

Evaluating the Geotechnical and Geophysical Characteristics of Expanding Districts in Tehran Using Field Experiments

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Abstract

Considering the increasing population growth and the rapid growth of urbanization and pollution in the environment, providing zoning maps and urban engineering geology seem to be important. The rapid construction growth of cities, as well as the confrontation with events such as earthquakes and failure to observe the geological and geotechnical issues, has caused many engineering problems. The use of geophysical methods not only cannot lonely provide us a complete and comprehensive information on the geotechnical conditions of the earth but also has many disturbances in urban areas, and its use in urban centers is almost impractical. Therefore, it seems that the best way of examining and interpreting the geotechnical characteristics of a site, especially in urban areas, is the use of suspicious data. Therefore, performing geotechnical studies and geotechnical zoning can be useful for retrofitting buildings and engineering structures and reducing their risks. Hence, zoning studies are conducted in this research in order to better recognize the technical soil status for safe construction due to rising the population of Tehran in recent decades and the concentration of population in certain areas of Tehran, especially in the eastern and western regions (districts 4 and 22). In this study, different geotechnical field tests such as standard penetration test (SPT), cone penetration test (CPT) were used to estimate parameters such as adhesion coefficient (C), internal friction angle (ϕ), Young modulus (E). Other common experiments with conventional geophysical experiments, such as in good experiments, refractive and CSSW were applied to estimate geophysical parameters of bedrock depth and shear wave velocity for zoning these areas.

Keywords: Cone Penetration Test; Standard Penetration Test; In-Well Test; Soil Adhesion Coefficient; Internal Friction Angle; Young Modulus.

1. Introduction

Given the high seismic location of Tehran and the presence of natural hazards in the city and the limited resources and facilities for effective coping in dealing with possible crises, it is necessary to reduce the risks by applying the measures. On the other hand, the new constructions unlike the past need for parking and other interconnections and thus an increase in the number of underground floors with the rise of land value in Tehran and increasing the number of floors. Therefore, identifying the geotechnical features of the construction site and the design of buildings based on local and environmental conditions plays an essential role in improving the quality of construction. Hence, zoning studies are conducted in this research in order to recognize the technical soil status better for safe construction due to rising the population of Tehran in recent decades and the concentration of population in certain areas of Tehran, especially in the eastern and western regions (districts 4 and 22). The purpose of this research is to investigate the geotechnical data related to the drilled boreholes in districts 4 and 22 of Tehran using statistical software. Accordingly, an estimation of the parameters is presented with the desired level of confidence. Finally, an appropriate method was detected using the inverse distance fourth-order interpolation statistical method according to the data type and scattering. Then, different maps of geotechnical micro-zonation of quaternary deposits of Tehran's 4nd and 22nd districts were prepared using various GIS software. In this study, different geotechnical field tests such as standard penetration test (SPT), cone

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penetration test (CPT) were used to estimate parameters such as adhesion coefficient (C), internal friction angle (ϕ), Young modulus (E). Other common experiments with conventional geophysical experiments, such as in-well experiments, refractive and CSSW were applied to estimate the geophysical parameters of bedrock depth and shear wave velocity for zoning these areas. Reza Behroo (2009) investigated the seismic micro position of GIS in Tehran. In this research, the seismic zoning and geotechnical zoning maps are plotted by geotechnical and geophysical data in GIS software [1]. Ejelooeian et al. (2012) investigated geotechnical properties in Isfahan using geotechnical data. According to these data, GIS maps are plotted [2]. Amani Nashed et al. (2012) studied the characteristics of soils and rocks in Toshka in Egypt based on sub-surface and laboratory data to prepare geotechnical plans for the construction of Sheikh Zayed channel and structures. In this research, geotechnical maps and geotechnical zoning of this region were done using GIS based on the results obtained from subsurface experiments and studies. The main objective was to identify the swellable soils of the area and determine their parameters [3].

Sharma et al. (2013) studied geotechnical zoning based on the data obtained from the borehole in Guwahati, the northwest of India. In these studies, 200 boreholes were drilled to a depth of 30 meters based on the data. According to the results of field trials such as Lefranc and SPT and the results of geophysical intrusions and experimental results, geotechnical zoning maps have been plotted based on GIS [4]. Wan-Mohamad et al. (2011) studied geotechnical data and geotechnical zoning using geotechnical data of boreholes drilled in the Perak Tengah, Sri Lanka using GIS [5]. Mozis t al. (2011) plotted the geotechnical maps of Mexico City using borehole data and CPT results in these boreholes by GIS. They also plotted the two and three-dimensional geotechnical profiles of the city using these maps and data [6]. Baghban Golpasand et al. studied Effect of engineering geological characteristics of Tehran's recent alluvia on ground settlement due to tunneling. Ground settlement due to the shallow tunneling in urban areas can have considerable implications for aboveground civil infrastructures. Engineering geological characteristics of the tunnel host ground including geotechnical parameters of surrounding soil, groundwater situation, and in situ stress condition are amongst the most important factors affecting settlement. In this research, ground settlement as a consequence of the excavation of the East-West lot of Tehran Metro line 7 (EWL7TM) has been investigated. In general, maximum settlements (S_{max}) occurred in the cohesion-less soil is greater than cohesive soil [7].

Dieudonné Epada et al. studied geophysical and Geotechnical Investigations of a Landslide in Kekem Area, Western Cameroon. Geophysical and geotechnical surveys were conducted in the Western Cameroon (Kekem area) following a landslide on argillaceous material in order to understand the triggering processes and mechanisms of this landslide and to assess the stability of the slope. The laboratory results exhibited a soil with low consistency, almost doughy. The mean value of the safety factor (1.4) been lower than the slope stability coefficient (1.5), revealed that the slope is unstable, likely to know at any moment a reactivation of the slide. This study showed that electrical soundings coupled with geotechnical surveys are useful tools for the characterization of landslides [8]. Adewoyin et al. studied application of Geophysical and Geotechnical Methods to Determine the Geotechnical Characteristics of a Reclaimed Land. Near-surface seismic refraction method and electrical resistivity methods were used to characterize the subsurface of a site reclaimed from water bodies, in order to determine the depth to the most competent layer for construction purposes. Nine seismic refraction profiles were surveyed and the data was interpreted using SeisImager software package. Also, twelve vertical electrical soundings were carried out and the acquired data was interpreted using WinResist computer package. The seismic refraction method delineated three layers while the electrical resistivity method revealed between four and five geoelectric layers. The result of the seismic refraction method showed that the third layer is the most competent layer having the highest elastic moduli [9].

Shan et al. studied integrated 2D modeling and interpretation of geophysical and geotechnical data to delineate quick clays at a landslide site in southwest Sweden. Radio magnetotellurics (RMT), electrical resistivity tomography (ERT), and high-resolution reflection seismic data were collected along four lines to characterize the geometry and physical properties of geologic structures at a quick-clay landslide site in southwest Sweden. Geotechnical data suggest the presence of quick clays above coarse-grained layers. These layers play a key role in the formation of quick clays and landslide triggering [10]. Oyedele et al. studied application of Geophysical and Geotechnical Methods to Site Characterization for Construction Purposes at Ikoyi, Lagos, Nigeria. An integrated geophysical and geotechnical survey was carried out in a proposed engineering site at Ikoyi, Lagos, Nigeria. The survey aimed to image shallow subsurface with a view to evaluate the stratigraphy and competency of the shallow formation as foundation materials. Geophysical and geotechnical tests showed good agreement. Four to five subsurface layers were delineated within the study area. The existence of loose sand, peat and clay near at the surface is capable of being inimical to building structures. The subsurface layers up to the depth of 16 m are mechanically unstable with low penetration resistance value which may not serve as good foundation materials [11].

2. Materials and Methods

2.1. Exploratory Drilling

In this research, the exploratory boreholes have been excavated in districts 4 and 22 of Tehran, which have been used to identify the area layers. Exploratory drill boreholes have been drilled with a diameter of 101, and the purpose of

drilling these boreholes was conducting experiments such as SPT, CPT, Lefranc permeability test, and downhole geophysical studies in addition to sub surface detection. It was also necessary to obtain intact sample for laboratory experiments such as aggregation, Atterberg range, consolidation, three axis and direct cutting. At the time of drilling exploratory boreholes, the experiments included SPT or CPT testing, Lefranc test, and downhole geophysical studies have been performed.

2.2. Laboratory Experiments

In order to complete the studies to identify and obtain the technical and mechanical specifications of the underground materials, physical and mechanical tests have been carried out on the samples taken either in the form of gutted or intact depths of the boreholes. The samples taken to carry out experiments were Kerberly's gutted samples and samples from the SPT sampler and Shelby samples. Experiments performed on samples were according to ASTM and AASHTO standards; including tests on moisture content, grain size, natural gravity, direct cutting.

2.3. Preparing a database

Only geotechnical viewpoint is considered at the conceptual level in geotechnical database prepared in Tehran's 4th and 22nd districts. In the design of geotechnical database of these districts of Tehran, a relational database management system has been used. In this design, according to the characteristics of the database of geotechnical database, the information is categorized and then analyzed. The geotechnical database contains several important components. These components include borehole location (geographic and altitude location), type of drilling, groundwater level, depth of drilling, classification of soil at different depths, depth of Atterberg (including LL, PL, and PI), permeability at different depths, shear strength parameters C and ϕ in direct cutting at different depths, Elastic parameters of soil including E and ν in deep loading, NSPT at different depths, N60 and N70 at different depths, soil density (in Normal, dry, and saturated mode) at different depths, moisture content at different depths. Table 1 shows the specification and number of boreholes in each district are shown, and Table 2 to 4 show the number of tests and parameters used in this research.

Table 1. Boreholes specifications

Depths	District 4	District 22
Less than 15 meters	55	30
15 to 25 meters	35	40
25 to 35 meters	40	36
35 to 50 meters	50	24
More than 50 meters	0	50
Total	180	180

Table 2. Field information

Depth	SPT test		Lefranc test		Plat load test		Direct shear test	
	District 4	District 22	District 4	District 22	District 4	District 22	District 4	District 22
< 15	1260	1260	900	900	900	900	900	900
15-25	625	750	375	450	375	450	375	450
25-35	450	550	270	330	270	330	270	330
35-50	350	520	250	370	250	370	250	370
> 50	-	500	-	350	-	350	-	350
Total	2685	3580	1795	2400	1795	2400	1795	2400

Table 3. Laboratory information

Depth	Sieve analysis		Density		Water Content		Atterberg limit	
	District 4	District 22	District 4	District 22	District 4	District 22	District 4	District 22
< 15	1260	1260	900	900	900	900	900	900
15-25	625	750	375	450	375	450	375	450
25-35	450	550	270	330	270	330	270	330
35-50	350	520	250	370	250	370	250	370
> 50	-	500	-	350	-	350	-	350
Total	2685	3580	1795	2400	1795	2400	1795	2400

Table 4. Inter borehole seismic data

Depths	District 4	District 22
Less than 15 meters	900	900
15 to 25 meters	375	450
25 to 35 meters	270	330
35 to 50 meters	250	370
More than 50 meters	-	350
Total	1795	2400

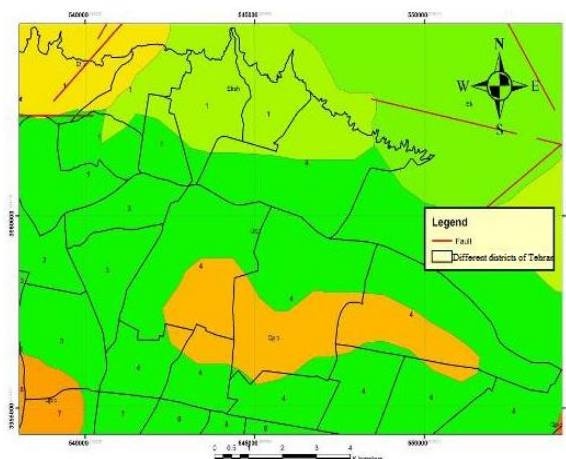
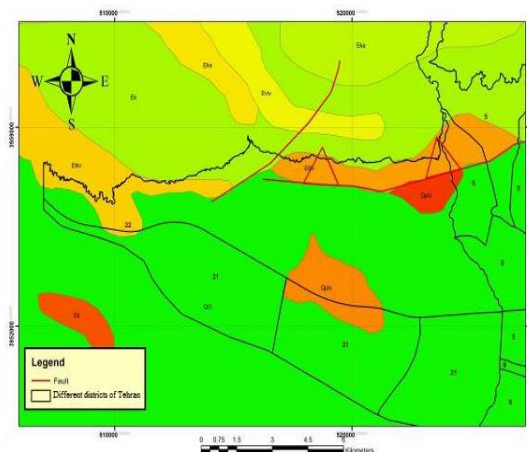
2.4. Geotechnical Zonation Using Arc GIS Software

The digital data provided on the city map, geology, and topography of Tehran, which were used by the mapping organization, were used to prepare the GIS plan for the geotechnical base of Tehran in developing districts 4 and 22. To this end, the digital map of Tehran is first provided. The possibility of zoning the geotechnical parameters in the residential and urban districts 4 and 22 was provided after correction, scaling the maps, collecting geotechnical data of boreholes in districts 4 and 22, and entering this information in ARC GIS software. The micro-station software and Arc view software were also used in addition to the ARC GIS software to prepare the geospatial GIS plan. Another positive feature of this study is the possibility of updating in the subsequent studies and further research. By completing geotechnical information in the future, the geotechnical parameters can be more accurately estimated [12].

3. Data Processing and Zoning

3.1. Geology

Tehran is based on alluvial deposits of the fourth period of geology. So the age of sediment is up to 5 million years. These alluvial deposits have been located in slopes and lowlands by floods that originated at the end of the third century and at the same time as the Alborz heights erupted from these heights. The classification of coarse-grained alluvial deposits in Tehran has been the subject of research by various researchers. The sediments were first developed by Rieben from 1953 to 1966, and then by other researchers such as Huber (1960), Cresch (1961), Neil and Jones (1968), Angallen (1968), Vita Phineasy (1969 and 1979), Besir (1971), according to Berberian et al. (1992). All surveyors have applied more or less the division by Rieben, and so far no major change has been made in this division [12]. Rieben divides Tehran's alluvial deposits into four sections called C, B, A, and D formations. Deposits A are oldest and deposits D are newest formations. According to the maps from different districts of Tehran, most parts of districts 4 and 22 are composed of Tehran's B submarine as shown as shown in Figures 5 and 6. of the map prepared by the Japan International Cooperation Agency (2001), which is presented in the Seismic micro zoning report of Grand Tehran [13, 14].

**Figure 1. Graphical geological map of district 22****Figure 2. Graphical geological map of district 4**

3.2. Applied Data in Districts 4 and 22

In this research, the data of drilled boreholes were collected and used by various geotechnical companies in these districts. Figure 7. shows the map of the boreholes in this research in district 4 with their names. The name of these boreholes includes the BH series boreholes, the P Series boreholes, and the T series boreholes that are shown on this map. Borehole names are based only on the name of the collected data series, and these boreholes are drilled by machine. These boreholes were drilled between depths of 15 to 36 meters. In district 22, these boreholes include the CH series boreholes and the H series boreholes, and the O series boreholes as shown in Figure 8. These boreholes have been excavated between depths of 40 to 70 meters and in the northern part of the district due to the mountainousness and the presence of constructional heights, there are fewer boreholes and the focus of drilling is higher in the center of the district.

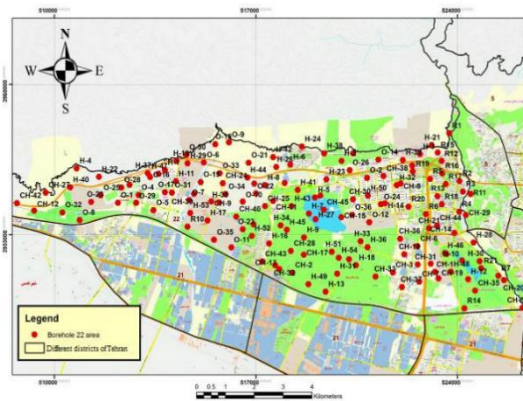


Figure 4. Boreholes used in district 22

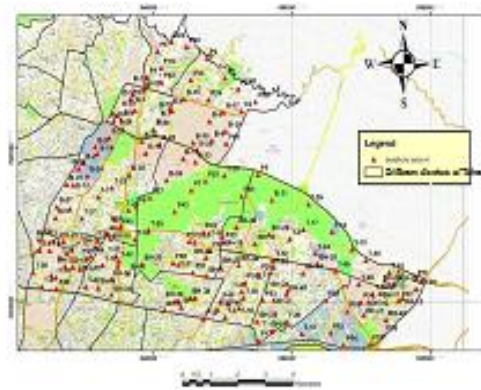


Figure 3. Boreholes used in district 4

3.3. Data Analysis in Districts 4 and 22

These drilled boreholes were used to study in the development projects and the data analysis has been performed using these data. According to the information obtained in district 4, the materials in districts 4 and 22 include GW, GM, GC, GP, SC, SW-SC, GP-GC, GW-GM, GP-GM, SP- SC, SW-SM, SM, GW-GC, SW, SP, SP-SM. According to the granulation, the aggregates in districts 4 and 22 are coarse grains in unit B of Tehran. In Figure 5, each sample of soil in the region is shown according to the obtained information from the boreholes. Figure 5. shows that the GW, GM, GC, GP, SC soils have the highest percentages so that the GW soil has the highest percentage of 25% of the most abundant soil in district 4 and the SP-SM, SP, SO with the percentage of approximately 0.43% is the least frequent. According to Figure 6, GM-GC, GW, GP, GC and GM soils have the highest percentages in district 22 so that GM soil has the highest percentage as much as 22.01% of the most abundant soil in district 22 and the SW, GW- GC, SP, SP-SM has the lowest percentage as much as 0.4%. Data analysis was performed using SPSS and ArcGIS software.

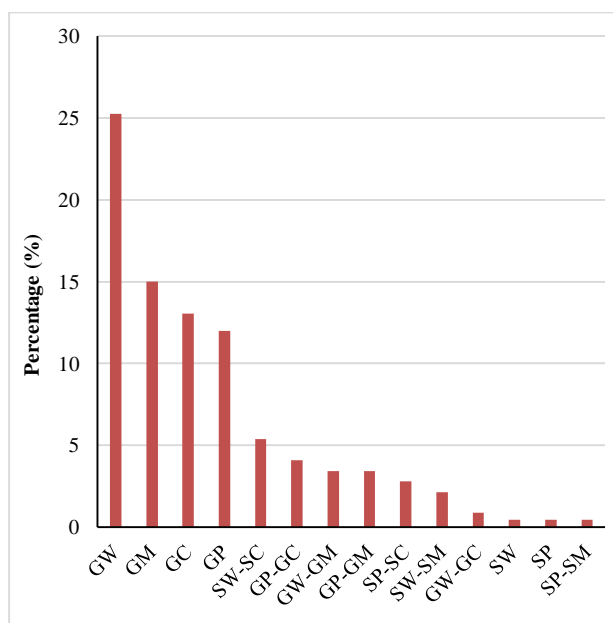


Figure 6. Column graph of different soils percentages in district 4

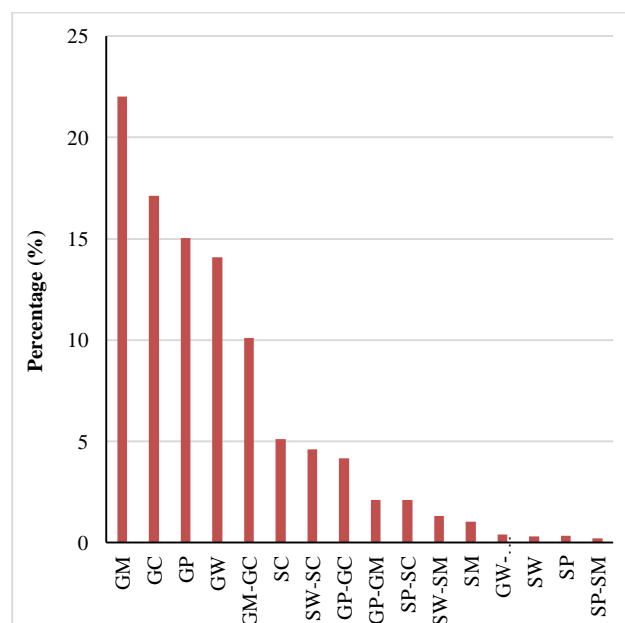


Figure 5. Column graph of different soils percentages in district 22

3.4. Atterberg Zoning Maps

According to borehole data at different depths of districts 4 and 22, the zoning maps were plotted. These maps include the Atterberg changes, plasticity density changes, and plasticity index changes relative to the different depths. At the depth of 4 meters, the Atterberg range varies from 0 to 30 to 36%. At the depth of 16 meters, the Atterberg range varies from 0 to 32%. The largest coverage of the area is around zero and also 20 to 30%. In district 22, the Atterberg range varies from 0 to 34% at 20 meters depth and with the highest coverage of the Atterberg region varies from 20 to 36%. The largest coverage of the area is around 25 to 33%.

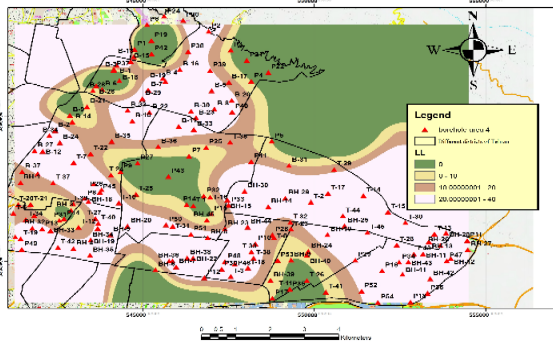


Figure 8. Atterberg Zoning Map at a depth of 16 meters in district 4

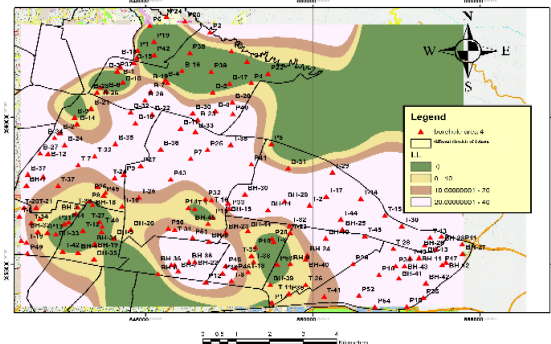


Figure 7. Atterberg Zoning Map at a depth of 4 meters in district 4

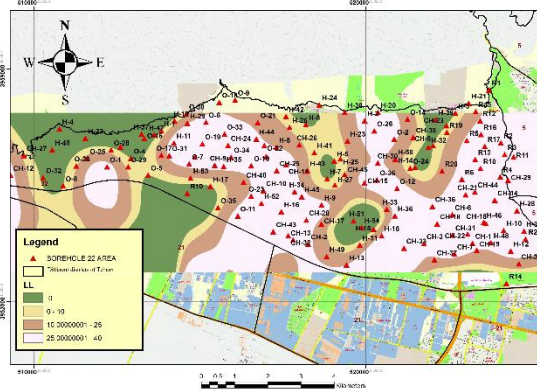


Figure 10. Atterberg Zoning Map at a depth of 40 meters in district 22

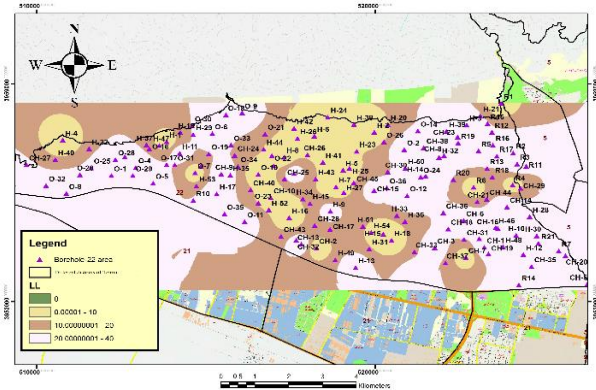


Figure 9. Atterberg Zoning Map at a depth of 20 meters in district 22

In Figures 11 to 14, the zoning maps show the plasticity range in different depths. In district 4, the plasticity range varies from 0 to 24% at a depth of 4 meters and the highest coverage of the area is about 0 and 20 to 25%. At a depth of 16 meters, the plasticity range varies from 0 to 24%, the highest coverage of Atterberg range varies from 0 to 24%, and the highest coverage of the plasticity range in the area is about more than 10%. At a depth of 40 meters, the plasticity range varies from 0 and 24%, the highest coverage of Atterberg range varies from 20 to 24%.

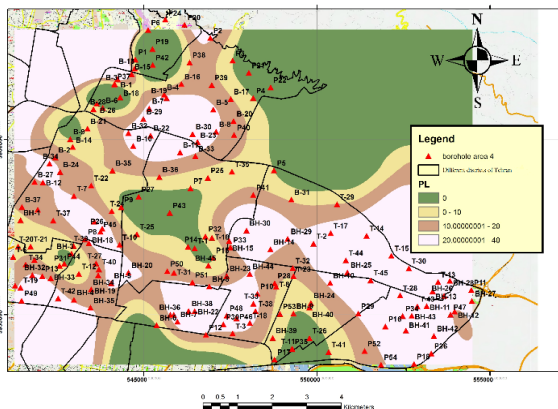


Figure 12. Zoning Map of plasticity range at a depth of 16m from district 4

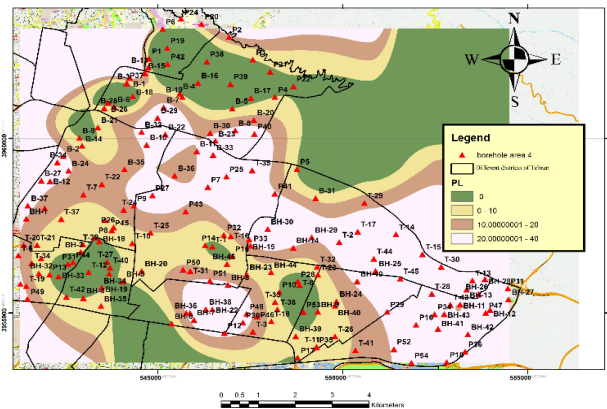


Figure 11. Zoning Map of plasticity range at a depth of 4m from district 4

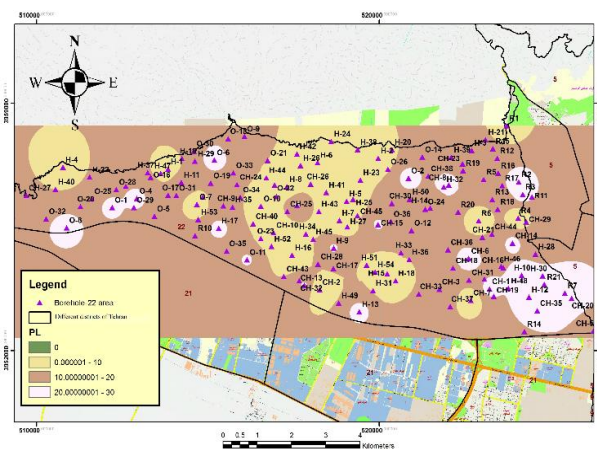


Figure 13. Zoning Map of plasticity range at a depth of 20m from district 22

Figure 15. zoning map of plasticity index at a depth of 4 meters in district 4

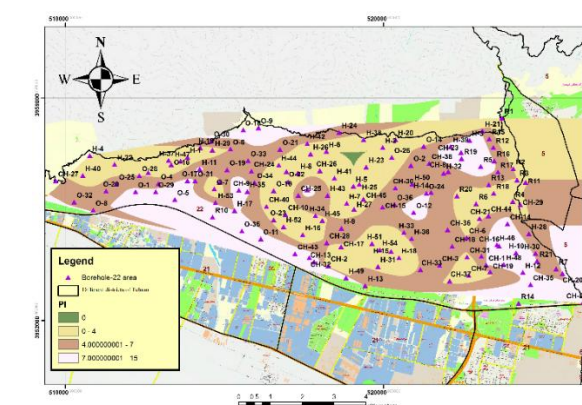


Figure 17. zoning map of plasticity index at a depth of 20 meters in district 22

3.5. Density Changes Maps

Dry density zoning maps are depicted in different depths in Figure 19 and 20. In district 4, the dry density varies from 1.91 to 2.24 grams per cubic centimeter, and the largest coverage area is larger than 2 grams per cubic centimeter. In district 22, the dry density varies from 1.88 to 2.20 grams per cubic centimeter, and the largest coverage area is between 1.95 to 0.2 grams per cubic centimeter. The dry density at a depth of 40 meters varies from 1.91 to 2.3 grams per cubic centimeter, and the largest coverage area is less than 2 grams per cubic centimeter.

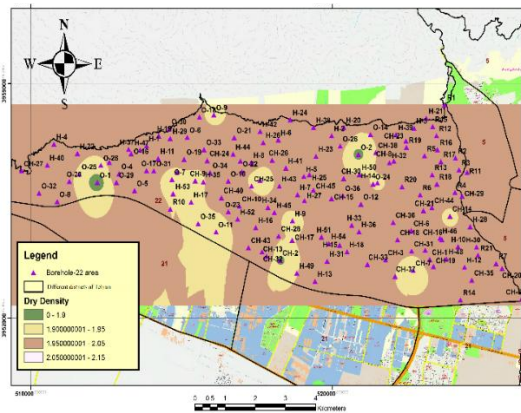


Figure 20. The dry density zoning map at a depth of 20 meters in district 22

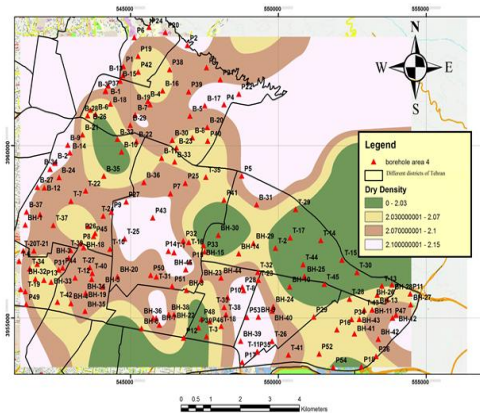


Figure 19. The dry density zoning map at a depth of 16 meters in district 4

Figures 21 to 24, show wet density zoning map in different depths. In district 4, the wet density at a depth of 4 meters varies from 1.96 to 1.22 grams per cubic centimeter, and the highest coverage is from 1.98 to 0.2 grams per cubic centimeter. At a depth of 16 meters, the wet density varies from 2.20 to 2.11 grams per cubic centimeter and the highest coverage is from 2 to 1.2 grams per cubic centimeter. In district 22, the wet density at a depth of 20 meters varies from 1.97 to 2.13 grams per cubic centimeter, with the highest coverage of 2 the wet density varies to 1.2 g per cubic centimeter. At a depth of 40 meters, from 2.00 to 2.13 grams per cubic centimeter, and the largest coverage area is from 0.2 to 1.2 grams per cubic centimeter.

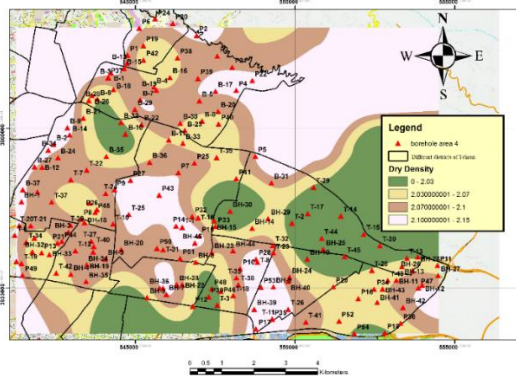


Figure 22. Wet density zoning map at a depth of 16 meters in district 4

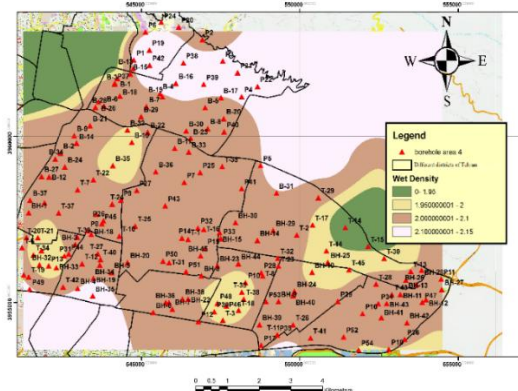


Figure 21. Wet density zoning map at a depth of 4 meters in district 4

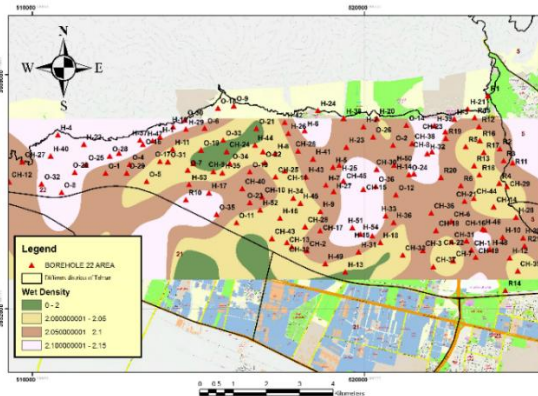


Figure 24. Wet density zoning map at a depth of 40 meters in district 22

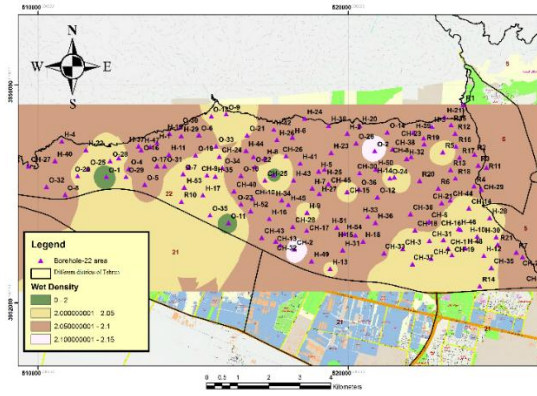


Figure 23. Wet density zoning map at a depth of 20 meters in district 22

3.6. Zoning Map of the Shear Parameters

These results include the results obtained from the cut-off experiment as outlined below. Figure 25 to 28. show the adhesion zoning maps at different depths. In district 4, the adhesion varies from 0 to 0.07 MPa, and the highest coverage is between 0.01 and 0.20 MPa. At a depth of 16 meters, the adhesion varies from 0 to 0.07 MPa, and the highest coverage is between 0.01 and 0.3 MPa. In district 22, at depths of 20 meters, the adhesion varies from 0 to 0.07 MPa, and the highest coverage area is between 0.0 and 0.03 MPa. At a depth of 40 meters, the adhesion varies from 0 to 0.07 MPa, and the highest coverage is between 0.02 and 0.02 MPa.

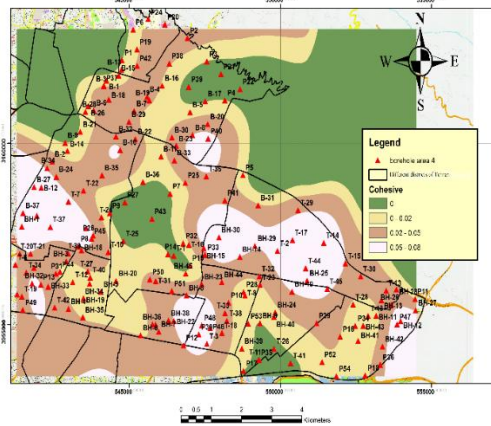


Figure 26. The adhesion zoning map at a depth of 16 meters in district 4

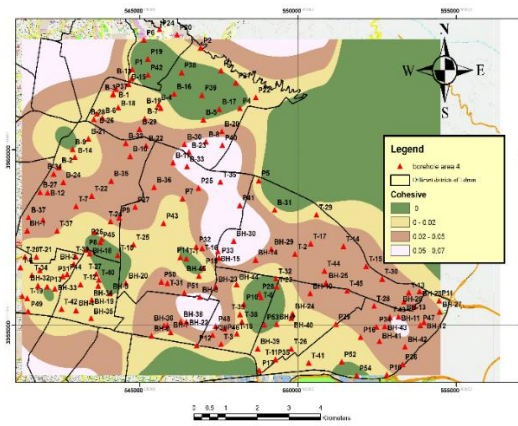


Figure 25. The adhesion zoning map at a depth of 4 meters in district 4

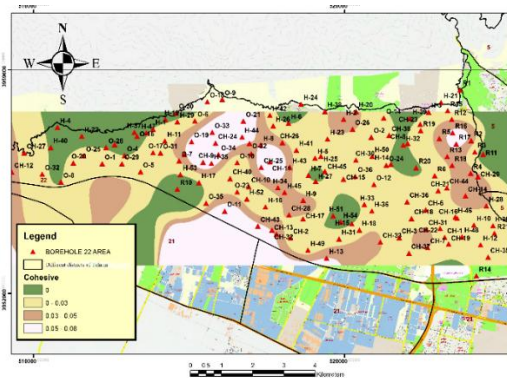


Figure 28. The adhesion zoning map at a depth of 40 meters in district 22

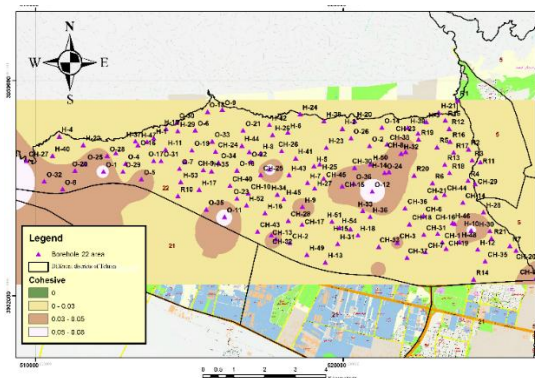


Figure 27. The adhesion zoning map at a depth of 20 meters in district 22

Figures 29 to 32. show the internal friction angle zoning maps in different depths. In district 4, the internal friction angle varies from 31 to 35.35 degrees at a depth of 4 meters and the largest coverage area is between 32 and 33 degrees. At a depth of 16 meters, the internal friction angle varies from 30 to 36.7 degrees, and the largest coverage area is between 33 and 35 degrees. In district 22, the internal friction angle varies from 28.9 and 36.3 degrees at a depth of 20 meters and the largest coverage area is between 32 and 34 degrees. At a depth of 40 meters, the internal friction angle varies from 30.5 to 36.4 degrees, and the largest coverage area is between 33 and 35 degrees.

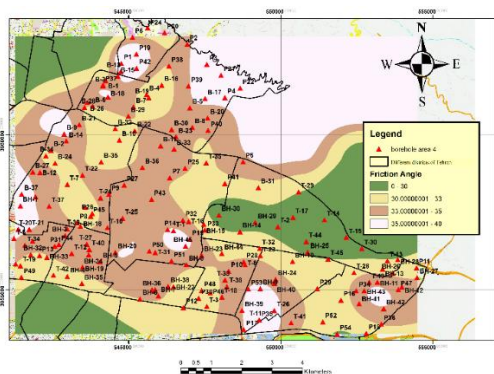


Figure 30. Internal friction angle zoning map at a depth of 16 meters in district 4

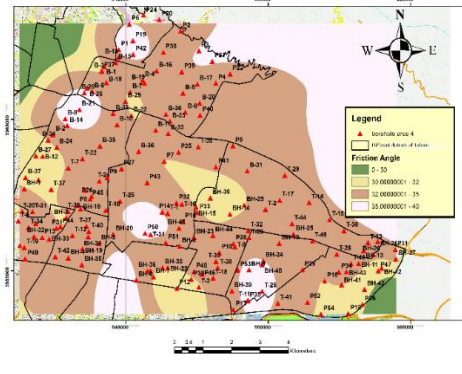


Figure 29. Internal friction angle zoning map at a depth of 4 meters in district 4

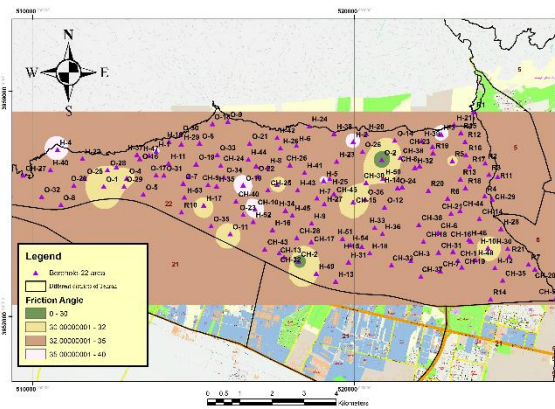


Figure 32. Internal friction angle zoning map at a depth of 40 meters in district 22

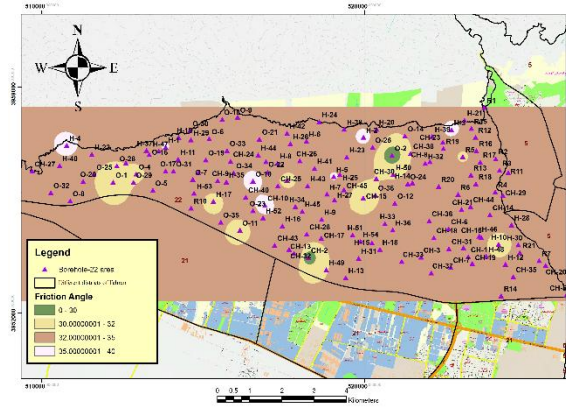


Figure 31. Internal friction angle zoning map at a depth of 20 meters in district 22

3.7. Elasticity Modulation Zoning Map

These results are based on the data obtained from the page loading, which is depicted in Figure 33 to 36, regarding the elasticity modulus mapping at different depths. In district 4, the modulus of elasticity varies from 200 to 600 MPa at a depth of 4 meters and the largest coverage area of 200 to 300 MPa. At a depth of 16 meters, the modulus of elasticity varies from 250 and 700 MPa, with the largest coverage of the area between 350 and 450 MPa. In district 22, the modulus of elasticity varies from 200 to 600 kilograms per square centimeter at a depth of 4 meters with the largest coverage of the area between 200 and 300 kilograms per square centimeter. At a depth of 40 meters, the Poisson ratio varies from 0.3 to 0.35, and the region's largest coverage is between 0.32 and 0.34. At a depth of 60 meters, the Poisson ratio varies from 0.3 to 0.35, and the region's largest coverage is between 0.31 and 0.32. At a depth of 70 meters, the Poisson ratio varies from 0.3 to 0.35, and the region's largest coverage is between 0.31 and 0.32.

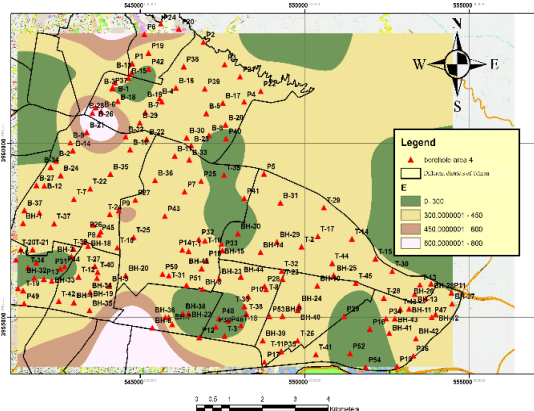


Figure 34. Elasticity modulus zoning map at a depth of 4 meters in district 4

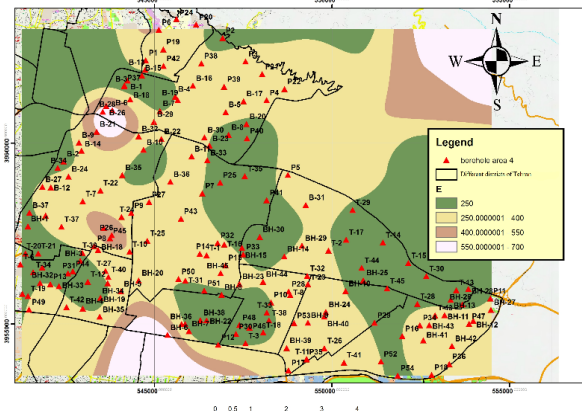


Figure 33. Elasticity modulus zoning map at a depth of 4 meters in district 4

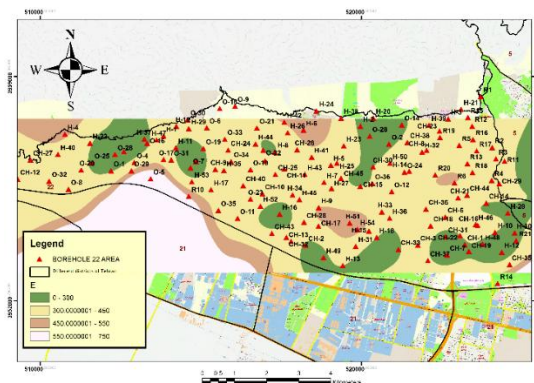


Figure 36. Elasticity modulus zoning map at a depth of 40 meters in district 22

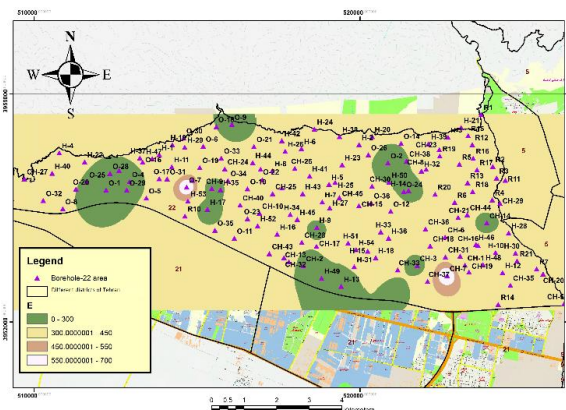


Figure 35. Elasticity modulus zoning map at a depth of 20 meters in district 22

Figure 37 to 40 show Poisson's ratio zoning maps at different depths. In district 4, the Poisson ratio varies from 0.3 to 0.35 at a depth of 4 meters and the region's largest coverage is between 0.32 and 0.33. At a depth of 16 meters, the

Poisson ratio varies from 0.3 to 0.35, and the region's largest coverage is between 0.34 and 0.35. At a depth of 20 meters, the Poisson ratio varies from 0.3 to 0.35, and the region's largest coverage is between 0.34 and 0.35. At a depth of 40 meters, the Poisson ratio varies from 0.3 to 0.35, and the region's largest coverage is between 0.32 and 0.34.

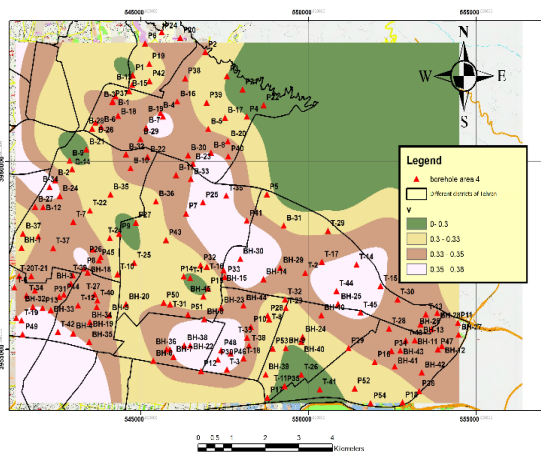


Figure 38. Poisson ratio zoning map at a depth of 16 meters in district 4

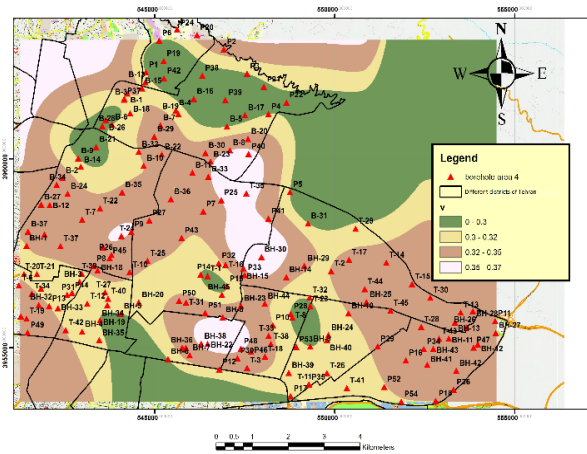


Figure 37. Poisson ratio zoning map at a depth of 4 meters in district 4

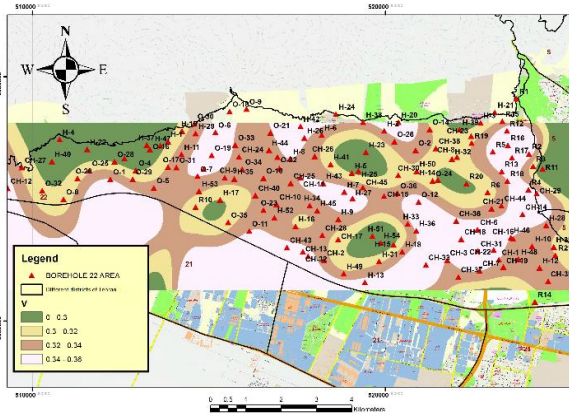


Figure 40. Poisson ratio zoning map at a depth of 40 meters in district 22

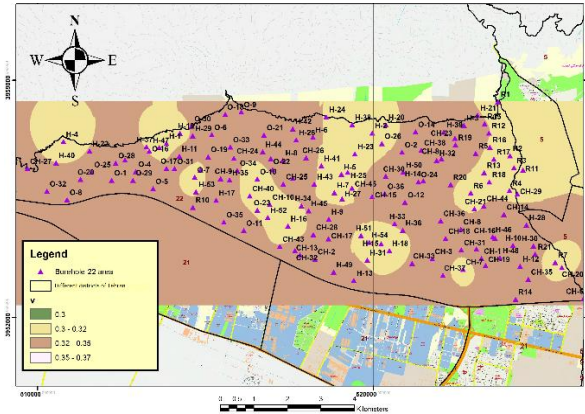


Figure 39. Poisson ratio zoning map at a depth of 20 meters in district 22

3.8. Wave Velocity Zoning Map

Figure 41 to 44 show the longitudinal wave velocity zoning maps in different depths. In district 4, the longitudinal wavelength varies from 330 to 1130 meters per second at a depth of 4 meters and the highest coverage is between 550 and 750 meters per second. At a depth of 16 meters, the longitudinal wavelength varies from 700 to 1730 meters per second and the highest coverage is between 1000 and 1200 meters per second. In district 22, the longitudinal wavelength varies from 630 to 1710 meters per second and the highest coverage is between 700 to 1710 meters per second and the highest coverage is between 1000 and 1250 meters per second.

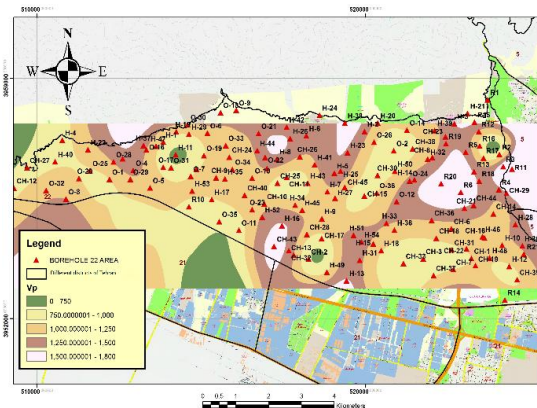


Figure 44. Longitudinal wave velocity zoning map at a depth of 40 meters in district 22

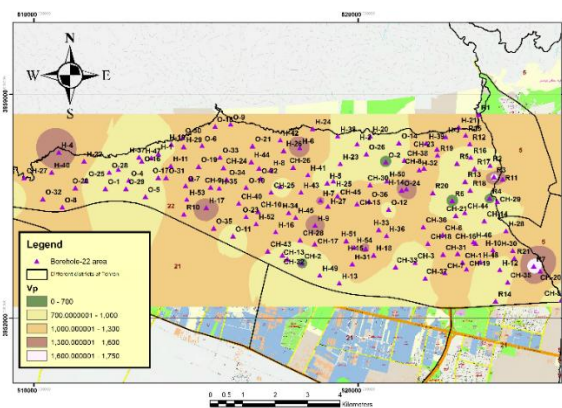


Figure 43. Longitudinal wave velocity zoning map at a depth of 20 meters in district 22

Figure 45 to 48 show the shear wave velocity zoning maps at different depths. In district 4, the shear wave velocity varies from 230 to 750 meter per second at a depth of 4 meters and the highest coverage is between 450 and 550 meter per second. At a depth of 16 meters, the shear wave velocity varies from 300 to 990 meter per second and the highest coverage is between 600 and 800 meter per second. In district 22, the shear wave velocity varies from 300 to 900 meter per second at a depth of 20 meters and the highest coverage is between 500 and 750 meter per second. At a depth of 40 meters, the shear wave velocity varies from 300 to 990 meter per second and the highest coverage is between 550 and 750 meter per second.

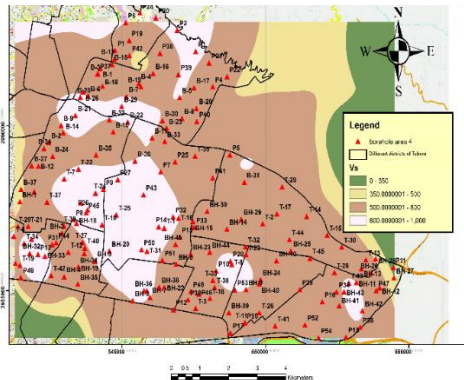


Figure 46. Shear wave velocity zoning maps at a depth of 16 meters in district 4

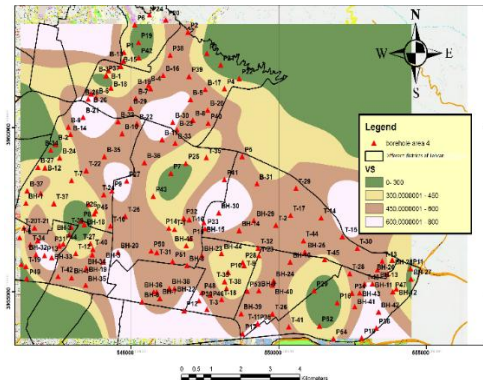


Figure 45. Shear wave velocity zoning maps at a depth of 4 meters in district 4

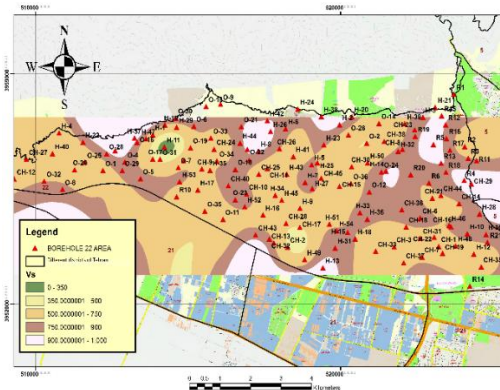


Figure 48. Shear wave velocity zoning maps at a depth of 40 meters in district 22

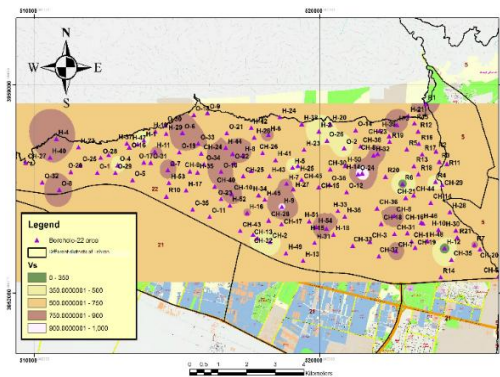


Figure 47. Shear wave velocity zoning maps at a depth of 20 meters in district 22

3.9. SPT Zoning Map

One of the fastest and cheapest tests to determine the relative density of granular soils, especially sand, is the use of the standard penetration test (SPT). Due to the presence of aggregates and the presence of gravel aggregates in this area, the whole results of the NSPT were higher than 50, and in many cases, the NSPT value was about 100. Thus, in Figures 49 and 50, NSPT zoning maps are depicted in different depths. In district 22, Figure 51 and 52. show SPT zoning maps in different depths. As shown in the figures, the SPT in this district is above 45 and in most of the depths above 50 pounds. Based on this number of pounds the region's soil will be at dense to very dense level. Another reason for the high SPT is the presence of coarse aggregates in the area.

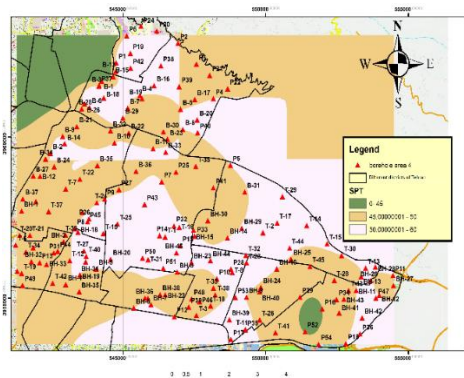


Figure 50. NSPT zoning map at a depth of 16 meters in district 4

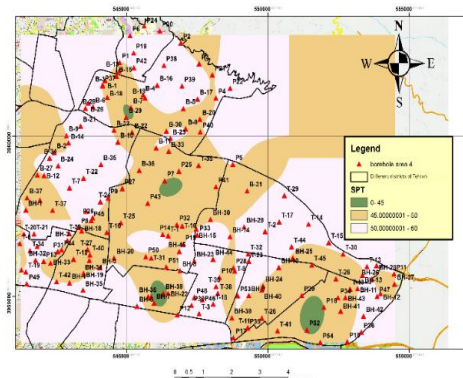


Figure 49. NSPT zoning map at a depth of 4 meters in district 4

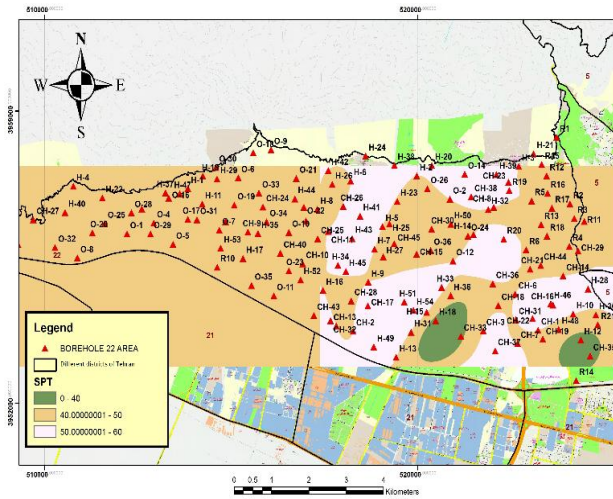


Figure 52. SPT zoning map at a depth of 40 meters in district 22

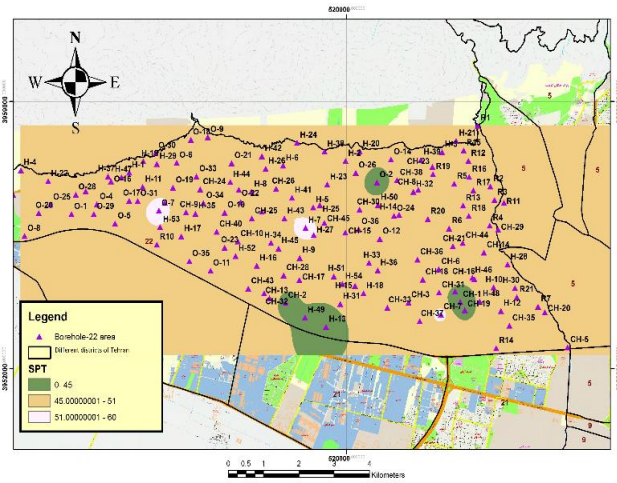


Figure 51. SPT zoning map at a depth of 20 meters in district 22

3.10. Permeability Zoning Map

Today, geotechnical studies should be carried out to design high-rise buildings according to the rules of the engineering organization. Usually designing the load capacity is based on the guesswork and estimation. For more accurate estimation, we can estimate geotechnical parameters (such as C and Φ) based on the information layers of these boreholes, using the geospatial information system (GIS) and available geotechnical data of the urban areas obtained from the drilled boreholes to design the buildings without geotechnical studies [3]. In this research it is shown that the parameters necessary for the engineering estimation can be estimated more accurately by the load bearing capacity. To accomplish this idea, urban geology, geology, topography and geotechnical studies should be accurately available. It is clear that the more complete and accurate the basic information is, the more accurate and complete the GIS analysis result will be. In preparing the GIS map of the geotechnical base of Tehran in developing zones 4 and 22, the digital information provided on the city map, geology and topography of Tehran, as a mapping organization, was used [3]. Figure 53 to 56. show the geotechnical zoning maps in different depths. According to available maps, the permeability of district 4 is between 4-10 and 2-10 cm per second. In district 22, the permeability in this region is above 10^{-3} to 10^{-5} cm per second.

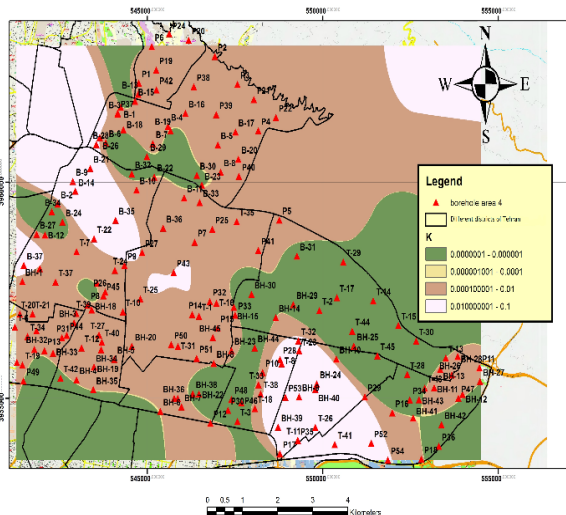


Figure 54. Permeability zoning map at a depth of 16 meters in district 4

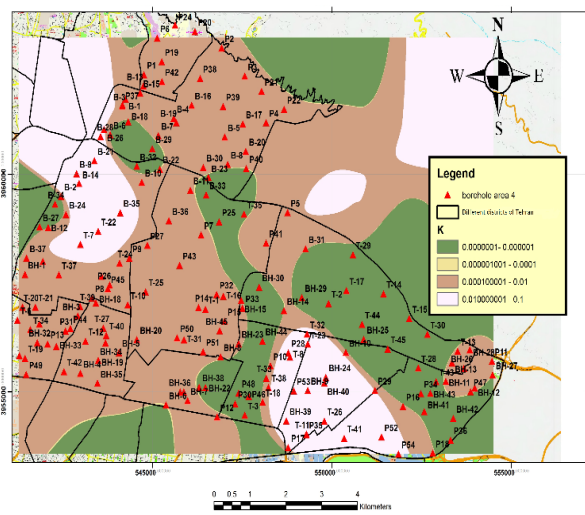


Figure 53. Permeability zoning map at a depth of 4 meters in district 4

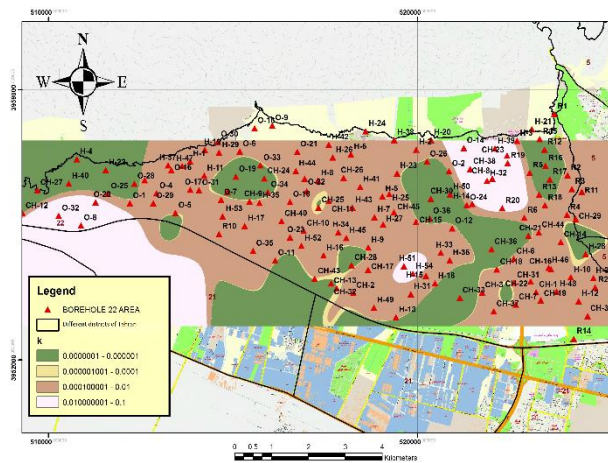


Figure 56. Permeability zoning map at a depth of 40 meters in district 22

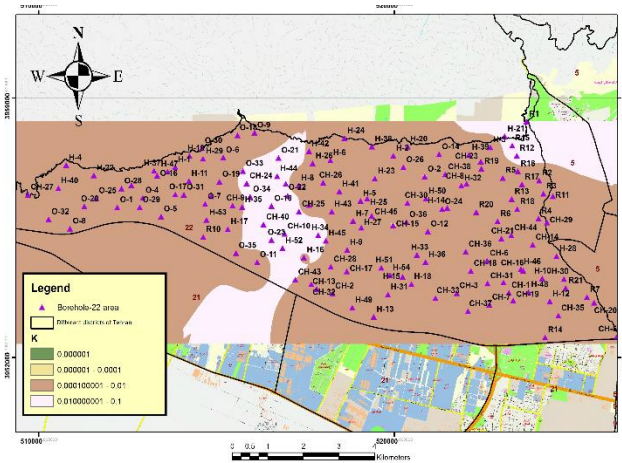


Figure 55. Permeability zoning map at a depth of 20 meters in district 22

4. Discussion

The existence of basic data in Iran's geotechnical database, in addition to the possibility of providing for examination of issues such as bearing capacity and sewage settlement, also allows for the analysis of seismic geotechnical parameters and seismic hazard zones in Tehran, which can have an important impact on the future development of Tehran. On the other hand, the implementation of these zoning procedures is not intended to meet the needs of a particular project and cannot replace the usual geotechnical studies for sites, and even if the location of the project is determined, then the geotechnical zoning route after definite geotechnical studies of the site should definitely be considered. Considering the administrative problems in these areas and considering the widespread use of urban areas in zones 4 and 22 of Tehran, it is better to use this map conservatively. This map has a higher accuracy than previous studies but it has still some problems, because with respect to the wide variations in the geotechnical issues of soils in each region, it is better to construct specific structures with high sensitivity and geotechnical tests as well as on-site experiments. The area is designed for the accuracy of the design. In these studies, drill boreholes have not undergone consolidation experiments, and the reason for not doing this is the presence of coarse aggregates. Therefore, in this area only the basic elastic meeting is available based on the elastic modulus data provided in the regions, that can be calculated at the time of determining the desired design in each area. These results are more important than previous studies, because in these studies local experiments have been used.

5. Conclusion

Application of geotechnical database, investigating engineering geological characteristics and geotechnical properties of quaternary deposits of west and east of Tehran, statistical studies on data and preparation of different maps of geotechnical micro zonation in Tehran (districts 4 and 22) in GIS (Geographical Information System) and creating an initial recognition of the characteristics of these areas can optimize the cost and time management by conducting the studies to the correct path. Due to the large size of the site, it is not possible to know its full features. Therefore, the nature of the site is random and the data are always faced with uncertainty. For this reason, the most important method for data analyzing in geotechnical engineering, statistical analysis, and modeling is using these methods with a certain confidence level of the unknown parameters of the site. In this research, some samples of statistical results including minimum, maximum, mean, standard deviation, etc. are provided, which yields a general information about the characteristics of Tehran's districts 4 and 22. The data of various depth of the site with soil characteristics should be evaluated for a closer check to analyze the change process. This can be used as a useful tool in addition to micro-zoning maps. Preparation of different geotechnical microzonation maps in districts 4 and 22 in the Geographic Information System (GIS) makes it possible to estimate all geotechnical parameters of that point at a different depth on micro-zoning maps by having the UTM coordinates of each point in the districts 4 and 22. It is possible to store and update data that is simultaneously depended in spatial and descriptive terms in a digital form using Geographic Information System (GIS). This system enables the user to display and analyze chart and table data simultaneously and provides the ability to provide high-level services to users in different fields. According to districts 4 and 22 soils, the soil materials in this region belongs to level B in Tehran (coarse-grained). The materials of districts 4 and 22 do not have fluidity and plasticity. Dry density and saturation are increased by depth. There is no phenomenon of swelling in these soils due to the low LL in the soils of the region and their coarse-graining. The phenomenon of liquefaction will not occur by the earthquake due to the coarse-grained nature of the soils of these districts. The plasticity index of the soils of these areas is usually in the non-plasticity to low plasticity. The friction angle between 30 to 37 degrees indicates coarse grain and moderate to high relative density. The shear wave velocities in districts 4 and 22 represent dense to very dense soil.

6. References

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