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SHORT COMMUNICATION

Creating spatial database of the foundation soil in Aljouf area using GIS

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Abstract

The area of Aljouf, KSA, is a promising area. Many huge structures are going to be built in this area due to spreading of urbanism and increasing of population. A survey study is performed to constitute database for the soil and the types of rocks in Aljouf area in general and Sakaka town in particular. The information or the data needed are collected from many of soil reports for different projects distributed in the region of Aljouf. Also, some borings are executed to investigate the soil and rock properties in the region. The data from the soil reports and the borings are arranged and summarized to form a database for the foundation soil and the types of rocks in the Aljouf area. The engineering properties for the foundation soil and the rocks in the area of Aljouf can be a reference to all engineers in the field of civil engineering. The data collected are analyzed statistically to get the typical foundation soil properties in the studied area. Also, the data are interpolated using GIS to produce guide maps for the different properties of the foundation soil and rocks in the region.

Keywords Borings · Topography · GIS · Bearing capacity · Maps · Interpolation

Introduction

Data showing the capacity of the foundation soil are needed in every construction phase of a building structure, especially for its foundation. Soil-bearing capacity needs to be evaluated to enable calculating and planning for correct foundation dimensions that can support the structure. If soil cannot carry the structure, intervention should be made to predict the soil behavior and improve the soil-bearing capacity into desired results [1]. The area of Aljouf is a promising area. There is no enough information about the types of soil and rocks in this region. Also, there are no references for the engineering properties and the bearing capacity of foundation soil and the rock in the region.

A survey study is performed to constitute database for the soil and the types of rocks in Aljouf area. Data needed are collected from many of soil reports for different projects distributed in the region of Aljouf. The data from the soil reports and the borings are arranged and summarized to form a database for the foundation soils and the types of rocks in the Aljouf area. Data collected for the soil foundation and rocks are analyzed using statistics program to get the typical foundation soil properties in the studied area. Also, the data are interpolated using GIS to produce guide maps for the different properties of the foundation soil and rocks in the region.

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Location and topography

Sakaka area is located between latitude (30 00 00″N, 31 00 00″N) and longitude (39 00 00″E, 40 30 00″E) in the northern part of the Kingdom as shown in Fig. 1. Toward the west and northwest, the old formations started to crop out at the foot of the Arabian shield. This sequence is overlain by the Ordovician–Silurian–Devonian Sequenas Groups (Tayma, Tabuk, Qalibah, and Huj). This Cambrian–Ordovician–Silurian–Devonian sequence is uncomfortably capped by the Tertiary formations.

In Hazm Al-Jalamid to the northeast direction, the Tertiary formations pass over the Middle-Late Mesozoic formations where the Early and Early-Middle Mesozoic are

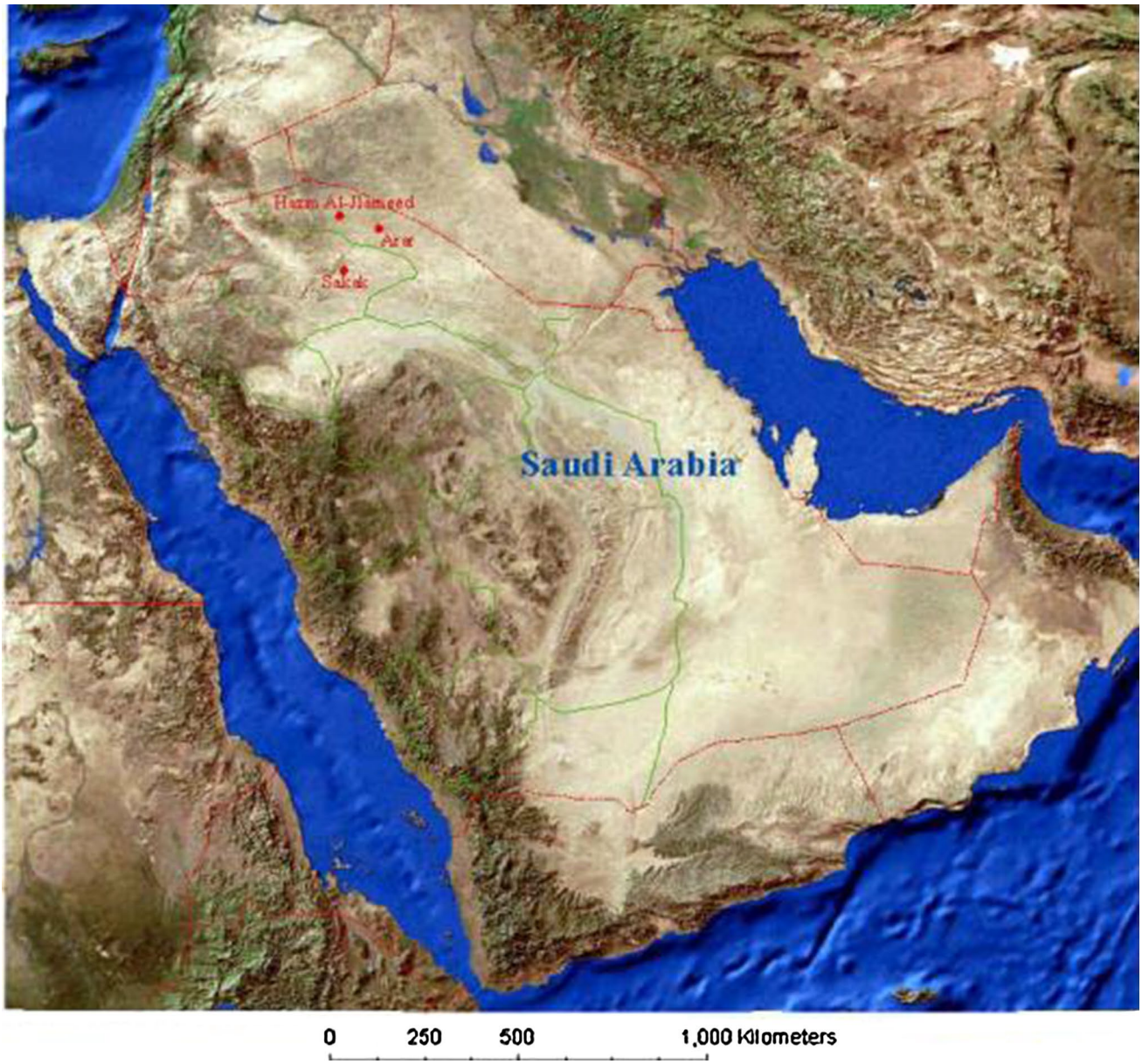

Fig. 1 Topographic features and borings location

missing but crop out in Sakaka City with an unconformity over Middle Devonian Jubah Formation (Fig. 1). In the area of Sakaka, the most prominent topographic feature is the escarpment of the Sakaka area, which is approximately 100 m high. In the northwest part, the most prominent topographic features are the rough topographic surface of lava flows and volcanic cones of the Harrah volcanic field. The highest volcanic cone, Jabal Al Amud, rises approximately 350 m above the low—relief plain to the southeast. Aljouf area contains the Sirhan-Turayf basin. Southeastern boundary of this basin terminates at the Al Jayb, Quraymis, and Ar Rummantayn escarpments, and Tertiary rocks in these escarpments contain phosphorite-bearing beds (Fig. 2).

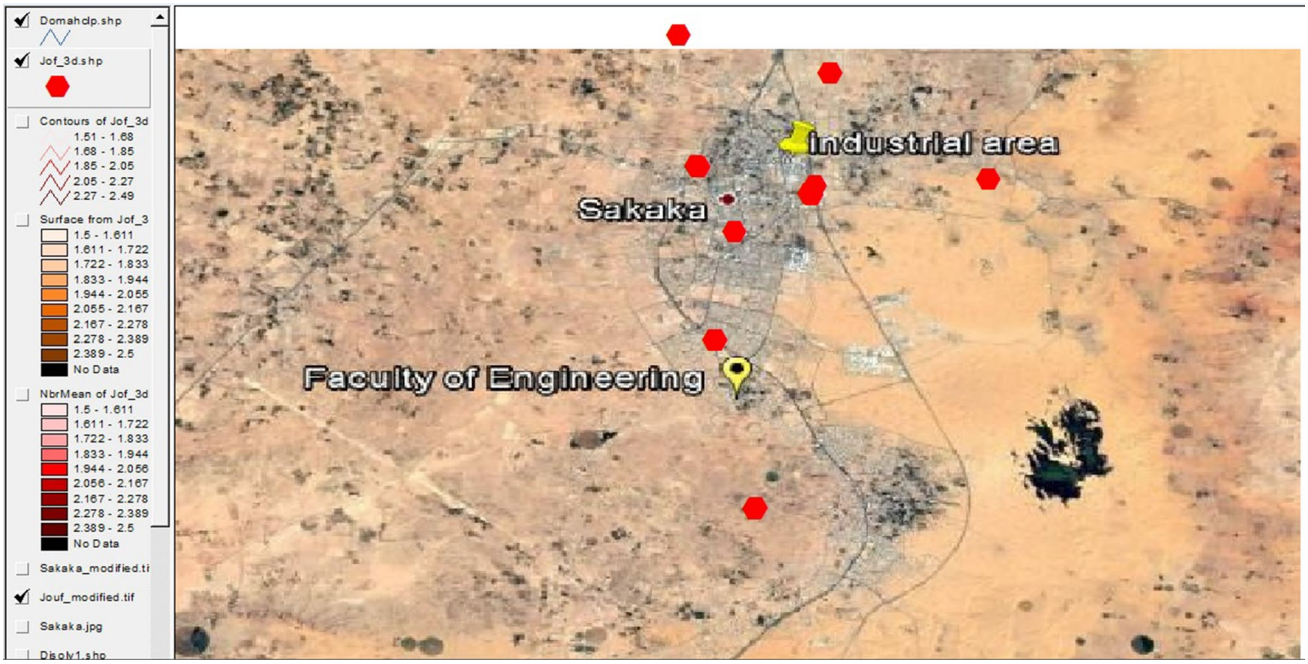

Fig. 2 Point map of borings over satellite image for Sakaka

Table 1 Borings data. *(Some sites)*

Project	(X) Final	(Y) Final	Soil description	Soil D (m)	q_{na} (kg/cm^2)	GWT
Alafash	40.18978	30.01305	Silty sand with gravel brown, very dense, dry		2.5	Not appear
Mosque	40.18969	30.01301	Silty sand with gravel brown, very dense, dry	0.2	2.5	
Water tank	40.20938	29.89236	Silty sand with gravel light brown		2	Not appear
Altwear	40.20902	29.89233	Silty sand with gravel light brown	0.3–0.5	2	
Alqayid Co	40.23375	29.97227	Silty sand brown med. Sand, dry		1.7	Not appear
Sakaka	40.23316	29.97255	Clayey sand light brown dense	1–1.5	2	
	40.22436	29.9745				
Development aquaria	40.20938	29.89236	Silty sand with gravel light brown, dry		3	Not appear
Sakaka	40.20902	29.89233	Sandy silt yellowish gray to reddish brown	0.5	1.5	Not appear
Residential building	40.1944	29.9795				
Silos street	40.1944	29.9794	Sandy silt brown, stiff to hard, dry		2.5	Not appear
Commercial hall	40.13149	29.56744	Poorly graded sand, loose, dry		1.9	Not appear

Data preparation and methodology

A survey study is performed to constitute database for the foundation soils and the types of rocks in Aljouf area. The information is collected from many of soil reports for different projects distributed in the region of Aljouf. To cover the entire Aljouf area, total borings of 33 were conducted in the Sakaka area and 10 in the university city. Also some borings are executed to investigate and explore the soils and types of rocks in the region. Data are summarized from different boring tables in one compacted table to be joined with a point map for the borings locations (Table 1).

Bearing capacity of the borings ranged between 1.5 and 3 kg/cm^2, and it was classified into 5 classes as shown in Fig. 3.

Analysis of data and implementation

Data collected for the soil foundation and rocks are analyzed statistically to get the typical foundation soil properties in the studied area. Also, the data are interpolated

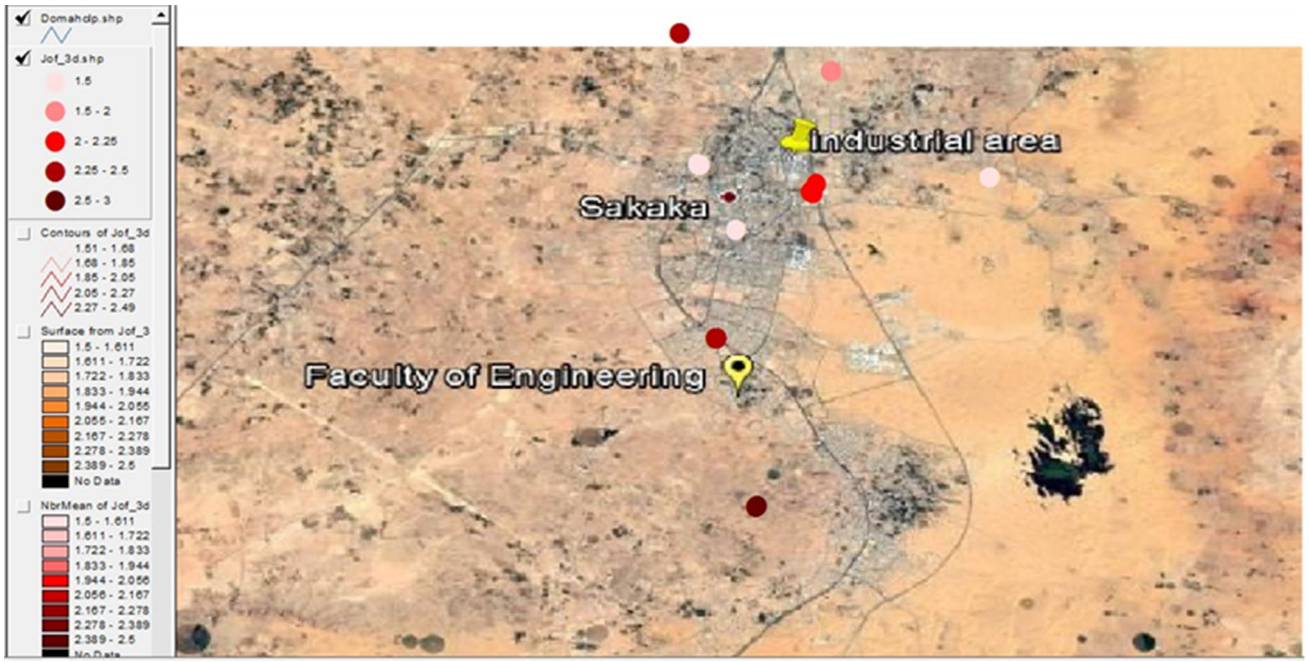

Fig. 3 Bearing capacity of foundation soil in Sakaka

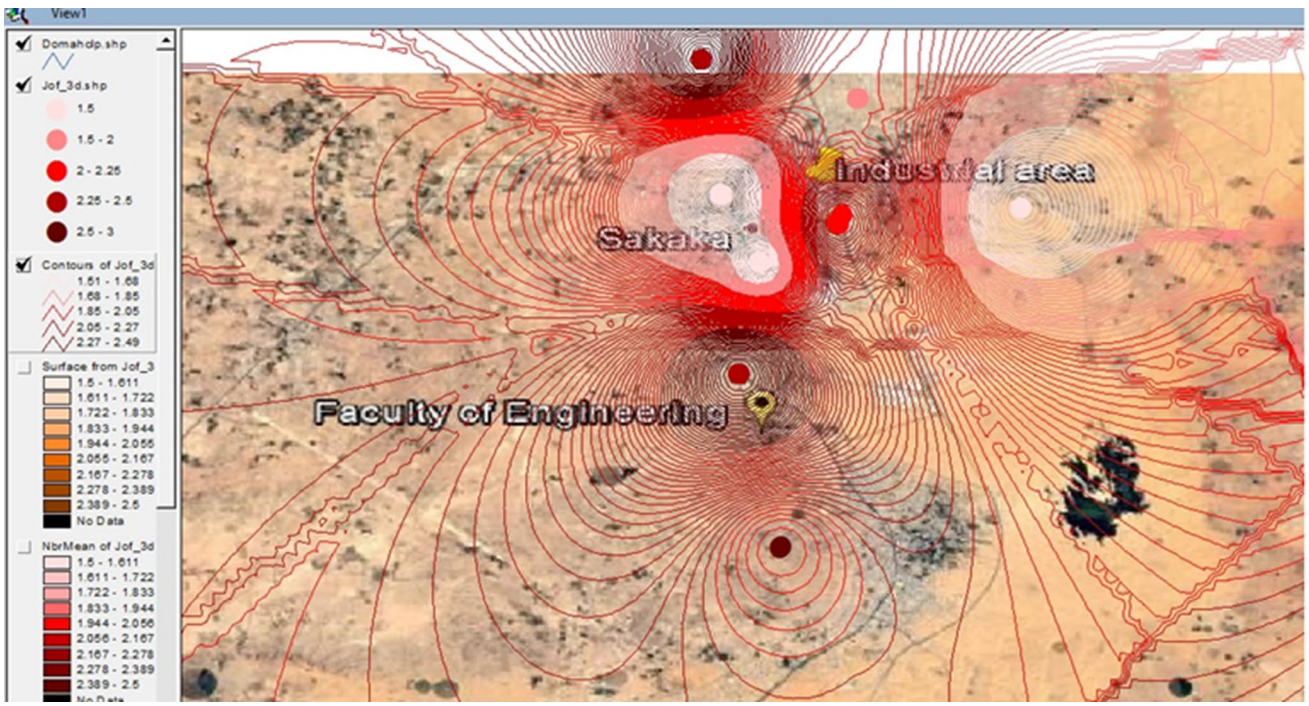

Fig. 4 Contour line map of the bearing capacity borings in Sakaka

using GIS to produce guide maps for the different properties of the foundation soil and rocks in the region.

The purpose of this research is to evaluate the subsurface conditions at the region of Sakaka town and develop the essential criteria and parameters required for foundation design and construction. The engineering properties for the foundation soil constitute a database as a reference to all engineers in the field of civil engineering. The point data of the boring with bearing capacity values were modeled in contour lines and interpolated into a surface using (IDW) tool as follows:

Figure 4 confirmed that IDW (inverse distance weighted) interpolation explicitly makes the assumption that things that are close to one another are more alike than those that are farther apart; this suits soil and represents its natural characteristics.

Soil condition

The subsurface conditions as revealed from the data of the boreholes collected from several locations in Sakaka town indicated that the typical soil condition in the studied area is underlain by silty sand (sometimes with gravel) to the depth ranging from 0 to about 3.0 m below the average ground surface. A formation of sandstone is then existing and extending until the maximum explored depths of the boreholes. Also, formations of mudstone and limestone are rarely found at depths of 2 to 5 m.

The sandstone formation is always light brown, medium grained, moderately to highly weathered and moderately to highly fractured. Also, the rock quality designation, RQD, of the sandstone formation is ranging from 0 to about 70% and the core recovery is ranging from 50 to 90%. The unconfined strength of sandstone core samples is ranging from 50 to 250 kg/cm^2.

Types and depth of foundations

In view of the subsurface conditions and nature of projects, shallow foundations are recommended. The conventional isolated footings and rafts are the most appropriate type of foundations. The foundation depth is up to 3.0 m below ground surface and the minimum depth is 1.5 m. In case of depth of sandstone rock less than 3.0 m below the existing ground level, it is recommended to lower the foundation depth to be 0.5 m into the sandstone layer.

Net safe bearing capacity

After studying the geotechnical reports of projects constructed in Sakaka town and the analysis of data of foundation soil in the area, it can be indicated that the net allowable bearing capacity of foundation soil in the studied area is ranging from 1.5 to 3.0 kg/cm^2.

Ground water

Ground water is not noted throughout the explored depths of the boreholes at the time of investigation works. A surface leakage is rarely recorded at a depth of about 3.0 m.

Cement for subsurface concrete

Chemical analysis of soil and rocks below ground surface indicated that low to moderate of sulfate content and chloride content existed. The tests showed also the pH is ranging between 6.4 and 7.2. Therefore, it is suggested to use sulfate-resisting cement for construction of subsurface concrete with minimum cement content of 300 kg/m^3 and maximum water-to-cement ratio of 0.5. Also full isolation of foundation is recommended.

Spatial analysis of soil-bearing capacity

The result analysis of the soil-bearing capacity using Mayeroff formula still comes in point. To predict the overall land surface, the GIS is used with the interpolation concept. The morphology of the rock upper part indicated that the surface is flat for most places of the studied region. Spatial classification based on the field soil-bearing capacity value is used in the application of this function [2, 3]. The distribution maps of soil-bearing capacity provide preliminary information on the soil-bearing capacity. Further analysis is related to the burden and depth of the foundation plan. It is to determine the technologies that will be applied based on the bearing capacity conditions.

In summary, interpolation is the process of changing the data points into the studied area as shown in Fig. 5. Inverse distance weighted, natural neighbor, spline, and kriging trend are rules used in the interpolation. The previous data from borings were collected, and its locations were identified in geographic format. Then, it was verified and validated, for consistency completeness and readiness for processing in GIS.

Conclusions and recommendations

The geology of Arabian Peninsula is studied, and the Aljouf geological history is explored. The types of foundation soil and rocks to the depth of about 12 m below the average ground surface in the area of Sakaka town are also investigated.

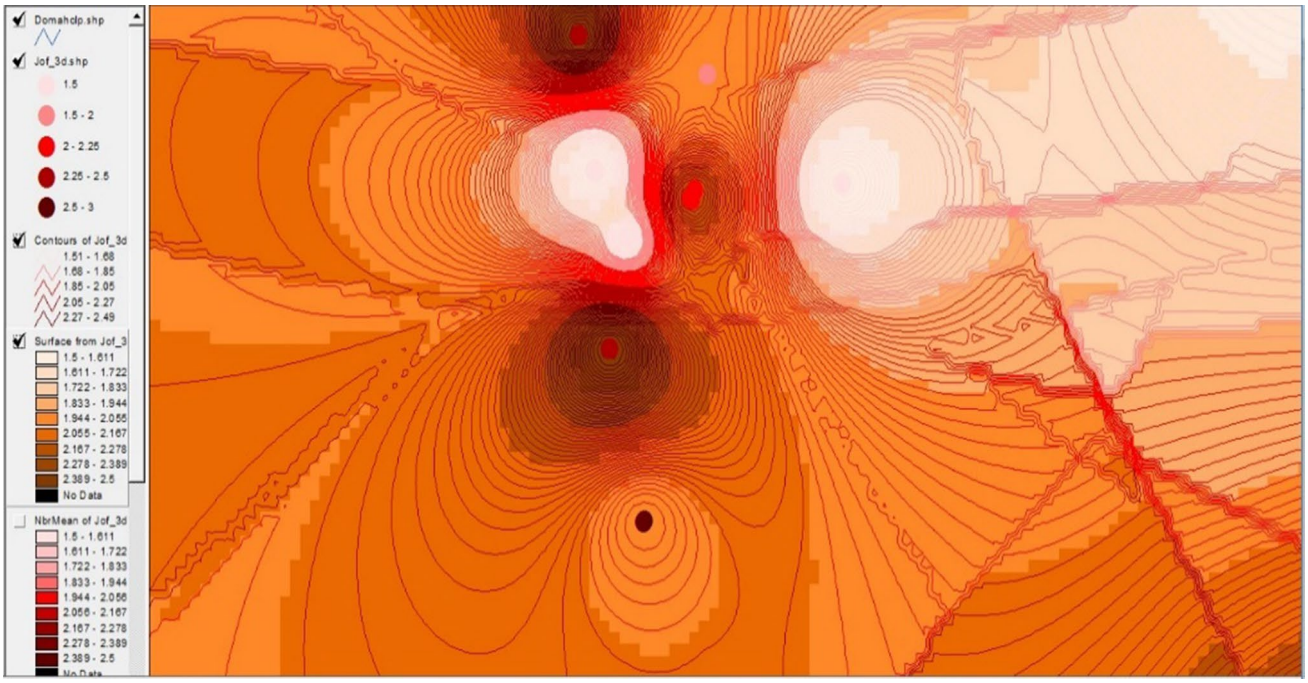

Fig. 5 Interpolated surface map of the bearing capacity borings in Aljouf

The purpose of this research is to evaluate the subsurface conditions at the region of Sakaka town and develop the essential criteria and parameters required for foundation design and construction. The engineering properties for the foundation soil and the rocks may constitute a database as a reference to all engineers in the field of civil engineering. The following conclusions can be recommended:

1. The typical soil condition in the studied area is underlain by Silty sand (sometimes with gravel) to the depth ranging from 0 to about 3.0 m below the average ground surface. A formation of sandstone is then existing and extending until the maximum explored depths of the boreholes. Also, formations of mudstone and limestone are rarely found at depths of 2 to 5 m.
2. The conventional isolated footings and rafts are the most appropriate type of foundations.
3. The foundation depth is up to 3.0 m below ground surface and the minimum depth is 1.5 m.
4. The net allowable bearing capacity of foundation soil in the studied area is ranging from 1.5 to 3.0 kg/cm^2.
5. Ground water is not noted throughout the explored depths of the boreholes at the time of investigation works.
6. It is suggested to use sulfate-resisting cement for construction of subsurface concrete with minimum cement content of 300 kg/m^3 and maximum water-to-cement ratio of 0.5.
7. GIS and modern technology are essential and more effective in collecting, solving, analyzing and showing spatial data on maps. For a broader context, this work can also consider the influence of various environmental variables such as hydrology, climate factors even disasters like floods, earthquakes.

Refrences

1. Rusdi M, Roosli R, Ahamad MS (2015) Land suitability evaluation for settlement based on soil bearing capacity in Banda Aceh, Indonesia. Adv Environ Biol 9(3):53–56
2. ESRI (2013) Understanding GIS: an ArcGIS Project Workbook. [cited 2013 Regular];Available from: http://resources.arcgis.com/en/communities/understanding-gis/. Accessed 25 Jan 2018
3. Prahasta E (2009) Sistem Informasi Geografis: Konsep-konsep Dasar (Perspektif Geodesi dan Geomatika). Informatika, Bandung, p 818