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Original Research

BEHAVIOR OF REINFORCEMENT BARS IN FOUNDATION WITH SOIL TO SATISFY SUSTAINABILITY

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Abstract: This study presents the behavior of using many types of reinforcement with slab foundations to satisfy sustainability. This foundation with soil effect and two types of bar reinforcement (steel bars and geogrid) are taken. Nonlinear analysis is used with the theoretical model by finite element program software ABAQUS to represent the many types of reinforced concrete foundations with both unsaturated and saturated soil with the effect of loading. Effect of load-displacement-relationships with many cases which were taken for this study such as the geogrid and steel bar ratio in reinforcement of foundation with unsaturated and saturated soil. From this study, it is shown that reinforcement by geogrid increased the strength of the member or the foundation when taken with different ratios of reinforcement by steel bars and get the best sustainable way or solution by decreasing the reinforcement by steel. The ratio of geogrid is 40% to 20 % from total reinforcement, while the required member or foundation in the case of soil, which is unsaturated, is more strength than it is in the case of saturated soil.

Keywords: *Geogrid; load-displacement; nonlinear analysis; saturated and unsaturated soil*

1. Introduction

The interaction between soil and structure is very important in civil engineering. The reinforcement for the foundation by bars for reinforcing concrete foundation is an important part of the quality and strength of a building. Geogrid reinforcement is used to give a suitable strength and cost. Geogrid can be used as a reinforcement in foundation with or without steel bar reinforcement, and that has an advantage by used with saturated and unsaturated soil. That means the geogrid reinforcement with a foundation in soil with liquid can satisfy the sustainability [1]. Widely used geosynthetics for sealing, separation, and protection. The geogrids which have high strength are more successful when used in structure. In terms of economics, geogrid reinforcement has a good advantage when compared with classic reinforcement by using steel bars [1-3]. Used the finite element to model the foundation member with many types of reinforcement bars (steel or geogrids) with the effect of soil. The behavior of reinforcement concrete foundation with soil shows the load capacity for the member. The ABAQUS software program uses to nonlinear model by finite elements with three dimensional. The goal of this study is to decrease the effect of

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corrosion in steel bars with cost by replacing it with geogrid. This satisfies sustainability. Two types of reinforcement bars in foundation with two types of soil, saturated and unsaturated, were shown in this study [4-7]. Many ratios of geogrid bars with reinforcement by steel bars were taken to show the behavior of load-capacity and the best ratio for that to satisfy a good strength and cost with sustainability and by controlling the corrosion effect in steel bar reinforcement by replacing it with geogrid. Many researchers studied geogrid and reinforcement [8-10]. This study is to find an alternative material or a partnership as a reinforcement with steel reinforcement by steel bars and geogrid were studied. Also, the model in this study is used to represent soil with foundation to give the most accurate representation of reality. Many types of soil can be used in this model, and two types are used in this study (saturated and unsaturated soil). Also, The future research directions and recommendations are as follows:

a) Use other types of soil

b) Take the effect of temperature

c)The analysis can be dynamic.

d) The foundation with piles effect can be taken.

Structural analysis of isotropic or anisotropic media is alternatively possible using other strong numerical methods or practical tests [11-20].

2. Modeling

2.1. General

The finite element model is used to represent the reinforcement in the foundation with two types of soil [1].

2.2. Types of Elements

2.2.1. Soil with foundation

Foundation members with soil were represented by 8-node brick linear which allowed displacement and load with required direction.

2.2.2 Reinforcement (steel bars).

This element represents the steel bar embedded in the foundation or member by a 3-d truss element and 2-node linear.

2.2.3. Geogrid reinforcement

This element represents the embedded geogrid as reinforcement in the member or foundation by 4-nodes quadrilateral and surface elements.

2.3. The Plastic Models

2.3.1. Member for foundation

The way for plastic models to get deformation in the foundation or member is concrete damage plasticity [1].

2.3.2. Soil

The way for the plastic model is Mohr coulomb (plasticity).

2.3.3. Reinforcement (geogrid with steel)

The way for a plastic model is classic metal plasticity.

3. Simulation of Reinforcement

For the steel bar reinforcement and geogrid, the simulation is as follows:

The concrete is in interaction with steel bars, which were inside and embedded in the foundation or member. The surface simulated geogrid reinforcement was embedded inside the concrete. All the models for reinforced foundation or concrete members with two methods of reinforcement bar (geogrid and steel) with two types of soil saturated and unsaturated as shown in Fig. 1 to Fig.8 [1]. These show the present model with details, elements, steel, and geogrid reinforcement.

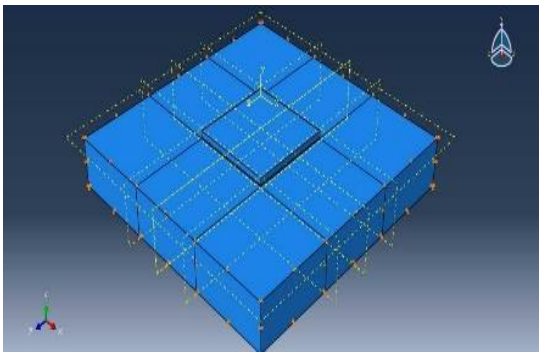

Figure 1. Present model

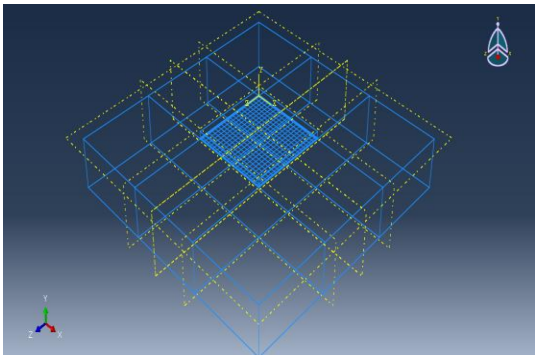

Figure 2. Details model.

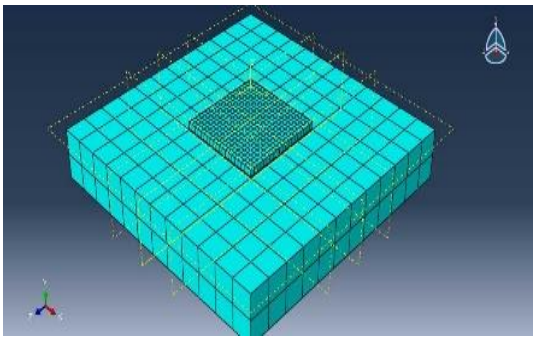

Figure 3. Elements model.

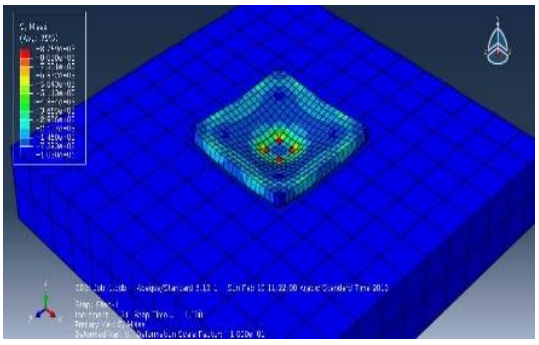

Figure 4. Steel reinforcement model.

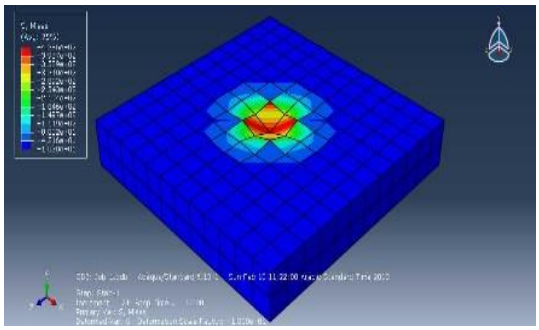

Figure 5. Work model.

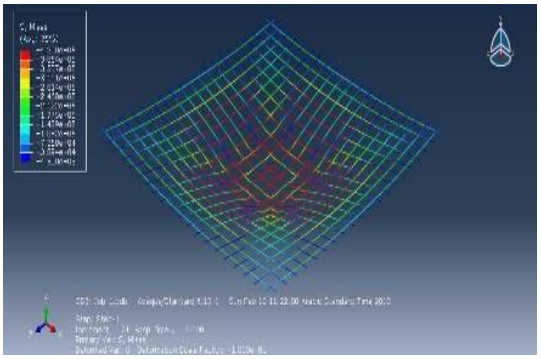

Figure 6. Steel bars with detailed model.

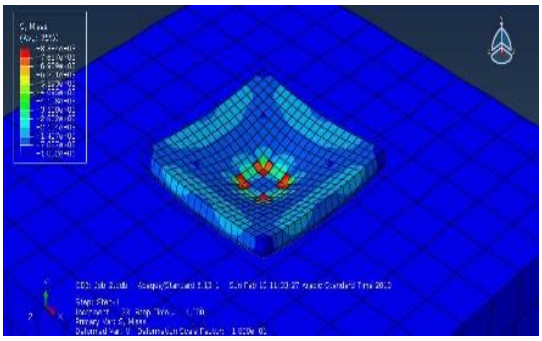

Figure 7. Steel bars with model.

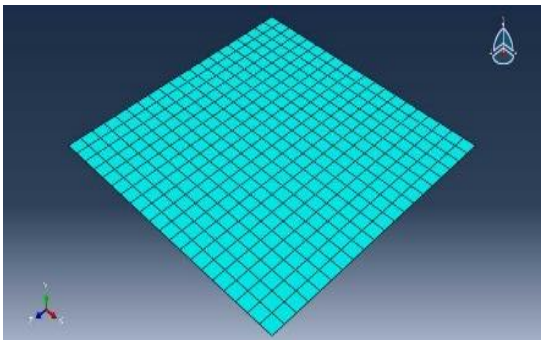

Figure 8. Geogrid model

4. Details of Material

The dimensions of the reinforced concrete foundation are 2 * 2 square meters with 0.15 m thickness and with an area for applied load 0.4*0.4 square meters. The properties of concrete that are used in ABAQUS program are Young's modulus E and compressive strength fc′ as 24000 MPa and 35 MPa [1].

For the soil details, the elastic-plastic parameters are shown in Table 1.

For the steel details, the elastic-plastic model for steel bars with a yield stress, Poisson ratio v, and Young's modulus (E) are 420MPa, 0.3, and 200000MPa, respectively.

For the geogrid details, the elastic-plastic model for geogrid reinforcement with bearing strength, Poisson ratio v, and Young's modulus E are 100 KN/m, 0.2, and 67000 MPa, respectively.

Table 1. Soil details [1]

Soil Parameter	Unsaturated	Saturated
The Young's modulus, E	50 MPa	40MPa
The Poisson ratio, v	0.3	0.49
The cohesion, c	90KPa	50KPa
The friction angle, ϕ°	20°	0
The dilatancy angle, Ψ°	0	0

5. Results and Discussion

Table 2 shows the results of using different steel bars in a foundation with unsaturated soil to get the ratios of increased deflection with different geogrid ratio reinforcement (100,85,75,60,50,40 and 20) % as compared with the reference (deflection) for reinforcement without reinforcement by geogrid (100% steel reinforcement).

From the results, it is shown that when increased the geogrid reinforcement ratio in reinforcement, the deflection values increase. Also, these values are acceptable and are given good strength with suitable cost and satisfy sustainability.

Table 2. Reinforcement ratios with deflection ratios in foundation with unsaturated soil [1].

Geogrid ratio reinforcement %	Steel ratio reinforcement %	Ratio of increased in deflection compared with reference *
100	0	20.576
85	15	18.315
75	25	16.28
60	40	13,135
50	50	10.822
40	60	8.47
20	80	4.207

Table 3 shows the results for different ratios of reinforcement geogrid and steel bars in foundations with saturated soil. The ratios of increased deflection in the foundation are compared with the case when using steel bar reinforcement only (100% steel reinforcement without geogrid) which is used as a reference. The results show that the deflections are increased when the geogrid ratios increase in reinforcement (i.e., steel bar reinforcement decreased). These values are acceptable, are given good strength, and satisfy sustainability.

Table 3. Reinforcement ratios with deflection ratios in foundation with saturated soil [1].

Geogrid ratio reinforcement %	Steel ratio reinforcement %	The ratio of increased in deflection compared with reference *
100	0	35.6
85	15	32.2
75	25	30
60	40	25
50	50	21.2
40	60	17.7
20	80	9.5

6. Conclusions

For this study, many important results are as follows:

- The geogrid ratios in the reinforcement of reinforced concrete foundations give good strength, and cost and satisfy sustainability.
- When the ratio of geogrid reinforcement increased, the deflection ratios are increased.
- The results of deflection ratios in reinforcement foundations with unsaturated soil are less than their values in saturated soil.
- Interaction between structure and soils is very important to give the best behavior by analyzing the foundation with many types of soil by finite element method.
- The steel bar reinforcement is very important, but it can decrease its ratio in reinforcement when the geogrid ratio increases to control corrosion.
- The software program ABAQUS is very good for representing the members of foundation and reinforcement (steel and geogrid) with any type of soil.

Conflict of interest

The authors declare that there is no conflict of interest about the publication of this manuscript.

Contribution Statement of Author

Authors Ali Sabah Al Amli, Nadhir Al-Ansari, and Jan Laue: proposed the research problem.

Author Ali Sabah Al Amli.: developed the theory and performed the computations.

Authors Nadhir Al-Ansari, and Jan Laue.: checked the theoretical analysis methods and supervised the results of this research.

The authors checked and discussed the results and contributed to this work to present the final manuscript.

Abbreviations

E	modulus of elasticity
fc´	Compressive strength
c	cohesion
ϕ°	Friction angle
ν	Poisson's ratio
Ψ°	dilatancy

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