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Foundation Assessment in Different Parts of Iraq Using STAAD Pro V8i

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Abstract: Foundation is considered as one of the main parts of any structure. The type of foundation used is highly dependent on the type and properties of soil. The design of foundations requires many factors that should be defined. There are number of differences in the geological and soil conditions in Iraq. As a consequence, these differences are reflected on the type of foundation to be used. Despite these differences, same materials and style of buildings are used all over Iraq. The main problems of Iraqi soil are high gypsum content, salinity and shallow water table depth. These factors that influence the foundations are the soil properties and the amount of loads that transmitted by the superstructure. The situation has been analysed through a case study which illustrated the link between soil and foundation types in three different parts of Iraq (Mosul, Baghdad and Basra). One building was analysed using "STAAD (structural analysis and design). Pro" software in these regions. It is evident that Iraqi designers and engineers require local code to define all the loads, materials and design of the foundation to be used. The use of local materials might be very effective from both engineering and economic perspectives.

Key words: Gypsum, bearing capacity, Iraqi soil, raft foundation, foundation design, base pressure.

1. Introduction

Iraq can be divided topographically into three major regions. These are the mountains and foothills, Mesopotamian plain and deserts (Fig. 1). Due to the differences in the geology and physiography of the country, the soil characteristics and types are different.

The most important properties of soil to be looked at are density, allowable pressure, shear resistance, settlement and effect of ground water. The soil must be able to hold loads of any engineering structure without causing any shear failure or settlement effects on the structure. The most important factor that affects the foundations is the shear resistance or ultimate bearing capacity (q_{ult}) of the soil. Buildings are collapsed or destroyed mainly due to the effect of soil shear failure [1, 2].

In this paper, soil condition in Iraq will be presented and evaluated. Its effect on the foundation of a building will be assessed. There are number of differences in the geological and soil conditions in Iraq. Despite these differences, same materials and style of buildings are used all over Iraq. The attention is not paid for the climate conditions or the different nature of Iraqi geology. Three different locations having different soil and geological characteristics were chosen in Mosul (northern of Iraq), Baghdad (centre of Iraq) and Basra (southern of Iraq). STAAD (structural analysis and design) Pro V8i software was used in this research for design and analysis. The program was used to clarify that different types of foundation can be used for the different regions of Iraq.

2. Soil Conditions in Iraq

Soil conditions in Iraq according to the physiographic provinces are as following.

2.1 The Mountains and Foothill Region

This region is confined to northern and north-eastern part of Iraq. Parts of this area consist of rocks with very thin layers of soil. The soils in the

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Fig. 1 Physiographic map of Iraq [3].

valleys and plains were accumulated due to physical, chemical and biological processes. Soil salinity is not a major problem in this area.

Mountains are confined to a relatively narrow strip to the north and east part of Iraq while the foothills are located to the west and south-west of this region. Foothill area is characterized by extensive plains and large towns like Mosul, Kirkuk and Erbil which are built within these plains [3]. Near the large river (Tigris River and its tributaries), three levels of accumulated terraces exist running parallel to the river banks. They consist of gravels, boulders, sands and clays that are poorly cemented. Flat areas between anticlines are covered by sheet run-off sediments. They comprise clay, sand and silt, and sometimes coated by scattered gravels. Most of the rocks and soil of this region are gypsum, sandstone and limestone. Valleys are locally developed with fill deposits, flood plain and sabkha sediments. Sand dunes are combined within the synclinal areas within the foothill area. The groundwater table in this area is about 20 m to 30 m deep. Moreover, the groundwater is not saline [4].

2.2 The Mesopotamian Plain

It is an area that extends from north west of Baiji city stretching to the Arabian Gulf. Fifty percent of the southern part of this plain is covered with water (marsh area). Soil of this area is covered by flat lying alluvium sediments brought by the Tigris and Euphrates Rivers. The soil contains (20%-30% lime) calcareous, saline and alluvial soils. Mesopotamia flood plain consists of quaternary fluvial origin sediments about 280 m thick, alluvial fans 50 m thick on the flanks and Aeolian sediments. The quaternary deposits near Baghdad are 80 m thick, and it increases to more than 250 m south east Basra. The plain sediments include levee silts and clays, plain flood clays and stacked river channel sand bodies with accidental marsh deposits. Furthermore, the area has complicated process of salinization. In some parts of this region, gypsum exists from the surface to 1 m depth. The ground water is shallow where the water table depth ranges from 1 m to 5 m between Baghdad and Kut City. South of Kut City to Basra City the water table depth is less than 1 m deep. In general, the ground water is extremely saline in the south eastern parts of this region [3-6].

2.3 The Deserts

They are covering more than half the area of Iraq. There are three main deserts, which are as following:

(1) Jezira desert: It is located northwest Iraq. The upper part of Al-Jezira is partly steppe area and partly desert. Large numbers of salt playas and thick gypcrete soil exist. The thickness of the gypcrete soil varies from 30 cm in the most elevated parts to more than 8 m in low areas. The soil covering the depressions usually contains a high percentage of gypsum, averaging 30% and might reach 80% in some local areas. Jezira area contains several major salt playas. These are the largest Sunailsla, the Bowara and the Twawila playas. The depth of ground water in Jezira area is between 10 m and 20 m;

(2) Western or northern desert (Rutba zone): This area is characterized by its quaternary sediment, which is confined to wadis and depressions. Rock fragments with thin veneer of loam covers large areas. Wadi fills sediments reach several meters in thicknesses and consist of boulders, cobbles and pebbles of limestone.

Wadi beds are partly coated by aeolian sand. In the western desert, the depth of ground water is 10 m in the area near the river to more than 250 m near the Iraq-Jordan, Saudi border;

(3) The southern desert (Salman zone): Very wide sand sheets coupled with active dunes are covering the area. Soil in this area is limy and sandy in southerly part and sandy dune in eastern part. The groundwater in this area is between 50 m and 100 m deep [1, 4].

The main problems of Iraqi soil are the relatively high gypsum content, salinity and shallow ground water depth. Mesopotamia soil has characterized by its high salt content. This is mainly due to the presence of gypsum and shallow water table, which enhances the evaporation of groundwater and as a result increases the salinity in the soil. In view of these facts, the ground water depth plays an important role in affecting the type of foundation used.

3. Soil Properties Effecting Foundation

The type of foundation to be used should be stabiles, safe, economical, capable to hold the loads to be applied and environmentally suitable. According to the source of loads, they are divided as dead, live and environment loads. Direction and magnitude of these loads may change during the life of the structure. The design and construction must give stable results for load bearing on the foundation. All loads to be applied should be in accordance to local codes [7, 8].

Bearing capacity defines the strength of geotechnical requirement. It is the most important load that affects the foundation design. Allowable stress on the foundation must not cause excessive and differential settlements or soil shear failure. Bearing capacity analysis should be based on assuming the worst soil condition during the suggested life time of the structure. There are number of methods established for the analysis of the unit ultimate bearing capacity. Meyerhof (1963) suggested the most comprehensive and general bearing capacity equation, because it includes all the factors affecting the foundations [9]. The equation is as following:

$$q_n = c\,N_c F_{cs} F_{cd} F_{ci} + q\,N_q F_{qs} F_{qd} F_{qi} + \frac{1}{2}\gamma\,B\,N_\lambda F_{\gamma s} F_{\gamma d} F_{\gamma i} \tag{1}$$

where,

c = cohesion (kN/m^2);

q = effective stress at the level of the bottom of the foundation (kN/m^2);

γ = unit weight of soil (kN/m^3);

B = width of foundation (= diameter for a circular foundation) (m);

F_{cs}, F_{qs}, F_{rs} = shape factors;

F_{cd}, F_{qd}, F_{rd} = depth factors;

F_{ci}, F_{qi}, F_{ri} = load inclination factors;

F_c, F_q, F_r = bearing capacity factors.

The factor of safety used in the design of foundation takes into considering the dead and live loads for the bearing capacity of soil. The relationship between deflection of soil and pressure is referred to as the modulus of sub grade reaction. This is used in the analysis of foundation of the structure. Its value depends on the soil type. To calculate the value of sub grade reaction (k_s) from the allowable bearing capacity q_a, the following equation is used [1, 10]:

$$SI:\ k_s = 40(SF)q_a \quad \text{kN/m}^3 \tag{2}$$

$$q_a = {q_{ult}}/{SF} \tag{3}$$

where,

SF = safety factor;

q_a = allowable bearing capacity;

q_{ult} = the ultimate soil pressure at the smaller allowable settlement ΔH = 0.0254 m and k_s is $q_{ult}/\Delta H$. Therefore, 40 is smaller displacement that can always be used.

4. Finite Element Software

Finite element software is a tool used in the design, analyses and solution of the problems of existing structures. They include many standards and codes for design. These kinds of software have been used all over the world by engineers working in industrial, sport, transportation and other facilities [11]. Many types of design and analyses software have been used with the last 30 years by different companies and universities such as: STAAD Pro., SAP 2000, ETABS, SAFE, and LUSAS, etc.. Generally, they use finite element method in the analysis. But there are some that use nonlinear analysis. These kinds of software are used efficiently for the design of buildings under the effect of seismic and earthquake [12-14].

As structural analysis and design software STAAD Pro V8i, STAAD Pro is an inclusive and integrated finite-element analysis and design software for civil and structural engineers. It sustains several concrete, timber, steel, and aluminium design codes. In addition, it has ISO 9001 certification [15-17]. The steps of using STAAD Pro for design and analysis are as following:

(1) Drawing the geometry structure using various methods;

(2) Specifying the profile of columns, beams and plates;

(3) Specifying the foundations, constants and supports;

(4) Specifying the loads added to the structure;

(5) Analysing the model using a suitable method of analysis such as 1st order static analysis, geometric non liner analysis, and 2nd order p-delta analysis (It is the analysis depending on the value of the secondary moment, which is equal to the axial force in the member (P), and Delta is the distance of one end of the member which is offset from the other end).

It has visualization tools, powerful design and analysis engines with advanced static and dynamic analysis capabilities. Loads can be added as member loads, nodal loads, trapezoidal pressure loads and uniform pressure over any area. The output of the software (programme) results includes shears, displacements and moments in the graphical and tabular forms. In addition to shears and moments at any point of the element and nodes can be obtained easily from the software output [18, 19]. It is widely used in Iraq for the design and analysis. It is also used to train students in the various universities.

5. Case Studies

An educational building in Mosul University with two floors (ground and first floors) having raft foundation type has been selected. The same building was used for the analysis at Baghdad and Basra Universities due to the differences in their soil conditions. The design loads (live and dead) which were uploaded in the program for all the three areas (Mosul, Baghdad and Basra) were the same. The code used was ACI (American Concrete Institute) because the majority of Iraqi designers are using this code. Bearing capacities of the three regions are shown in Table 1 (the magnitudes were taken out from ground investigations of the three projects in each region).

The loads which were uploaded were as following:

(1) Dead load:

- 25 kN/m^2 for foundation (normal dead load + some heavy equipment);
- 21 kN/m^2 for first floor (18 kN/m^2 for partitions + 3 kN/m^2 for finish load);
- 7.5 kN/m^2 for second floor (4.5 kN/m^2 for finish load + 3 kN/m^2 for partitions);

(2) Live load:

- 5 kN/m^2 for first floor;
- 3 kN/m^2 for second floor.

In addition to the above loads, the self-weight of the structure was calculated directly by the program.

Fig. 2 shows the model of the building that was used in the program. Exactly the same loads were used for the three regions (Mosul, Baghdad and Basra) as they are tabulated in Tables 2 and 3.

Table 1 Value of bearing capacity.

No.	Area	Bearing capacity (kN/m^2)
1	Mosul	300
2	Baghdad	70
3	Basra	50

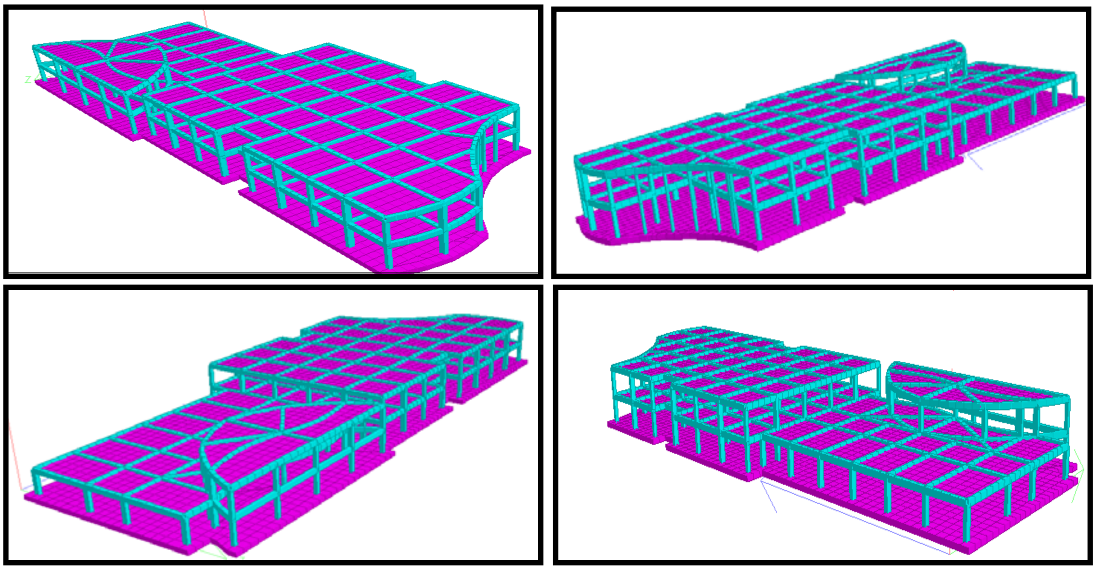

Fig. 2 Building model draw in STAAD Pro V8i.

Table 2 Basic load cases.

No.	Name
1	Load Case 1/Self weight
2	Load Case 2/Finish load-partitic
3	Load Case 3/Total live load
4	Load Case 4/Partial live load 1
5	Load Case 5/partial live load 2

Table 3 Combination load cases [20].

Comb.	Combination L/C name	Primary	Primary L/C name	Factor
6	Combination load Case 6	1	Load Case 1/Self weight	1.20
		2	Load Case 2/Finis load-partitic	1.20
7	Combination load Case 7	1	Load Case 1/Self weight	1.20
		2	Load Case 2/Finis load-partitic	1.20
		3	Load Case 3/Total live load	1.60
8	Combination load Case 8	1	Load Case 1/Self weight	1.20
		2	Load Case 2/Finis load-partitic	1.20
		4	Load Case 4/Partial live load 1	1.60
9	Combination load Case 9	1	Load Case 1/Self weight	1.20
		2	Load Case 2/Finis load-partitic	1.20
		5	Load Case 5/Partial live load 2	1.60
10	Combination load Case 10	1	Load Case 1/Self weight	1.00
		2	Load Case 2/Finis load-partitic	1.00
11	Combination load Case 11	1	Load Case 1/Self weight	1.00
		2	Load Case 2/Finis load-partitic	1.00
		3	Load Case 3/Total live load	1.00
12	Combination load Case 12	1	Load Case 1/Self weight	1.00
		2	Load Case 2/Finis load-partitic	1.00
		4	Load Case 4/Partial live load 1	1.00
13	Combination load Case 13	1	Load Case 1/Self weight	1.00
		2	Load Case 2/Finis load-partitic	1.00
		5	Load Case 5/Partial live load 2	1.00

Fig. 3 shows the analysis of the building design. In Cases 1 and 2, the load is assumed to be distributed on the whole building (full floor area). In Case 3, however, the uploading was like a checker board pattern, while Case 4 was opposite to Case 3. The base pressure distribution on the soil beneath the foundation is shown in Figs. 3-8. Fig. 3 shows the contour of the load Cases 1 and 2 for Mosul University. It can be noticed that most of the area of the raft has blue colour. This implies that the base pressure in this area does not exceed the range from 70-75 kN/m^2 for the both cases. The maximum soil pressures for the Cases 1 and 2 are 103 kN/m^2 and 115 kN/m^2, respectively. They are much lower compared with the real soil pressure taken out from soil investigations (Table 1). In such a case, it is better to choose another type of foundation that will be more suitable to save time and money. In Cases 3 and 4 in Fig. 4, the maximum soil pressures for the both cases were 111 kN/m^2 and 110 kN/m^2, respectively. Most of the area beneath the raft has blue colour and its pressure does not exceed 73 kN/m^2. In such a case, it is better to choose another type of foundation because the base pressure is lower than what is it in the soil.

The analysis of the building in Baghdad soil is shown in Figs. 5 and 6. The pressure of soil under the

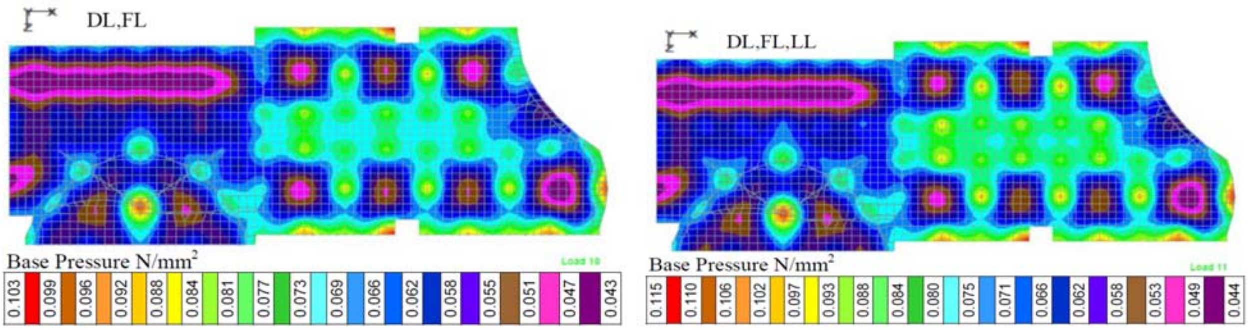

Fig. 3 The base pressure contour for Mosul University (Case 1 and Case 2).

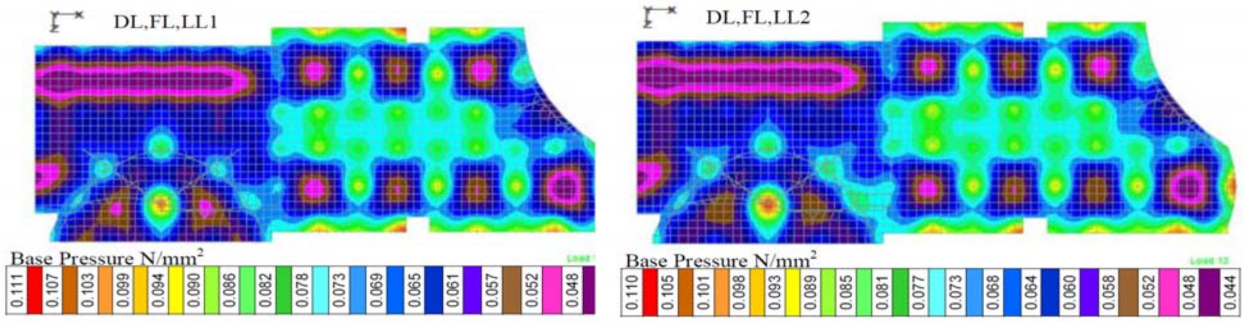

Fig. 4 The base pressure contour for Mosul University (Case 3 and Case 4).

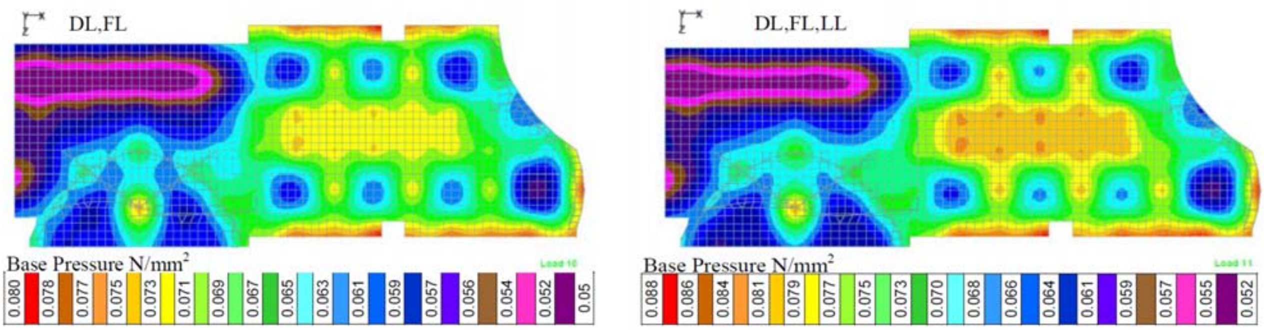

Fig. 5 Base pressure contour for Baghdad University (Case 1 and Case 2).

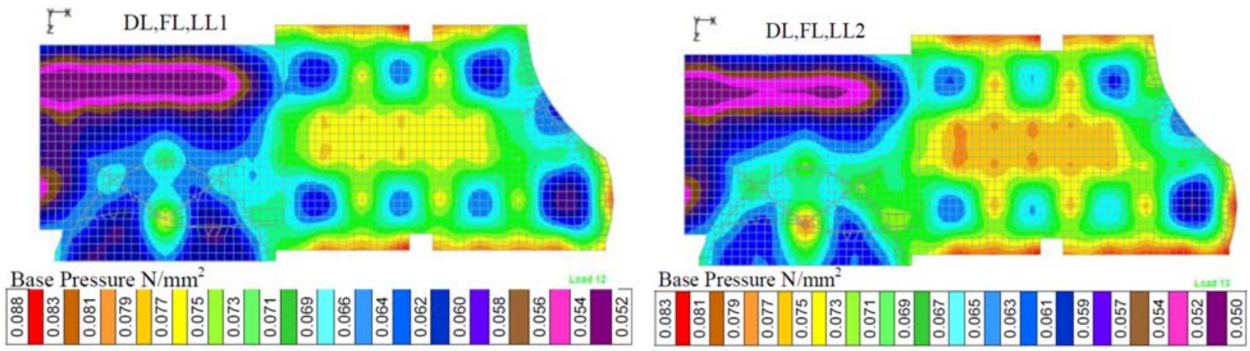

Fig. 6 Base pressure contour for Baghdad University (Case 3 and Case 4).

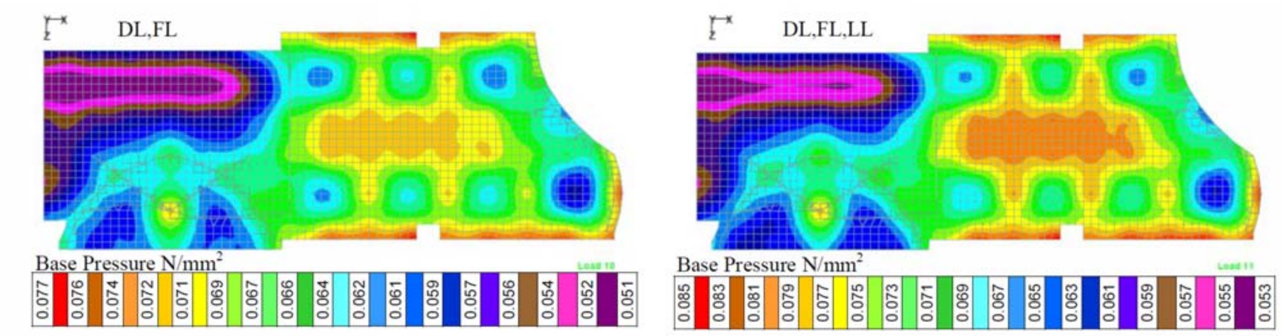

Fig. 7 Base pressure contour for Basra University (Case 1 and Case 2).

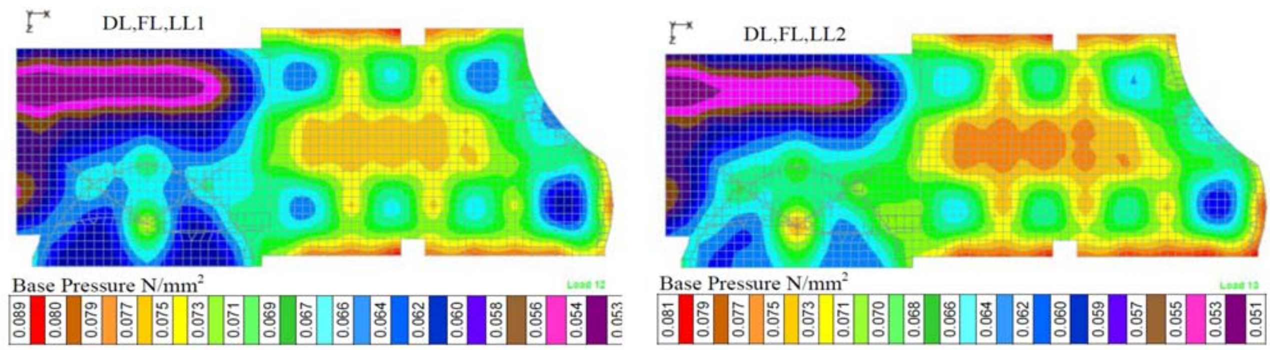

Fig. 8 Base pressure contour for Basra University (Case 3 and Case 4).

raft was between 63 kN/m^2 and 69 kN/m^2 for Case 1 in Fig. 4, and the maximum was 80 kN/m^2 as shown in the index bar. For Case 2, the base pressure was 68-77 kN/m^2 and the maximum was 88 kN/m^2 in few places. The type of the raft foundation is suitable in this case. Furthermore, two types (raft and continuous) of foundations can be used in this case. Fig. 6 illustrated Cases 3 and 4, which show the soil pressure under the foundation was 64-75 kN/m^2. The maximum was 86 kN/m^2 for Case 3. Where the base pressure for Case 4 was 65-73 kN/m^{2}and maximum was 83 kN/m^2. In such a case, the raft type is a good chooses, or it is possible to use two different types for left and right parts.

Fig. 7 clarifies the analysis contour of Basra University building for the load Cases 1 and 2. The distribution of the soil pressure under the foundation was 60-70 kN/m^2 in Case 1 and the maximum was 77 kN/m^2. While in Case 2, the base pressure was 77 kN/m^2 over almost the whole foundation area and the maximum was 85 kN/m^2. The soil pressure was 75 kN/m^2 in Case 3 and maximum was 82 kN/m^2 (Fig. 8). Case 4 shows that the maximum pressure was 81 kN/m^2 and the pressure distributed to the foundation was about 71 kN/m^2. The base pressure is higher than what is it in the soil. The raft type is a suitable chose for Basra soil conditions.

6. Conclusions

In view of the results obtained using STAAD Pro V8i software on the same educational building in three different sites in Iraq having different soil conditions, it was concluded that:

(1) The base pressure on soil under the whole foundation of the building in Mosul was low. For this region, it is possible to use raft foundation or another type, which will be suitable and more economical;

(2) Baghdad region soil is less in its hardness compared with that in Mosul. The analysis of the building shows that base pressure under the right part of the building foundation was higher than the left part. This leads to more than one choice. The first is using two types of foundations, raft type for the left part and continuous type for the right part. The second is to build the complete foundation as raft type;

(3) The base pressure in Basra region is very high for the whole area under the foundation. Raft type is suitable to be used for Basra soil.

The results imply that Iraqi engineers should use new design style for the buildings. Modern systems should be adopted depending on using different materials such as cold formed steel, pre cast, wood and thermistor bricks. Local materials are recommended to be used. This will decrease the loads of the building transmitted to the soil. Special code is to be used for construction and design in Iraq. Such code should include all the modern requirements for construction and design according to type of soil, geological and environmental conditions of Iraq.

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