APPLICATION OF THE LANDSCAPE GENESIS MODEL IN ENGINEERING GEOLOGY FOR (AL-NAJAF AL-ASHRAF CITY AREA)

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ABSTRACT

The objective of the study is to produce digital geotechnical maps of Najaf city and Kufa through employing the capabilities of GIS techniques. Those maps can represent the distribution of different geotechnical properties in an accurate easy to use manner.

This study provides an easy method to analyze the spatial information and the link between them to give an overview of the geographic location and characteristics of comprehensiveness, as well as to extract information from (DTM) the new through the original information on the map such as extract contour maps. In this research data has been taken on some of the properties of the soil to the Najaf city and Kufa, bearing capacity, layer description, dry soil density, wet soil density, chemical tests of the soil, where they include values and concentrations both of: (organic matter, SO3, Gyp and TSS (Total Soluble Salts)) and analysis of this data using GIS to produce maps with contour.

The data included the properties of the soil for (181) boreholes with depth (15m) distributed randomly on residential areas in all districts of the Najaf city and Kufa.

The most important conclusions in this study were the bearing capacity ranged between (3.0-22.0T/m²). Soil of Najaf city and Kufa was being in the form of layers and these layers were composed of: sand, clay, gypsum and silt in various percentage which randomly distributed at different depths and the water table is seasonally variable. The use of the software (GIS) in linking the geotechnical properties of the soil is useful in reducing the time, cost and effort, as well as considered as a tool to help when a conventional soil being investigated.

Key words: Geotechnical Properties, Interpolation, Geographic Information Systems, Geotechnical Maps, Database Systems.

1. INTRODUCTION

In the field of civil engineering, all projects are nearly built on to, or into, the ground. Whether the project is a structure, a roadway, a tunnel, or a bridge, the nature of soil at that location is of great importance to the civil engineer (Al-Baaj, 2017).

Therefore, in order to assess the general suitability of the site and to prepare an adequate and economic safe design for the proposed project, proper subsurface investigation is to be made. The primary objective of subsoil investigation in civil engineering is to determine the geotechnical properties of the soil underlying the site, and for the necessity of getting it in possible minimum time, cost, efforts and staff the need arises to employ modern means. Nowadays, with the advances of the information technology including Geographic Information System (GIS) and remote sensing at present, can serve the geotechnical engineer as the very effective tools, not only for non-data area prediction but also used to interpret the complex data area with reliability and accuracy (Panoot, 2001).

The essence of using remote sensing techniques to study earth materials is to represent earth surface landscape by various kinds of image and to extract the information of earth surface environment and resources. The imaging process of remote sensing is to record the radiant and reflectance energy of earth materials by different kind of images (Al-Mokredi, 2007).

GIS is a powerful tool by evaluating of huge numbers of data for the geoenvironmental evaluation in performing of such analyses on very large areas in very short times. An important feature of a GIS is the ability to generate new information by integrating the existing diverse datasets sharing a compatible spatial referencing system (Orhan, et, 2009).

GIS are commonly used in a wide span of applications (e.g. topographic base mapping, socio-economic and environmental modeling, and global modeling) that treats information about spatial phenomena. For geotechnical engineering purposes in particular, GIS has been used extensively for slope stability problems, engineering geological, geophysical and geotechnical surface mapping and site investigation data management. Thus, the present study is undertaken, applying the advantage of the capabilities of GIS and remote sensing techniques to develop a user friendly suitability digital geotechnical map of the study area.

2. MODELS OF LANDSCAPE

A landscape is the general shape of the land surface. Landscapes include a variety of topographic features related to the processes that shaped the surface. A landform is a single feature of a landscape. Landscapes are generally made of a variety of related landforms such as mountains, valleys, and river systems. Geological structures are major influences on landscapes. There are many different ways to model or represent landscape structure corresponding to different perspectives on landscape heterogeneity. The choice of model in any particular application depends on several criteria: (Thomas, 2004)

- The ecological pattern-process under consideration and the objective of the analysis
- The spatial character of the landscape with respect to the relevant attributes
- Available spatial data (type, structure and quality)
- Available analytical methods (software tools)
- Available computational resources
This report presents a full description and classification of the landscapes within the study area, together with an analysis of its engineering geology for soil properties. It will provide a valuable source of information for planning and land management in Al-Najaf Al-Ashraf area and Al-Kufa.

3. CONCEPT OF GIS
Geographic information systems (GIS) as a set of regulations and duty data analysis and processing through the use of a computer, and by linking this information geographical their positions on according to specific coordinates, organize information in the form of layers (Layers) and collectively be maps for the area geographic, and thus show the geographic or other attributes of that area. Also known as a flag for the collection of geographical and descriptive information and entry, processing, analysis, presentation and reformatted to specific targets, and this definition involve the ability of the systems on descriptive names, tables, reports and information of the quantity. The insertion of geographic data (aerial photographs, video satellite and maps), treated (reiterated from error), stored, the investigation, the analyses (a statistical analyses and spatial) and showed on paper or on the computer screen in shape of graphs, maps and reports. This way or method to organize the geographical and descriptive information by computer and linked to geographical their positions depending on the specific coordinates. (George, 2001, Anu, et, 2013)

4. STUDY AREA
The study area is located in AL-Najaf Al-Ashraf Governorate at the southwest of Iraq. It has an area of 29000 Km$^2$. It constitutes approximately 7% of total Iraq's area. Its geographical area extends between longitudes (44º27'5-44415) Eastwards and (31º96'9–32º06'4) latitudes northwards by degrees (ALkhafaji, M,.K,.2012). Najaf Governorate ground level is 70m above sea level. It has a flat topography for the most parts. It has a desert climate which is characterized by a lack of rainfall (102mm) annually, with high temperatures in summer of up to 44 cº. Domainted by north wind or the North West (AL-khafaji, M,K,.2012).The city of Najaf is located 163 km south of Baghdad and 81 km and 63km south of the important centers of Karbala and Hilla, respectively . Map (1a) Iraqi Map shows Najaf Governorate and the study area, figure (1b) shows district of Najaf and Kufa Cities boreholes location in the study area. (The Directorate General of Urban Planning in Najaf).

Map (1a) Iraqi Map shows Najaf Governorate
5. PRESENT STUDY OBJECTIVES
This research aims to produce engineering Geotechnical maps of the cities of Najaf and Kufa, in order to provide Geotechnical information easily and quickly, and lower costs. Because Al Najaf city is one of the important city of Iraq due to the high religious attraction for Moslems. It is expected to have a huge development program in the coming years where huge structures like hotels, markets and building are expected to be constructed. For this reasons it is important to collect all data and observations related to the geological and geotechnical information about the city for produce Geotechnical map.

6. METHODOLOGY
The methodology of this research can be summarized in the following steps:

1. Collection data on the proportion of bearing capacity (B.C), strength parameters, chemical tests of soil, specific gravity, classification of layers, soil activity, water table and chemical tests of ground water . The data was carried from soil investigations reports by, AL- Mawal Company for Soil Investigation, National Center for Construction Laboratories (NCCL), and researches on the sites of the projects during the years from 2003 to 2017. It was given a sequence of (1-181) reports and were then sorted the data using the Excel program according to type of test and drilling depth.
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2. Obtain a satellite image of the study area and conduct the correction process using GIS techniques to be a base in determining the locations of the studied soil samples.

3. Download the locations of the boreholes test taken in paragraph (1) are summarized on the satellite image. Where test drilling sites are identified using (global positioning system) GPS coordinates.

4. Enter all data within a database within a program Arc GIS 10.2.

5. Spatial analysis of all data obtained using the tool Kriging to produce maps showing the nature of the physical, engineering and chemical properties to the cities of Najaf and Kufa area.

7. RESULTS AND DISCUSSION

Collected soil data for the following variables: - the physical properties such as layer description, wet soil density, moisture content, standard penetration test (SPT) and engineering properties such as strength parameter and bearing capacity and chemical tests of the soil and water, such as: (SO3, Gyp, TSS, (Total Soluble Salts) and organic matter), (SO4 and TDS) and the water table level for all test wells that contain this information. Fed were data in tabular form through the Arc GIS program. In this program different layers were formed according to the properties of the soil and thus the information is ready for spatial analysis to obtain results of benefit to engineers and decision-makers.

8. PHYSICAL SOIL PROPERTIES

Description of Soil Layers

The study was conducted on 181 test holes in study area. For the purpose of preparing Geotechnical maps of the depths (0-15 m) showing the horizontal and vertical distribution of soil type in figures (2a-g) shows thickness and layers description of boreholes in Al-Najaf and Al-Kufa cities. The soil in Al-Najaf and Kufa were composed of different proportions of sand, silt and mud at different depths. Where in the center of the city of Najaf and the northern and western and eastern regions consist of a high proportion of sand, while the eastern region of the city of Kufa appear layers of muddy green sand on the depths of (2-10 m). This overlap in features is due to the nature of the geological region, which is dominated by the deposits of the Dabdeba formation in the western and northwestern regions and the city center. And river deposits and sediments of the Euphrates river in the eastern regions.
Wet Density
The weight unit gives a good estimate or information about the soil conditions in terms of overburden pressure as well as the determination of the over consolidation ratio. The settlement and calculating the lateral earth pressure of the retaining structures. In the cohesionless soil, the friction angle depends on the weight unit (Jumikis, 1962).

Calculated of wet density for the soil of Al-Najaf and Al-Kufa ranged between (1.0-2.31) gm/cm$^3$. Geotechnical maps have been prepared for the layer of the soil that is located under foundation for depths (0-15m). Figures (3a-b) shows wet density Al-Najaf and Al-Kufa soil to these depths. The variance in weight unit values is due to the soil type in terms of grains size and the type of minerals formed vertically and horizontally.

Moisture content MC
Moisture content plays an important role especially in the case of soil related high gypsum content and important in the calculation of hydraulic analysis of soil. Through the moisture content data obtained to depths (0 - 15 m) above ground level, the available results for 181 test boreholes, procedure of spatial analysis for it. It was got Predictive maps. Where moisture content values in Al-Najaf and Al-Kufa ranged between (0.0-31.40%) as shown in figures (4a-b). for predictive maps of moisture content at different depths.
Standard Penetration Test (SPT)

This is an important field test, which gives a good estimate of the bearing capacity and shear strength values of sandy soil. It also gives an indication of the conditions of the subsurface soil layers of change in the vertical and horizontal direction (Lambe and Whitman, 1969).

Geotechnical maps of standard penetration testing values have been prepared as shown in figures (5a-b). These showed a maximum value of (58 bowls) and a minimum value of (3 bowls). The results show that the northern and central western parts of the study area have low SPT values which will result in low values of bearing capacity, and that coincides with the distribution of bearing capacity in those areas shown in figure (7a-d).

The maps show a similarity between them and an increase in SPT values with the depth, but only in some sites, where there is a difference between depth and another of the site itself. It can be concluded that the soil of the city of Al-Najaf is highly in bearing capacity in the western regions, North West, south and south west and the center of the city. And the medium bearing capacity in the eastern region of the city of Al-Kufa.
9. ENGINEERING SOIL PROPERTIES

Strength parameters

It is important and essential for to process geotechnical problems, is to know the soil strength, for engineering Projects, such as, the design of foundations, balance slopes, airstrips, retaining walls design, design of the establishments of streets, etc. Soil strength is represented information incorporates by (un-drained Cohesion (C_u), (un-drained angle of Internal friction (\(\phi_u\)), wet density (\(\rho_{\text{wet}}\)), dry density (\(\rho_{\text{dry}}\)) and extreme bearing capacity (qu)) (Smith, 1991) that possessed from the test of unconfined. The test of direct shear and the test of triaxial Shear resistance comprises As follows:

1. Resistance creating from interfere of the soil particles with each other (Internal friction).
2. Resistance of the creating force which is attempting to connect soil particles in the soil mass with each other (Cohesion).

Tests of shear strength parameters for Al-Najaf city and Al-Kufa city at depth from 2.0-10.0m. The results in cohesive values between (0.0 -15.47 T/m\(^2\)) and internal friction angle between (2-45) degree, figures (6a-g) shows cohesive values and internal friction in Al-Najaf and Al-Kufa cities. From this it can concluded that the density of sandy soil increases means the friction angle increases while the shear resistance to the soil is high if the clay ratio is high in the soil, low the internal friction angle between the granules is small it causes increases in resistance to cohesion in this case.
10. BEARING CAPACITY

The ultimate bearing capacity of soil beneath a foundation load depends primarily on the shear strength. The working or allowable, value for design will take into consideration both strength and deformation characteristics (Bowles, 1988). Represent geotechnical maps which were concerned for bearing capacity that in this study for Al-Najaf and Al-Kufa at depths (1.0-4.0 m) are shown in figures (7a-d). It was the highest value B.C was (22.00 T/m²) at depth (4m). Minimum B.C was (3.00 T/m²) at depth (2m). The foundations of installations designed depending on bearing capacity of soil because, it is considered the most important engineering properties. In general the bearing capacity of residential areas is increased in Al-Najaf city center, as well as for shallow depths, large change in groundwater levels that affected the bearing capacity.
Chemical Properties of Soil
The chemical properties of the soil are measured when the projects are set up, for the purpose of benefiting from them in the design of the foundations of the different plants and their implementation in terms of protecting the foundations using special types of cement resistant to sulfur salts. The chemical properties of the soil can also be used to determine the suitability of the soil for burial, earthmoving and road construction. Tests of chemical of soil in Najaf city and Kufa city are carried at depths (2.0-10.0) m

Soil chemistry tests include the determination of the percentage of sulphates SO3%, gypsum, soluble salts (TSS %) and organic matter.

Sulfates content SO3 %:
Sulfur salts found in soil and groundwater is interacting with cohesive concrete. Its effect is transmitted through the capillary of the concrete, where it spreads and interacts with the cement compounds, leading to the expansion of the concrete and its separation in case the salts are high. The spread of salts can be controlled using materials that prevent the permeability of soil salts into concrete, (Kezdi, 1974). The percentage of sulphates SO3% was measured in the soil of the cities of Najaf and Al-Kufa between (0.19 – 17.70% ) more than (1.0%). Geotechnical maps were prepared for depths (0-10 m) and as in figures (8a –b). It was see an increase in the direction of the north-west and the center of the city of Najaf and the south-west direction and less in the soil of the city of Kufa. When comparing the results of the sulphate ratio with the values produced by (Tomlinson, 1988), some of them are very high, high, medium and low. Where the permissible rate is less than 1%. It is therefore necessary to use salt resistant cement, sewage pipes and manholes with non-permeable material to preserve corrosion. It can be concluded that this factor is very important in the underground projects because sulfates form a danger to the concrete and then the failure of these facilities and foundations, especially in the soil of the site with a high content of sulphates.
Gypsum content (CaSO₄) %

Tests important to investigate the properties of the soil is to examine the gypsum content for its importance, especially in the case of a change in the level of groundwater due to the melting of gypsum, which creates spaces and changes the structure of the soil, which is reflected negatively on the behavior of the soil. There are three sources of the problems of soil gypsum first of which is soluble gypsum and move through the soil, causing continuous loss of mass of soil and an increase in the blanks that leads to a substantial decrease in shear strength of the soil and increase the compressibility. The second source is it causes changed shear strength and compressibility of the soil in turn a result of hydration and saturation. The third source is it causes changing the volumetric for soil, result Utilities reactions gypsum. Predictive maps were made for gypsum content depths (0-10 m) from the ground level for the samples taken from the 181-bore holes tests. The values high gypsum % more than (5.0%) is dangerous on the foundation (Arutynyan and Manukyan, 1982). Between (0.41–37.82%) After entering the data of gypsum in the program has been produced geotechnical color maps representing distributed gypsum to the Najaf city and Kufa city for each (2m) depth up to the depth (10m) and as in Figure (9a-b). Note the increased gypsum concentration in the city center, north-west direction, south-west direction and south-east. Considering the values of the (Gypsum) found that a high proportion compared with the B.S 1377:1990, must have: (Gypsum no more than 10.0 %), so by knowing the amount of gypsum in the region, we can put the solutions to processing this problem when creating engineering projects over the soil and determined the quality of the cement used, as well as the exclusion of the water from the foundations of buildings when there are gypsum, in addition to the kind of foundation. Through these results when we want build the construction, we can know the values gypsum for the purpose of establishing the foundations for building through knowledge of cement type used for the foundations, as well as recommended the exclusion of the water as much as possible when
buildings do not even get soluble and thus get cavitation because of the presence of gypsum that negatively affected construction.

**Total Soluble Salts T.S.S%:**

The importance of this test is to estimate the proportions of salts that cause the erosion of concrete and pipes and reinforcing steel. When their solubility is free in water, it has a significant impact on the degree of damage to the concrete.

The percentage of soluble salts in the soil of Najaf city and Kufa city is between (0.95–41.0%). Geotechnical maps were prepared showing the heterogeneity ratio of dissolved salts of the depths (0-10 m) figures (10 a –b). It was noted an increase in salt concentration in the center, north, west and south of the city of Najaf and less in the city of Kufa. The ratio is high if it reaches more than 5% (Baver, 1972) because it works to increase the strain in the soil layers, as salts work to define the distances between the grains and then work salts as one of the main composition of strain (Lambe & Whitman, 1969).
Organic matter content (org %)

Measuring the proportion of organic matter in the soil is one of the important chemical tests to indicate the origin, quality and strength of the soil. Volumetric changes in organic soil that absorbs water can lead to swelling. The proportion of organic matter in the soil ranged from (0.01-3.40 %). Geotechnical maps of depths (0-10 m) shown in figures (11a-b). The percentage of organic matter in the soil can be described as higher than 1% (Baver, 1972). It is harmful to the soil. The solubility of organic matter in the water leads to the formation of organic acids, which change the soil environment through the oxidation of organic carbon and thus reduce soil strength. (Lawrence, 1993).
The result is according to the standard B.S 1377:1990. The limits of (SO3, and TSS) were not ok for the soil of Najaf city and Kufa city. Thus it can reduce these ratios using appropriate quality cement and many other ways.

**Ground water table location**

The ground water level from sea level was measured through 24 hours. The ground water level were shown in figure (12). In general, ground water level is seasonally variable. The depth of groundwater in the study area ranges from (0.1-14 m) below the ground surface.
Chemical Tests of Ground Water

Chemical tests on ground water were: TDS (Total Dissolved Salts) and SO4 (salphates). The value of total dissolved salts (TDS) of the study area ranged (1237 - 7456) ppm. Figure (13) shows geotechnical map for study area. Salts are classified by (Tode, 2005) as a brackish water. It contains a small percentage of salts because it is between (1000-10000 ppm). The solid materials dissolved in the study area were effective for being less than (500 ppm) according to the standard Iraqi standards and therefore will affect the foundations and reinforcing steel. As shown in Fig. 13, which shows the ratio of dissolved solids in groundwater to all test boreholes, the variation in the solubility potential of these salts in water depends on the strength of the correlation between the negative and positive ions of the salt. In a negative ion, ion with the positive the salt complex is formed. At the same time there is a reverse reaction that returns the compound to its original ions. Salts with slow solubility in water have a slow reaction which results in sedimentation. This means that salt ions with slow water solubility have priority in water. The Union, Note that the negative ion first combines with the positive ion, and this depends on the nature of ions found in the groundwater. (Baver, 1972). Measure the proportion sulfur ion (SO4) in ground water, the maximum value of sulfur ions is (2870 ppm) and the minimum values of sulfur ions (132 ppm). In both cases, they will cause corrosion of concrete and reinforcing steel. Fig. (14), shows the rate of sulfur ions in the groundwater for all the test boreholes.
11. CONCLUSIONS

1. The digital geotechnical maps delivered for the study region which utilized the geotechnical properties in GIS procedures were representative, simple to utilize, and spare time and cost since they speak to the ground truth in a basic way.

2. The capacity of GIS to deliver overlaid data of more than one geotechnical property as topical guide can help in speaking to the data and properties gathered in an alternate prospective that check the joined effect of the properties.

3. Studying the geotechnical properties of the soil in the study area, which were reported in soil investigation reports to 15 m depth, showed that there were some important ranges for some of the properties such as the allowable bearing capacity \((3.00-22.0) \text{T/m}^2\).

4. Some regions in study area shows high percentages of sulphate content (SO3) therefore these areas should be either treated or avoided to reduce the effect of sulphate.

5. Across Najaf city and Kufa, maximum Gyp was \((37.82\%)\) at depth \((2.0m)\), minimum Gyp was \((0.14\%)\) at depth \((8m)\). By knowing the amount of gypsum in the soil it can be processed using the appropriate cement, as well as to protect the foundations from the ground water as much as possible.

6. Soil of Najaf city and Kufa has TSS ranged \((0.95 – 41.0 \%)\).
7. Soil of Al-Najaf city and Kufa is a layered soil, those layers are: clayey sand, silty sand, gypsum and sand distributed randomly on the depths.

8. Groundwater table of Najaf city and Kufa is seasonally variable and has depth (0.1-14 m) below ground surface.

9. Through looking to geotechnical maps relating to bearing capacity and plan load for structures that can be taken as a fitting choice on sort of establishment and number of floors in the building

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