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Detecting the effect of soil compaction processes on the distribution of subsurface resistivity using 2D resistivity imaging

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ABSTRACT

In many countries, some buildings are constructed on compacted soil brought from another site. Therefore, the soil examination of the physical and engineering properties one of the important procedures in civil engineering to determine the characteristics and amount of buildings volume that this soil can bear.

There are several methods to test the physical and engineering properties of the compacted soil as well as to identify its suitability for construction; some of them are laboratory methods, while others are field methods by conducting various geophysical surveys, which is considered one of the most important field methods as it provides wide coverage of the test site.

The current study aimed to show the variation in the effect of the soil compaction process on the distribution of its resistivity, determine the subsurface distribution of soil components, and attempt to determine the effect of the compaction process on the same soil type.

A 2D resistivity imaging was conducted an area of land inside the University of Mosul estimated to be about 11,000 m2, which was filled with soil transferred from another site and then compacted.

The study included a 2D resistivity imaging of 10 profiles with a length of 40 m. for each profile and a distance of 30 m. between one profile and another.

The results of the study showed that there is the difference in the soil resistivity distribution after the compaction as a result of the variation in size gradient and the variation in compaction degree on the burial soil.

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الكشف عن تأثير عمليات ضغط التربة على توزيع المقاومية تحت السطيحة باستخدام مسح المقاومية ثنائي الأبعاد

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الملخص

يتم تشييد العديد من المباني الحضرية على تربة مضغوطة تم إحضارها من مكان آخر غير موقع البناء. لذلك ، يعتبر اختبار صلابة تربة الموقع أحد الإجراءات المهمة في أعمال الهندسة المدنية لتحديد خصائص المباني التي سيتم تشييدها على هذه التربة.

هناك عدة طرق لاختبار صلابة التربة بعد عملية ضغطها وكذلك التعرف على مدى ملاءمتها للبناء, وتعتبر المسوحات الجيوفيزيائية واحدة من أهم هذه الطرق حيث تعطي تغطية واسعة لموقع الاختبار.

هدفت الدراسة الحالية إلى إظهار التباين في تأثير عملية الضغط على خواص التربة من خلال الاختلافات التحت سطحية في توزيع مقاومة هذه التربة.

تم اجراء مسح للمقاومية ثنائي البعد لمساحة من الارض داخل جامعة الموصل تقدر بحوالي 11000 م2 تم دفنها بتربة منقولة من موقع اخر ثم حدلها.

تضمنت الدراسة الحالية إجراء مسح ثنائي الأبعاد لـ 10 خطوط مسح مقاومية ثنائية الابعاد بطول 40 مترا لكل خط وبمسافة 30 متر بين خط واخر.

وضحت نتائج الدراسة ان هنالك تباين في توزيع المقاومة النوعية تحت سطح المنطقة المحدولة وان هذا الاختلاف حدث بسبب تباين التدرج الحجمي وتباين تأثير عملية الحدل على تربة الدفن.

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Introduction

The resistivity method has been used in many engineering studies and to determine the types of soil and subsurface rocks and their physical and engineering properties (Alsharari, et al., 2020; Gutiérrez-Martín et al, 2021; Sagar, 2021). The type of soil and rocks and their physical properties are very important in determining their engineering properties and the extent of their load bearing (Das, 2011).

Understanding the type of soil and the extent to which it affects the stability and durability of the project is necessary for the construction process, in addition to the effort that these buildings will produce on the surface of the earth and the materials beneath it (Thabit and El-Asho, 1993).

Soil bears most of the weight of the building on which it is built, it is necessary to conduct a thorough study of its physical and mechanical properties. Construction experiences in several countries have proven that the exorbitant sums spent on correcting some defects after construction greatly exceed the sums spent on conducting a study or evaluation of the land prior to construction (Pheng and Hou, 2019)

Soil compaction is one of the important methods in preparing the soil for the purposes of construction, and it can be defined as a rearrangement of soil grains and their compaction by using mechanical means, and this results in a decrease in the size of the pores between these grains and increase in the density of the soil (Kodikara et al, 2018).

The process of soil compaction leads to the expulsion of liquids and air inside the pores, as well as reducing the size of pores and their ratio inside the soil (Hasnat, et al, 2019; Qian et al., 2020), which leads to an increase in its electrical resistivity. The verity of the volume gradient of the soil material increases the impact of the comprission process on it and increases its density after the reduction process, as the reduction helps to insert fine size materials into the pores between the other sizes, thereby closing the pores and increasing the density and resistance of the compacted soil.

The objective of soil compaction is to increase the bearing capacity of the soil, as compaction increases the shear and slip resistance of the soil, also reduces the porosity and permeability of the soil, and thus reduces its ability to seep water, and the soil compaction reduces the soil's ability to subside (Liu, et al., 2022).

One technique for determining the physical and mechanical characteristics of soils and shallow depth subsurface rocks is the resistivity method (Telford et al, 1990), as it analyzes the distribution of potentials and gives a clear picture of the distribution of electrical resistivity under the surface of the earth (Afuwai, 2013; Hasan et al, 2021). The effect of buildings on the surface of the earth depends primarily on the properties of the active layer, which is the soil close to the surface of the earth, which usually has a moisture content in a state of continuous change due to weather and climate changes such as rain in winter and evaporation in summer (Al Saady, 2022). The thickness of this layer varies in the city of Mosul from several centimeters to few meters, and this layer is the cause of any engineering problem (Adeeb, 1988).

The aim of the current study is to reveal the distribution of soil types and the extent of their influence on the compaction process by interpreting the distribution of the subsurface resistivity of this soil.

Location and Geology of the study area

The study area is located in the eastern side of the city of Mosul within the campus of the University of Mosul (Figure 1), and the coordinates of the center of the area are (43˚14′57″, 36˚38′69″).

The geological formations of the study area, which are from the oldest to the most recent of the Triassic period, the Fatha Formation (middle Miocene), the Injana Formation (the upper Miocene), then the quaternary sediments come from river terrace deposits or floodplain deposits, and sometimes soil deposits (Al-Jubouri, 1988). The river terraces are represented by the four terraces.

The study area is located on the third terrace (Al-Naqeeb and Suleiman, 2008). These banks consist of a series of conglomerate sediments composed of gravels and sand that is not well cohesive with clay (Al-Jabouri, 1988). The thickness of these terraces varies from (1-25 meters) due to erosion factors that are affected by the topography of the area (Al-Saigh, and Shanshal, 1994).

There are some geophysical studies conducted in the areas close to the current study area like (Al-juraisy, 2021; Al-Heety, et al, 2022), which confirmed that the surface soil of the area was composed of a mixture of aggregates with clay materials.

The study included a semi rectangular area of land estimated at 11000 m2 that had been cleared of bushes and covered with 2-4 meters of movable soil (sub-base materials) consisting of a mixture of gravel, sand and clay, and then compacted.

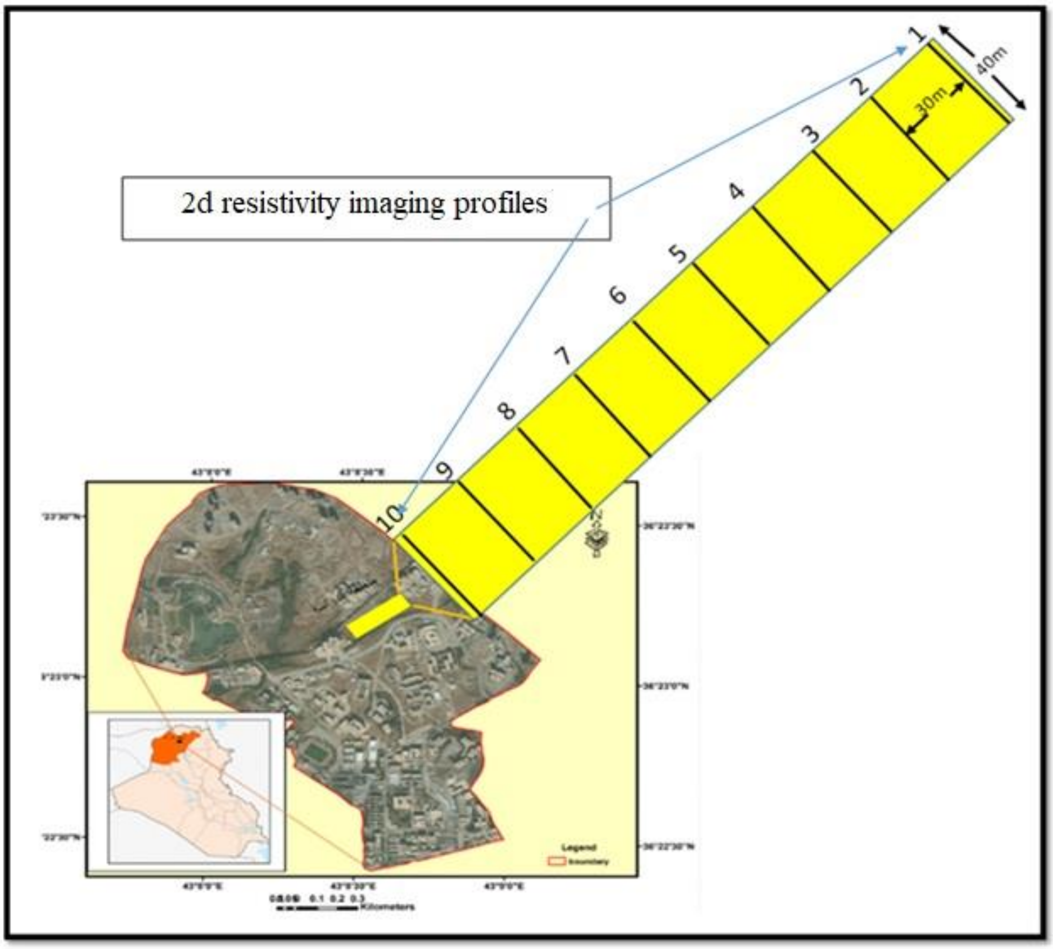

Fig. 1. Location map of the studied area with 2D resistivity profiles

Methodology

The current study included conducting a two-dimensional resistivity imaging along ten profiles have length of 40 meters (Fig. 1). Since the survey was conducted in the topsoil, there are no limitations in choosing the direction of the survey other than obstacles in the field therfore, the direction NW-SE was chosen The Wenner electrode array was used, with an electrode spacing of 1 m. thus, 41 electrodes were used for each profile with 40 m. length, The lengths of the profiles were determined according to field obstacles. Measurements were made using a SAS 4000 resistivity meter (Fig.2), Which consists of two main units: The first unit (Fig.2a) is the control, measurement and results storage unit, while the second unit (Fig.2b) is the current distribution unit on the electrodes. The two units are connected via a special cable and an appropriate power supply (Fig.2f) is connected to them. The steel electrodes are connected to the device via cable reels.

Res2DInv version 3.56.44 was used to interpret the survey data, and a linear scale was chosen for distance and depth, in addition to standardizing the colors that indicate resistivity (using a linear scale) to facilitate visual comparison.

Fig.2. SAS 4000 whith it`s accossorys: (a) the main unit, (b) electrode selector and cable connectors (b1, b2), (c) cable, (c1) cables connector, (d) electrodes, (e) connectors cable (f) power supply(battery)

Results and Discussion

In the current study, three geoelectrical zones were identified based on the resistivity values obtained from the results of 2D resistivity inversion of the profiles 1 and 2 (Figs. 3 and 4), the first in which the resistivity values less than 80 ohm.m (The blue color with its gradations) which may be represents the sites of aggregation of clay materials that were variously affected by the compact processes, and this zone can be observed in all survey profiles. The second in which the resistivity values ranged between 80-200 ohm.m (The green

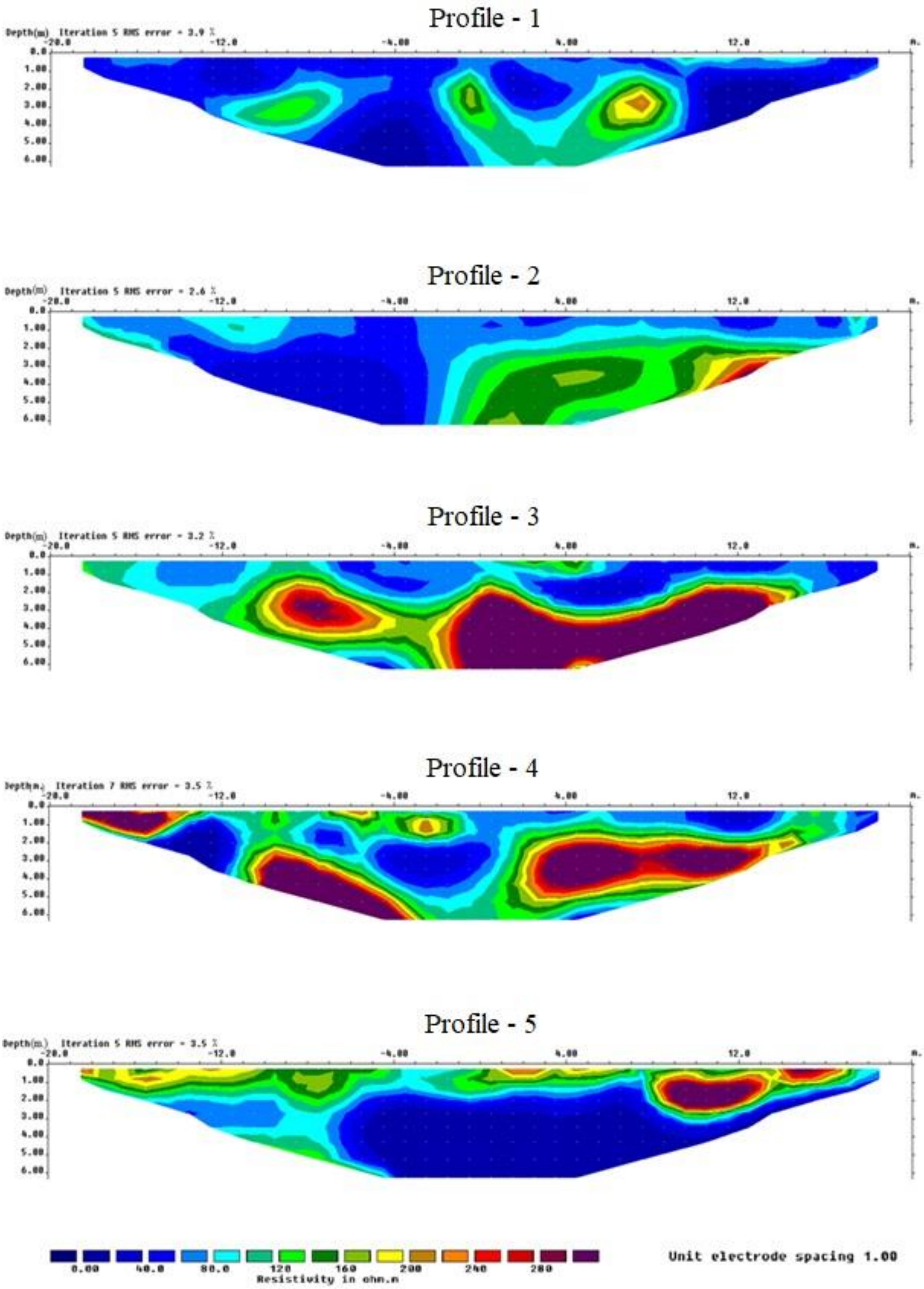

Fig. 3. Two-dimensional inverse section of profiles 1,2,3,4, and 5

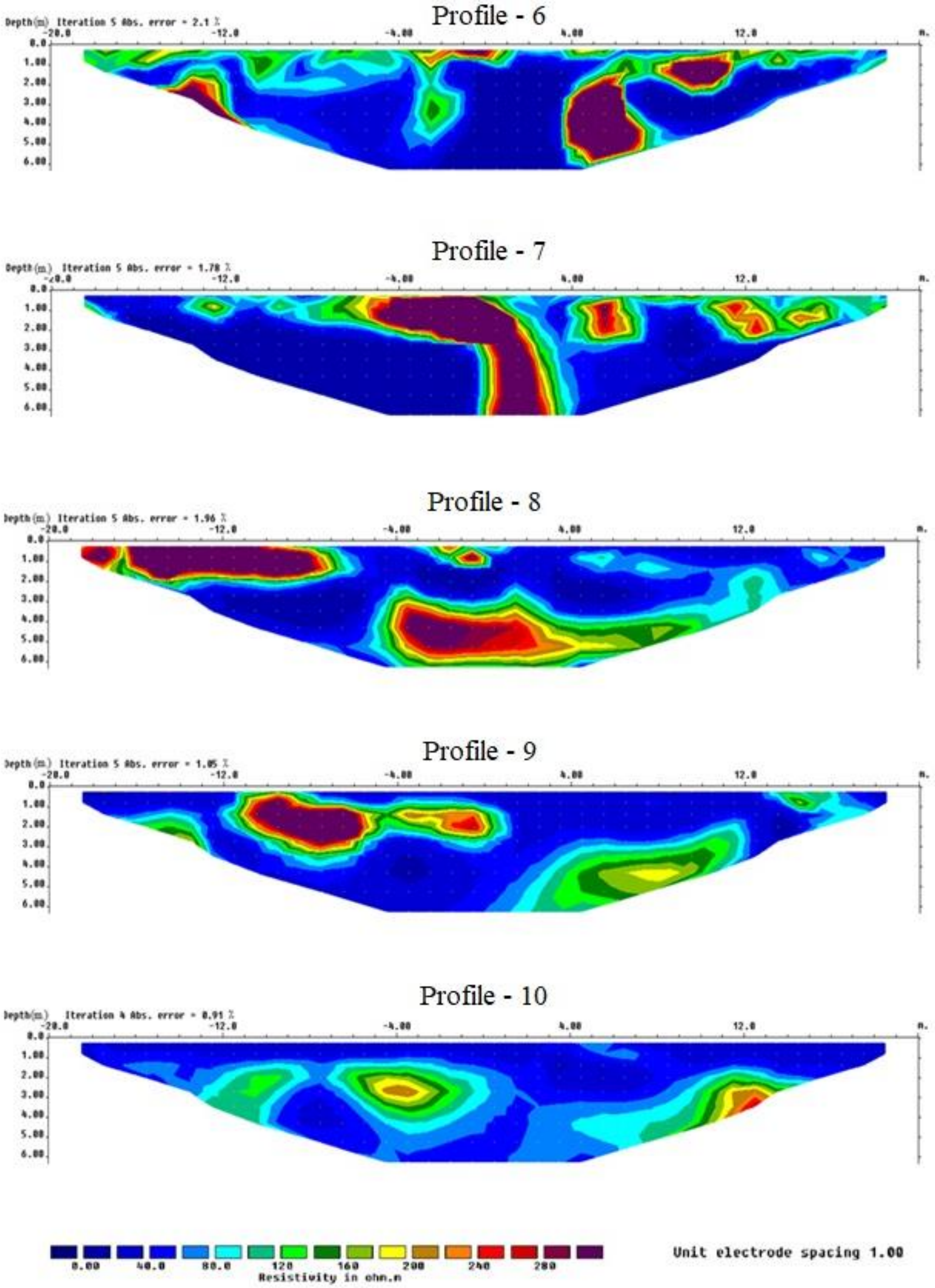

Fig. 4. Two-dimensional inverse section of profiles 6,7,8,9, and 10

color with its gradations in addition to the yellow color) which may be **represents aggregate** materials with a low grade of compaction. As for the third layer, the resistivity values was greater than 200 ohm.m up to about 300 ohm.m (Brown color with its gradations) which is probably the most compacted layer of aggregate.

The distribution of the three zones varies under the two-dimensional imaging profiles while the first band shows small resistivity distributed under all the survey profiles, it can be noted that the third zone (large resistivity) is variously located under these profilels, as its presence is limited to a small area under profile 1, 2 (Fig.3) and 10 (Fig.4) and it can also be noted that the location of this zone is near the surface under some profiles such as profile 7, 8 and 9 (Fig.4).

The resistivity values varied in the compaction zones, perhaps due to the difference in the sorting process of the transported soil components because of the variation in the compressive strength from one place to another.

The distribution of backfill materials depends on the type of materials that are unloaded by trucks and distributed by the bulldozers and graders, which settles these materials before starting the process of compacting them by compactors. Two-dimensional resistivity sections (Profiles 1-10) indicates how different types of backfilled soil are distributed under the earth's surface and the degree to which they are affected by compaction.

The two-dimensional resistivity interpretation profiles showed some sites where the resistivity values were relatively high (greater than 200 ohm.m), possibly representing soil compaction sites of various sizes, while other sites showed low resistivity values (less than 80 ohm.m) which probably represents the clay soil aggregation at those sites. This distribution of resistivity may help to recognize the variation of soil density after the compaction and thus to identify the sites of geotechnical weakness of the site.

The lack of exploration depth can be attributed to the spread of conductive clay soil under most of the 2d resistivity profiles, which causes a relatively large variation in resistivity near the surface and thus may have led to a reduction in exploration depth. In general, soil information at these depths (6 meters) can be used when constructing small and medium-sized buildings.

The wide spread of clay (low resistivity) near the surface under most parts of the profiles led to a relatively large variation in resistivity near the surface, and this may have led to a decrease in exploration depth. But in general, soil information at these depths (6 meters) It may be useful when constructing small and medium buildings.

Conclusion

From analyzing and comparing the results of two-dimensional survey profiles interpretation, the study reached some observations, which can be summarized as follows:

- The study showed that there is an irregular distribution of resistivity values under the defined area, and that the irregular distribution was mainly a result of the difference in the distribution of soil types, as well as due to the difference in the amount and degree of reduction.
- Two-dimensional resistance survey can be used to identify the locations of weakness in the compressed backfill soil.

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References

Adeeb, H. G. M., 1988. Structure and Stratigraphy of Mosul City -the Right Bank, Unpub. MSc thesis, Univ. of Mosul, Iraq, 167 p.

Afuwai, C., 2013. Understanding the basics of Electrical Resistivity Geophysical Survey (1st ed.). LAP LAMBERT Academic Publishing. Retrieved from https://www.perlego.com/book/3316013

Al-Heety,A.J., Shanshal, Z.M.m and Al-Mashhadany, A.y., 2022. Application of Multi-Channel Analysis Surface Waves and Electrical Resistivity Tomography Methods to dentify Weak Zones at University of Mosul, Northern Iraq. Vol.55, 1D, pp. 47-69, DOI: 10.46717/igj.55.1D.4Ms-2022-04-20

Al-Jubouri, M.A., 1988. Geology of Mosul Area, East of Tigris River. MSc. Thesis, Mosul University, Iraq. 158p.

Al-Juraisy, B.A., 2021. The Effects of Some Physical and Chemical Factors on Apparent Resistivity of Surface Soil in the University of Mosul, Mosul City, Northern Iraq. Iraqi Journal of Science, Vol. 62, No. 11, pp: 3973-3983, DOI: 10.24996/ijs.2021.62.11.18.

Al-Naqeeb, S.Q., Sulaiman, A.M., 2008. Quality study of groundwater at Mosul University Campus and its evaluation for irrigation validity. The 6th Periodical Scientific Conference of Dams and Water Resources Research Center, Mosul University, 27 – 28, pp.141-148.

Al-Saady, M.T., 2022. Climate change and its impact on soil moisture or water content change (1950-2020) soil of north of Baghdad as a specimen (GIS،RS), International Journal of Special Education, Vol.37, No.3, pp.10552- 10578.

Al-Saigh, N.H., Shanshal, Z.M., 2014. 2D imaging for mapping river terraces deposits. J Geol Soc India 85, 722–726, https://doi.org/10.1007/s12594-015-0269-5.

Alsharari, B., Olenko, A., Abuel-Naga, H., 2020. Modeling of electrical resistivity of soil based on geotechnical properties, Expert Systems with Applications, Volume 141, 112966, https://doi.org/10.1016/j.eswa.2019.112966.

Das, M.B., 2011. Geotechnical engineering handbook, J. Ross Publishing, Inc., ISBN 978-1-932159-83-7, 787p.

Gutiérrez-Martín, A.; Yenes, J.I.; Fernández-Hernández, M.; Castedo, R.m 2021. Stabilization, Methodology in Foundation Soils by ERT-3D Application in Estepona, South Spain., Appl. Sci. V. 11, 4455, https://doi.org/10.3390/app11104455.

Hasan, M.E., Abuel-Naga H. and Leong E.C., 2021. A modified series-parallel electrical resistivity model of saturated sand/clay mixture. Engineering Geology, Vol. 290, 106193, https://doi.org/10.1016/j.enggeo.2021.106193.

Hasnat, A., Hasan, M., Islam, R., Abdul Alim, M., 2019. Prediction of Compaction Parameters of Soil using Support Vector Regression. Cur Trends Civil & Struct Eng., Vol.4, No.1, CTCSE.MS.ID.000580.

Kodikara, J., Islam, T. and Sounthararajah A., 2018. Review of soil compaction: History and recent developments, Transportation Geotechnics, Vol.17, Part B, 15, pp. 24-34, DOI: 10.1016/j.trgeo.2018.09.006.

Liu, K., Benetti, M., Sozzi, M., Gasparini, F. and Sartori, L., 2022. Soil Compaction under Different Traction Resistance Conditions—A Case Study in North Italy. Agriculture, V 12, 1954. https:// doi.org/10.3390/agriculture12111954

Pheng, L. and Hou, L., 2019. Construction Quality and the Economy: A Study at the Firm Level. Springer, 268p.

Qian G., Hu K., Li J., Bai X. and Li N., 2020. Compaction process tracking for asphalt mixture using discrete element method. Construction and Building Materials. Vol. 235, 28 February 2020.

Sagar, D., Dwivedi, S.B., Basudhar, P.K. ,2021. Electrical Resistivity Tomography in Geotechnical Engineering Applications. In: Patel, S., Solanki, C.H., Reddy, K.R., Shukla, S.K. (eds) Proceedings of the Indian Geotechnical Conference 2019. Lecture Notes in Civil Engineering, vol 133. Springer, Singapore. https://doi.org/10.1007/978-981-33-6346-5_14.

Telford, W.M., Geldart, L.P. and Sheriff, R.E., 1990. Applied Geophysics. 2nd Edition, Cambridge University Press, Cambridge, 770 p. https://doi.org/10.1017/CBO9781139167932.

Thabit K.M. and El-Asho, M.O., 1993. The Foundations of Geology for Engineers. House of books for printing and publishing, University of Mosul.