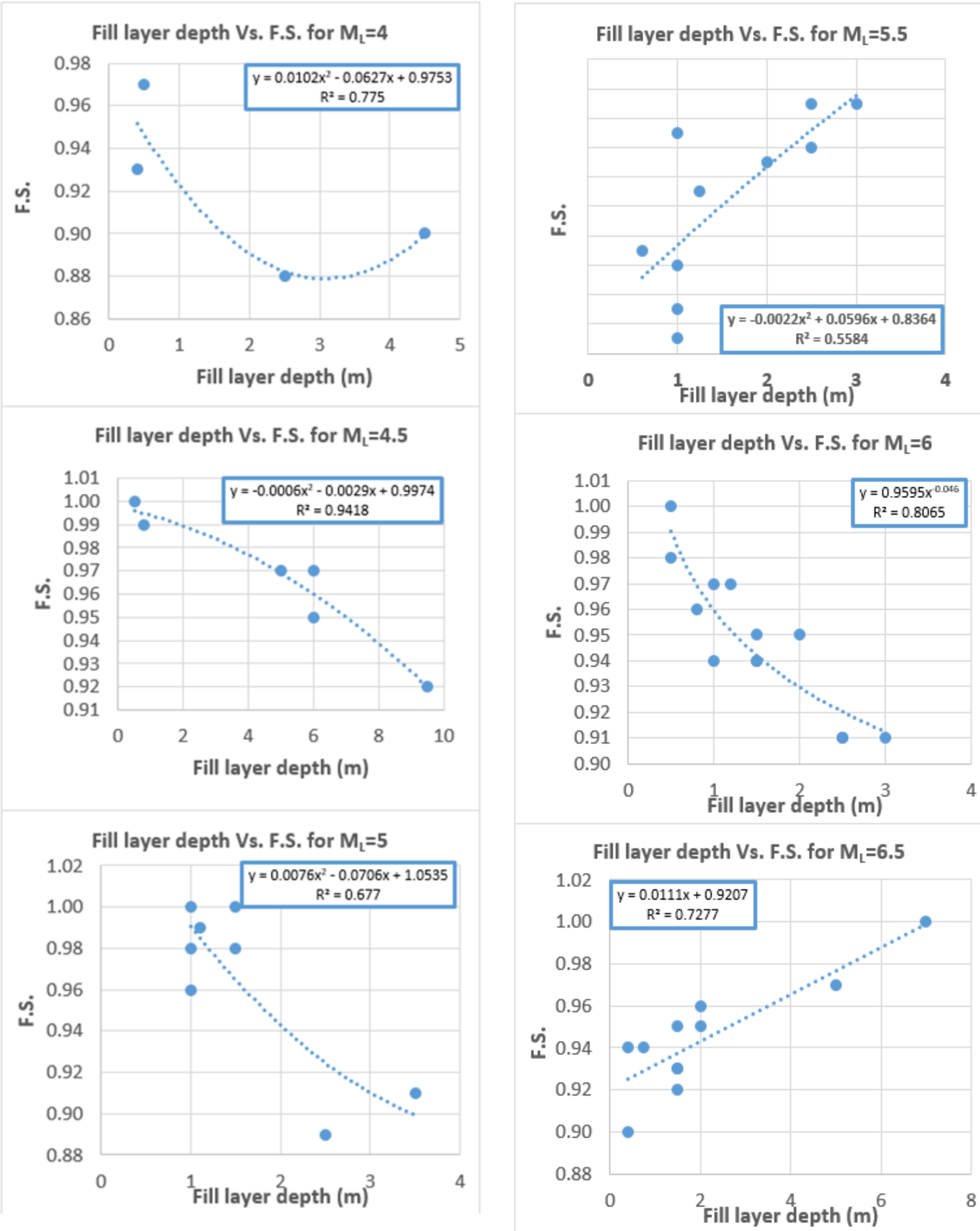

Figure 3: Relationship between fill layer depth and F.S. for M_L=4-6.5.

III. Standard Penetration Test (SPT - N value)

The widely used field test is the penetration testing. The SPT test is very valued for soil investigation and in liquefaction potential evaluation Figure 4 displays the relationship between SPT and factor of safety.

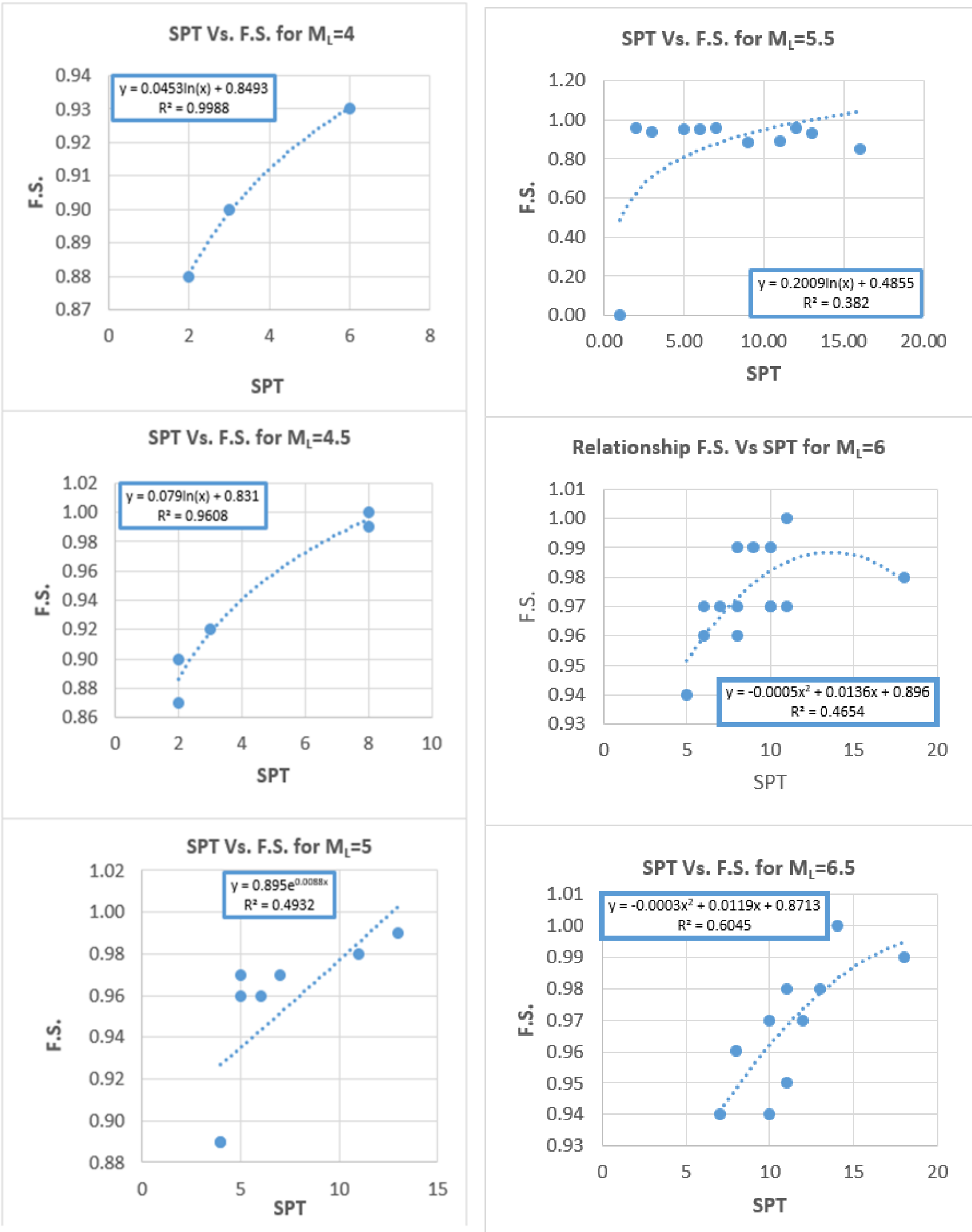

Figure 4: Relationship between SPT and F.S for M_L=4-6.5.

IV.Saturated Unit weight (γ)

The bulk, saturated, dry and submerged Unit weights are different expressions for the soil unit weight depending on the purpose of study required. Bulk unit weight Is used in the field to define the weight per unit volume while saturated unit weight means that the water fills all the voids, which in most cases liquefaction do through. Therefore, the unit weight has a great effect on the value of factor of safety, which determines the liquefied point. Figure 5 represents the relation between factor of safety and unit weight as shown below.

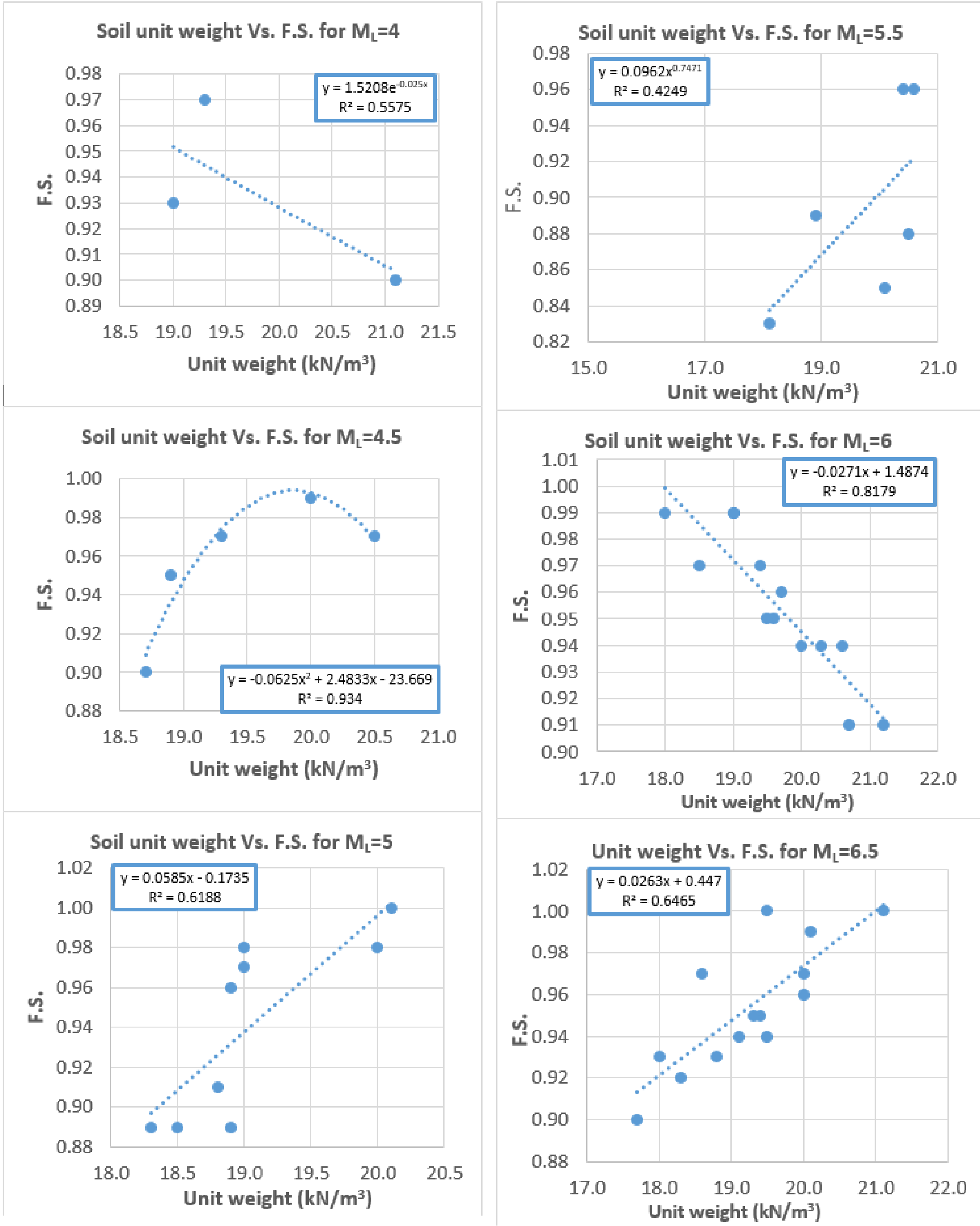

Figure 5: Relationship between saturated unit weight and F.S. for M_L=4-6.5.

IV. Relative 'density (Dr %)

To calculate' the field degree of compaction for granular soil, the relative 'density should be measured. It is the ratio of the 'difference between the void ratio of a loosest condition of granular soil and natural state to the difference between its void ratio in the loosest and densest conditions. It must notice that the relative density have a considerable effect on the value of factor of safety as well as liquefaction of soil. Figure 6 represents the mathematical relationship between relative density and factor of safety.

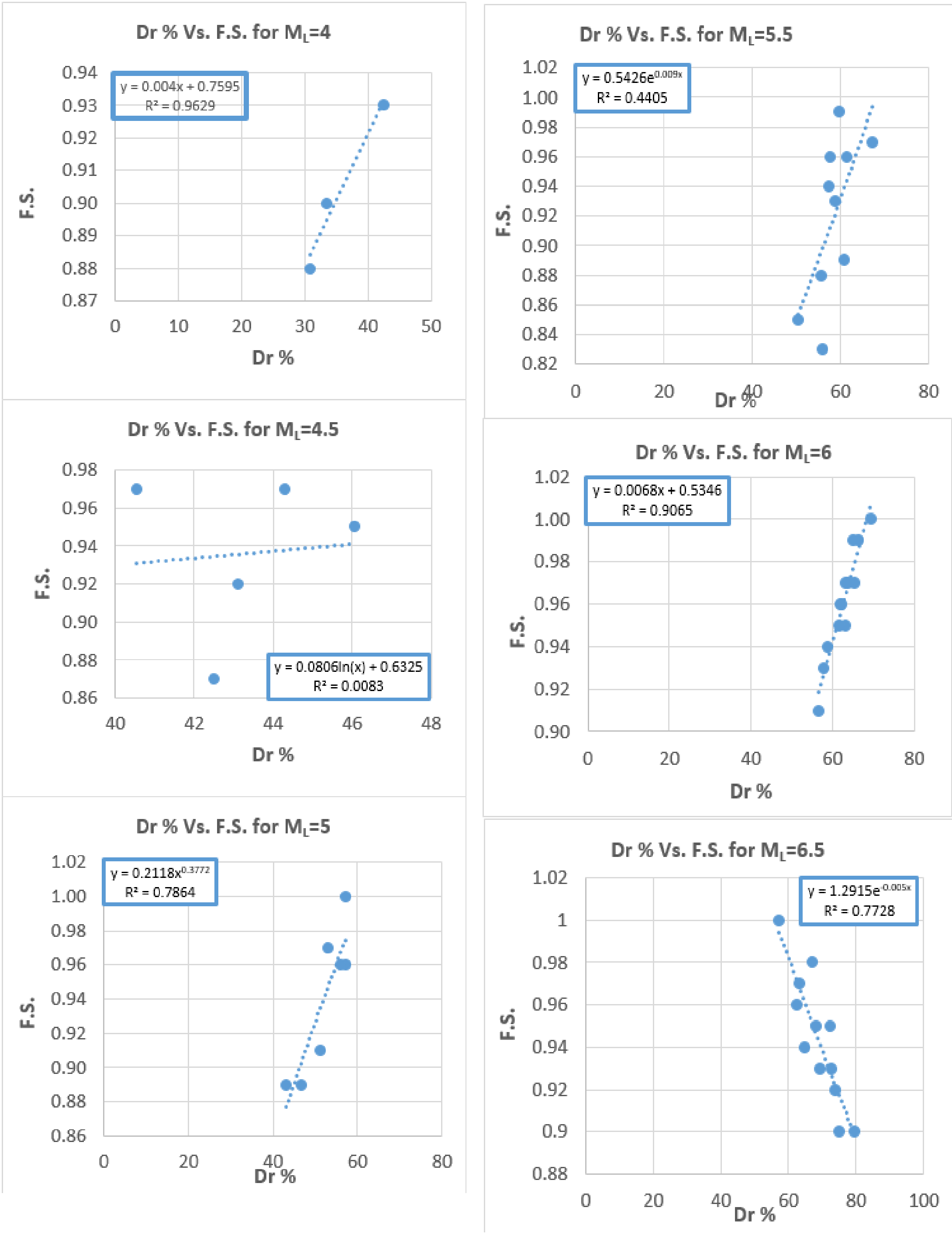

Figure 6: Relationship between relative density and F.S. for M_L-4-6.5.

V. fraction of soil, (clay, silt and sand %)

Baghdad soil contain fines content such as clay. In addition, silt and coarse-grained content such as sand and gravel. The presence of water affects the behavior of fines more than coarse-grained, most soil of Baghdad is consisting of fines, which have great effect on liquefaction. Figure 7a to c represents the mathematical relationship between soil fractions (sand, silt and clay %) and factor of safety respectively.

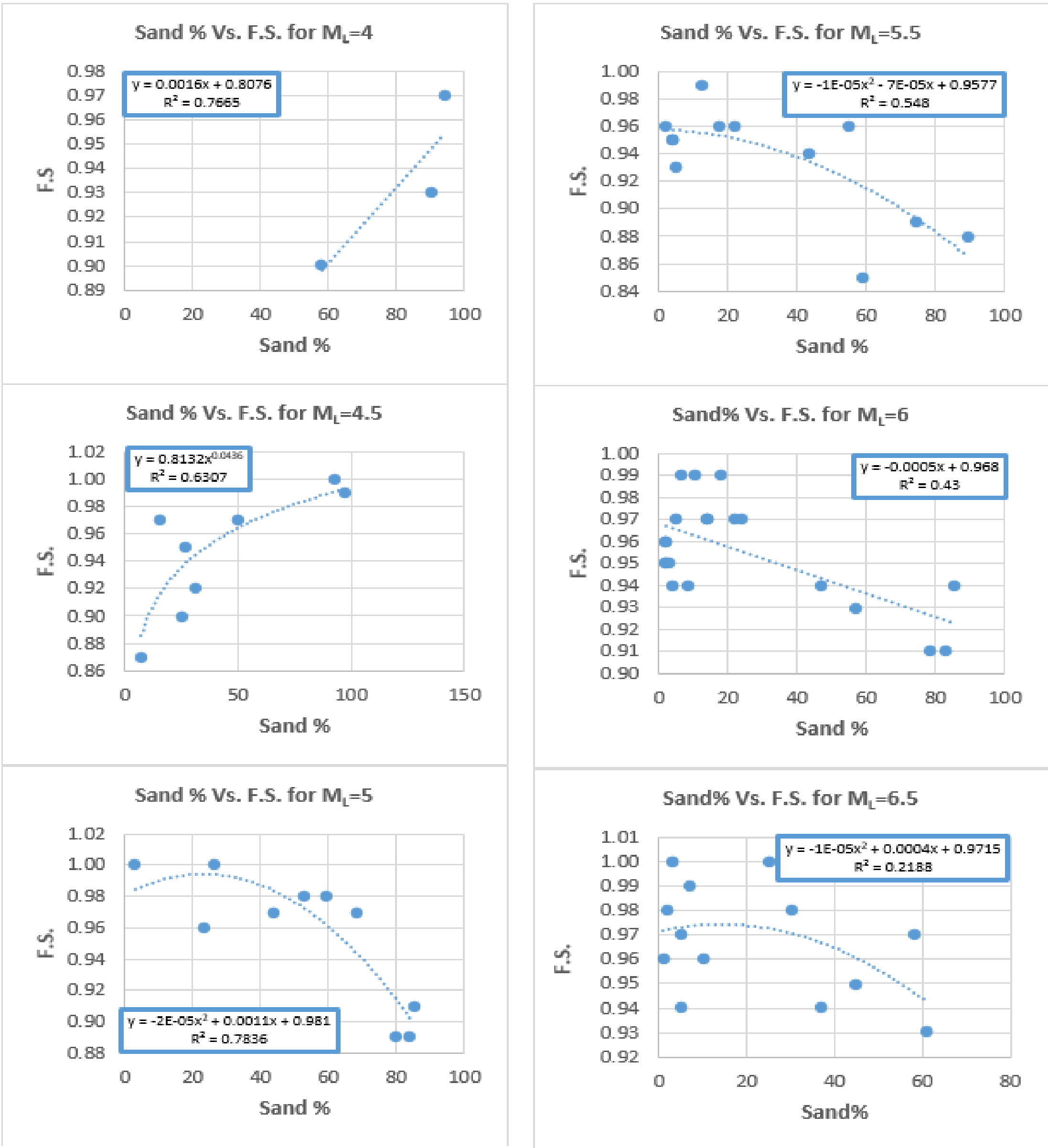

Figure 7-a: Relationship between sand content % and F.S. for M_L=4-6.5.

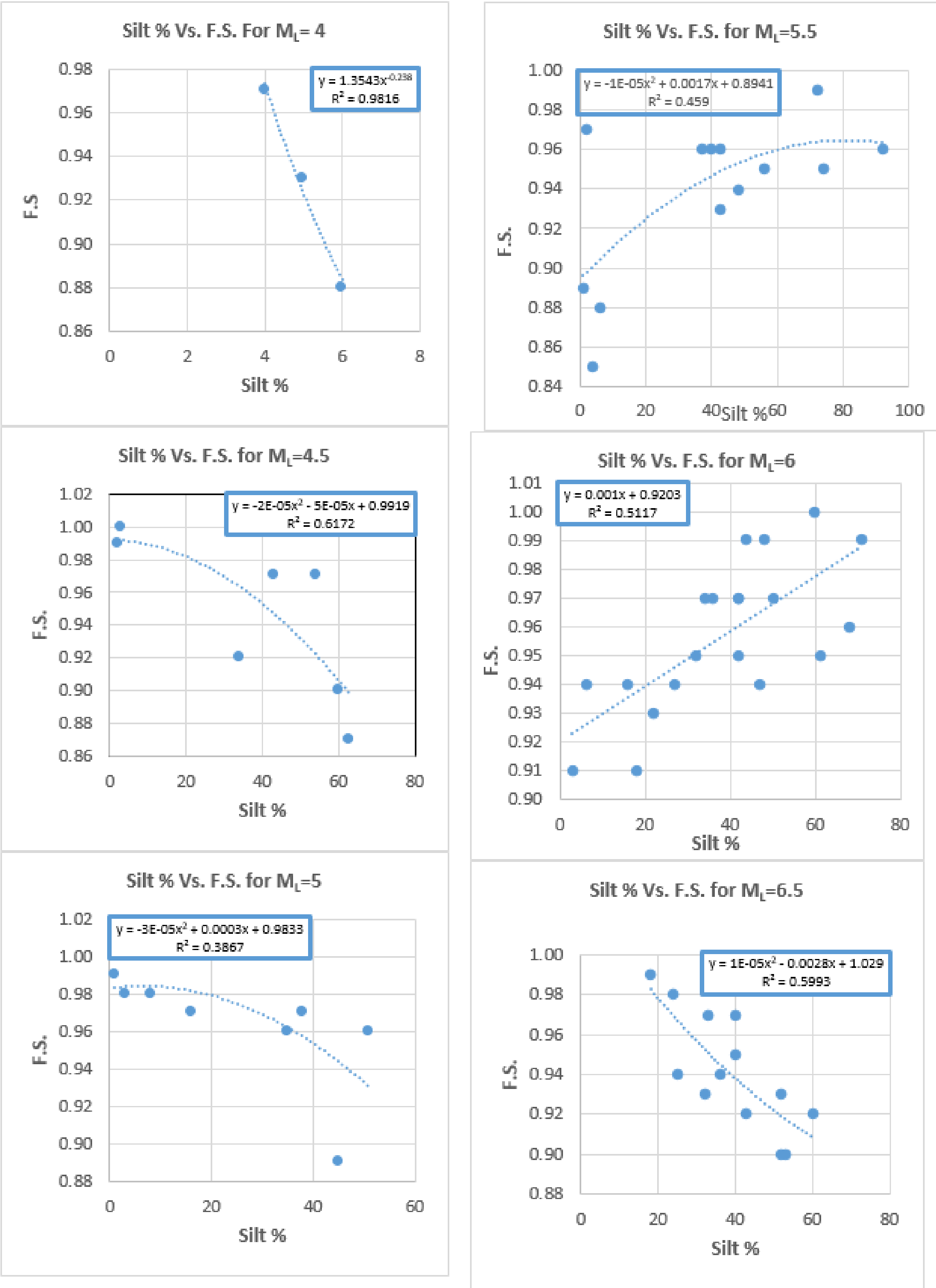

Figure 7-b: Relationship between silt content % and F.S. for M_L=4-6.5.

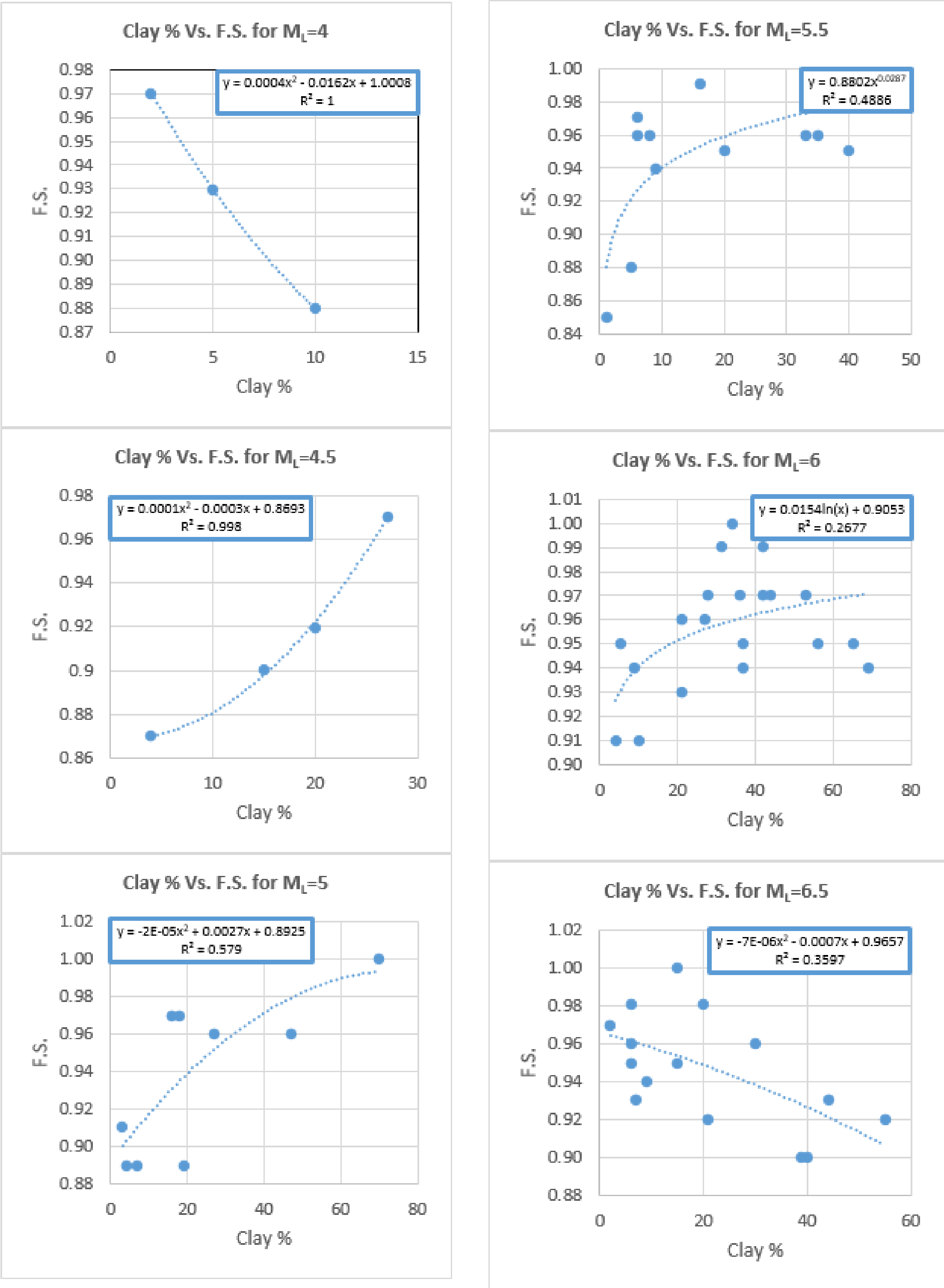

Figure 7-c: Relationship between clay content % and F.S. for M_L=4-6.5

VI. Total settlement (S_{tot})

In general, when earthquakes happened and liquefactions of the soil is present that made increment in the clayey soil. The value of earthquake is directly proportion with the settlement in the soil of Baghdad. Figure 8 displays the mathematical relationship between settlement and factor of safety.

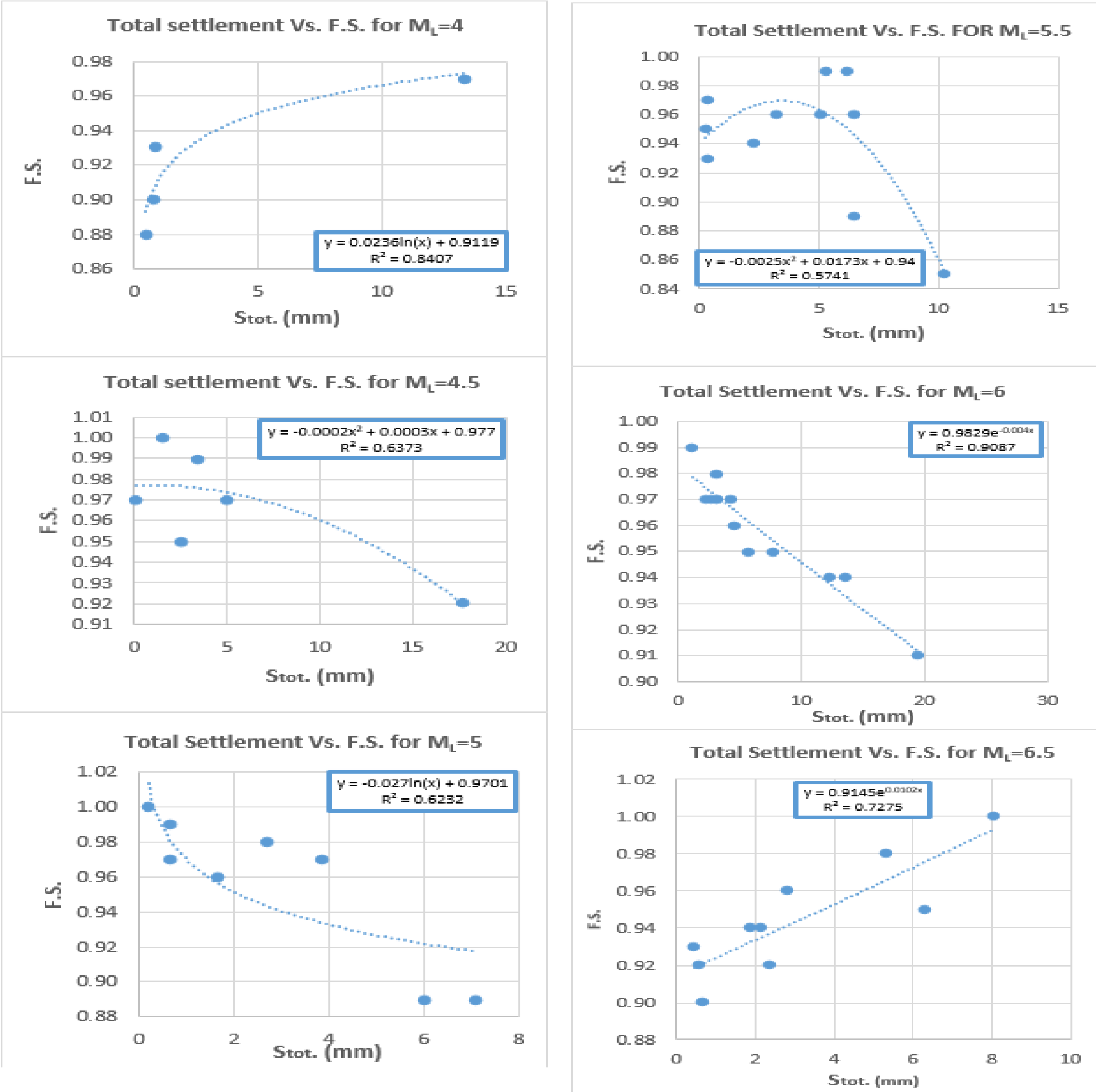

Figure 8: Relationship between total settlement and F.S. for M_{L}=4-6.5.

4. Results and Discussion

The 200 site points mapped by GIS techniques were applied to show the spatial locations and distributions of site point's location of Baghdad as shown in Figure 1. These points were analyzed using excel 2013 program as a charts represent the relationship for soil properties and the Safety factor against liquefaction with six different earthquake magnitudes have been constructed using specific equations and coefficient of determination in order to show liquefaction potential index.

The correlation between the safety factor and the geotechnical properties are presented in the following paragraphs along with Figures 2 to 8. Here one can note that the relationship between the factor of safety and the water table (Figure 2) is of direct relation for the values of earthquake magnitude 4.5-6.5 unlike for magnitude 4, which is of inverse relation.

One can also note that the relationship between the factor of safety and fill layer depth (Figure 3) is of direct relation, while for the relationship between the factor of safety and the standard penetration test (Figure 4) is a positive relationship to all the values of earthquake magnitude.

The relationship between saturated unit weight and factor of safety (Figure 5) it is positive for the points with earthquake magnitudes 4.5, 5, 5.5 and 6.5 unlike magnitudes 4 and 6 where the relationship is inverse. The relationship between factor of safety and relative density it is positive for points have earthquake magnitudes 4.5 to 6 while it is of negative relation for magnitude 6.5 (Figure 6) .The relationship between factor of safety and percent of sand contents (Figure 7a) is negative for points have earthquake magnitudes 5 to 6.5 except for magnitudes 4, and 4.5, which shows direct relation. The relationship between factor of safety and percent of silt contents (Figure 7b) is negative for points with earthquake magnitudes 4, 4.5, 5, and 6.5 except for magnitudes 5.5 and 6 where it is positive.

The relationship between factor of safety and percent of clay contents (Figure 7c) is positive for points have earthquake magnitudes 4.5, 5, 5.5, and 6 except for magnitudes 4 and 6.5 where it is negative.

The relationship between factor of safety and total settlement (Figure 8) is negative for points with earthquake magnitudes 4.5, 5, 5.5, and 6 except for magnitudes 4 and 6.5 where the relation is direct.

A wide scattering shown by the obtained results between the distribution and correlation of some studied geotechnical properties with the factor of safety could be related to geotechnical-geological nature of the soil where the compositions and stratification inhomogeneous in addition to other reasons such as human activities.

The non-significant relation in addition to scattering shown by the obtained results between the distribution and some studied geotechnical properties with the factor of safety could be due to the scarcity of liquefied points. Finally as revealed from the results. it can be stated that the factor of safety is clearly changed with the earthquake magnitudes and as the increment in magnitude is 0.5 each time (from 4.0-6.5) , which will lead to reduce the safety factor from 90% at magnitude 4.0 to 26% at magnitude 6.5, and by 23, 16, 11, 8 and 6% for the in-between magnitudes respectively. The reason of this means (i.e. the non-proportional reduction) may be due to the variant of soil properties behavior Under the effect of earthquake magnitudes.

4. Conclusions

1. The obtained results show a wide scattering between the distribution and correlation of some studied geotechnical properties with the factor of safety, which could be due to geotechnical-geological nature of the soil in addition to human activities.
2. The obtained results sometimes show no significant relation in addition to scattering_between the distribution and some studied geotechnical properties with the factor of safety, which could be due to the scarcity of liquefied points.
3. As revealed from the results that the factor of safety is clearly changed with the earthquake magnitudes. The reason of the non-proportional reduction of F.S. with earthquake magnitudes may be due to the variation of soil properties behavior under the effect of earthquake magnitude.
4. In general, it can be stated that a direct relation is shown between the factor of safety for Baghdad soil and some geotechnical properties (such as groundwater level, landfill depth, SPT value, saturated unit weight of the soil, relative density of the soil, and clay content). While an inverse, relation is obtained with silt and sand contents and total settlement.

References

[1]C. R. I. Clayton, M. C. Matthews, and N. E. Simons, “Site investigation,” Wiley-Blackwell, second edition, 1995

[2]H. H. Karim, and S.J. Wadaa, “Evaluation of liquefaction potential of Baghdad soil during earthquakes,” Global Journal of Engineering Science and Research Management, 4, 5, 86-99, 2017.

[3]H. H. Karim, and T. Schanz, “A study of sediments homogeneity of Baghdad area with evaluating liquefaction potential and settlement,” Iraqi Geol. J., 40, 1, 2006.

[4]H. H. Karim, M. Y. Fattah, and A.M. Hasan, “Evaluation of some geotechnical properties and liquefaction potential from seismic parameters,” Iraqi Journal of Civil Engineering, 6, 3, 30-45, 2010.

[5]H. H. Karim, and S. J. Wadaa, “Geotechnical study of Baghdad soil,” Global Journal of Engineering Science and Research Management, 4, 9, 92-106, 2017b.

[6]S. Toprak, and T.L. Holzer, “Liquefaction potential index field assessment,” J. of Geotechnical and Geoenvironmental Engineering, ASCE, 129, 4, 315-322, 2003.

[7]T. Iwasaki, F. Tatsuoka, K. Tokida, and S. Yasuda, “A practical method for assessing soil liquefaction potential based on case studies at various sites in Japan,” Proc. 2nd Int. Conf. on Microzonation, San Francisco, 885-896, 1978.

[8]T. Iwasaki, T. Arakawa, and K. Tokida, “Simplified procedures for assessing soil liquefaction during Earthquakes, Proc. of the conference on Soil Dynamics and Earthquake Engineering, Southampton, UK, 925-939, 1982.

[9]R. Luna, and I.D. Frost, “Spatial liquefaction analysis system,” J. Comput. Civ. Eng., 12, 11, 48-56. 1998.

[10] C.H. Juang, H. Yuan, D.K. Lee, S.F. Yang, and R.A. Christopher, “Estimating severity of liquefaction–induced damage near foundation,” Soil Dynamics and Earthquake Engineering, 2005.