Numerical Investigation of Geogrid-Reinforced Strip Foundations Subjected to Adjacent Excavation Using PLAXIS 2D

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ABSTRACT

Excavation activities carried out near existing foundations can significantly alter the stress state of the surrounding soil, resulting in reduced bearing capacity and increased settlement that may compromise the stability and serviceability of structures. This issue is particularly important in urban areas, where new construction is frequently undertaken adjacent to existing buildings with limited available space. The present study evaluates the effectiveness of geogrid reinforcement in improving the performance of strip foundations subjected to the influence of nearby excavations through numerical modelling using PLAXIS 2D. A series of finite element analyses was performed by varying the excavation depth and horizontal distance from the existing strip foundation to assess their effects on foundation behaviour. Both reinforced and unreinforced soil conditions were analysed under identical loading and boundary conditions to enable a systematic comparison of their performance. The response of the foundation system was evaluated in terms of ultimate bearing capacity and settlement. The numerical results demonstrate that the incorporation of geogrid reinforcement effectively mitigates the adverse effects of adjacent excavation by improving the load-carrying capacity of the foundation soil and limiting excessive deformation. Depending on the excavation geometry, the reinforced soil exhibited an increase in ultimate bearing capacity ranging from 14% to 27%**,** while the corresponding settlement decreased by approximately 11% to 16% compared with the unreinforced condition. The improvement is attributed to the ability of the geogrid to provide tensile reinforcement, enhance stress distribution, and improve soil confinement beneath the foundation. Overall, the study demonstrates that geogrid reinforcement is an effective ground improvement technique for maintaining the stability and performance of existing strip foundations subjected to nearby excavation, thereby providing useful guidance for the design and rehabilitation of foundation systems in urban construction projects.

Keywords: Bearing Capacity, Settlement, Geogrid, Foundation soil, Excavation.

INTRODUCTION

Generally, foundations are made to meet bearing capacity and settling requirements. Despite this, contemporary research has continued to focus on the issue of foundation soil bearing capacity for various conditions. Most people agree that the settlement condition is because of the degree of structure performance. The settlement is typically viewed as a sum of two parts, namely immediate (short term) and consolidation (long term). When the settlement limit is exceeded, the footing size and geometry must be altered, or the soil must be strengthened in foundation settlement calculations.

The temporal occurrence of the vertical deflection beneath the foundation, which is dependent on the rate of loading in relation to the permeability of the soil, is what separates these two components. The first is incorrectly called "elastic. “Settlement", as the elasticity theory has been widely used in computations. The conduct of the earth is not malleable or even changeable. However, because of its simplicity, elasticity theory has been generally accepted and used in geotechnical engineering for the computation of rapid settlement.

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It is very necessary to understand the behavior of soil below ground level due to external load coming from super structure directly or adjacent structure. The distribution of load should be assessed below ground level in the form of stress.

Geogrid

Geogrids are made with high-modulus polymer materials, such as polypropylene and polyethylene through tensile drawing. Geogrids are made of a net-like material with big openings known as apertures and high tensile stiffness. These holes allow the earth to connect with the surrounding soil, strengthening it. There are two main types of geogrids: biaxial, triaxial and geocell. The nominal rib thickness of the commercial geogrids that are now on the market for soil reinforcement is between 0.5 and 1.5 mm, and the junctions are between 2.5- and 5-mm. Apertures in soil reinforcement grids are typically elliptical or rectangular in shape. The apertures range in size from roughly 25 to 150 mm. The aperture dimensions range from around 25 to 150 mm. Geogrids is designed so that the open portions of the grids exceed 50% of the overall area. Because of their high tensile stiffness, these geogrids produce reinforcing strength at strain rates as low as 2%. Fig. 1 indicates the different types of geogrid used in construction.

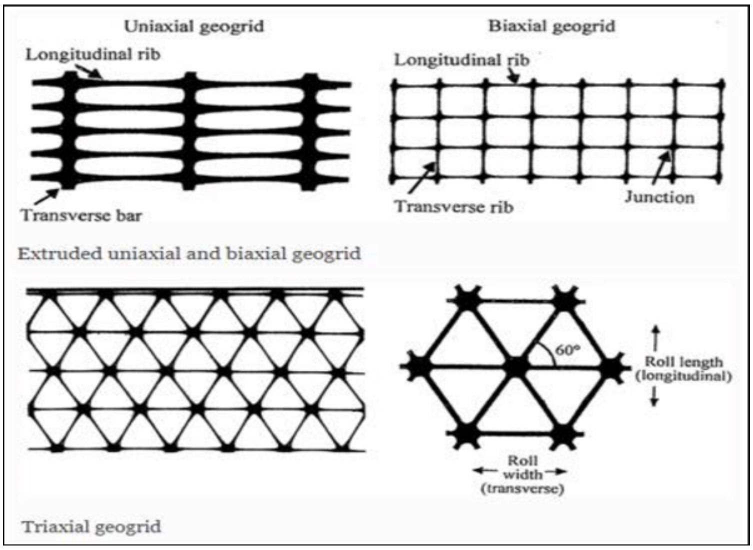

Fig. 1: Different types of Geogrids (Source: Google)

Problem Definition

PLAXIS 2D is a widely used finite element software for analyzing the behaviour of soil and geotechnical structures under different loading conditions. It enables realistic simulation of soil–structure interaction, making it an effective tool for predicting deformation, settlement, and stability in geotechnical engineering problems. Ground improvement method by using geogrid has been extensively used from last few decades. A biaxial geogrid with a length of 4 m was used as the reinforcing material beneath the footing. A total of five geogrid layers were provided at a vertical spacing of 1.0 m between successive layers. The first geogrid layer was placed at a depth of 0.5 m below the footing, while the remaining layers were positioned at regular intervals of 1.0 m. The footing had a width (B) of 2.0 m, excavation depth (Y) and the horizontal distance between the edge of the footing and the excavation was represented by X, which was varied from 2m to 5m to investigate its influence on the footing response. This reinforcement configuration shown in Fig. 2 and 3 was adopted to evaluate the effectiveness of geogrid reinforcement in improving soil stability and mitigating the adverse effects of adjacent excavation.

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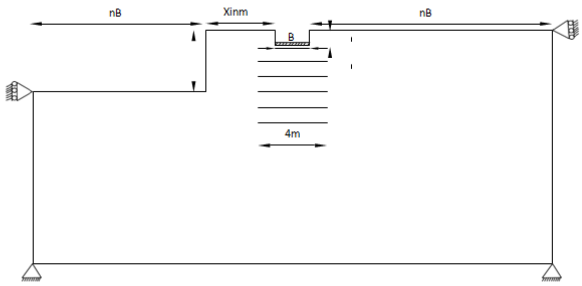

Fig. 2: Schematic representation of excavation near foundation supported with geogrid.

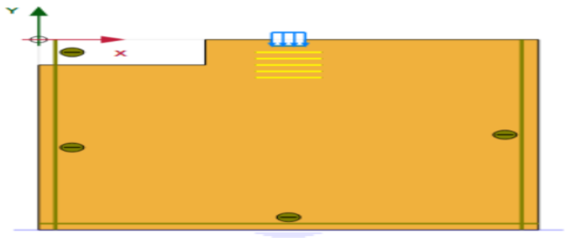

Fig. 3: Plaxis2D model with geogrid

RESULT AND DISCUSSION

Effect of Neighbouring excavation at X=2m on Bearing capacity and Settlement of Existing Foundation Soil with and without Geogrid.

Table 1 and Fig.4 represents the effect of using geogrids by comparing the results of bearing capacity of existing foundation soil for various depth of excavation at a horizontal distance of X=2m from edge of footing to excavation.

Table 1: Effect of excavation at X=2m on Bearing capacity of foundation soil

Y	Unreinforced soil (kN/m^2)	Reinforced soil (kN/m^2)	% of increase in bearing capacity
Y=2m	106	147	27
Y=3m	104	134	22
Y=4m	104	127	18
Y=5m	103	124	17

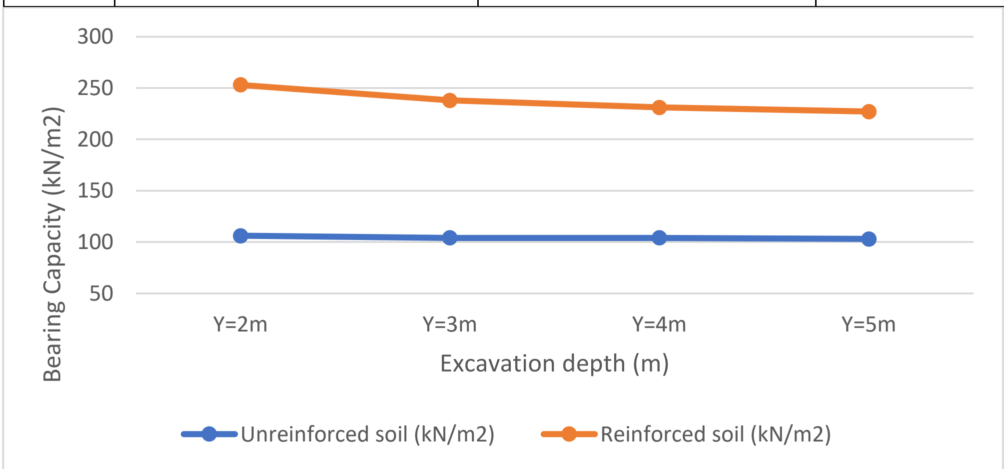

Fig.4: Effect of excavation at X=2m on Bearing capacity of foundation soil

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Table 2 and Fig.5 represents the effect of using geogrids by comparing the results of settlement of existing foundation soil for various depth of excavation at a horizontal distance of X=2m from edge of footing to excavation.

Table 2: Effect of excavation at X=2m on Settlement of foundation soil

Y	Unreinforced soil (mm)	Reinforced soil (mm)	% of decrease in settlement
Y=2m	21.09	19.09	11
Y=3m	19.5	17.5	12
Y=4m	18	15	13
Y=5m	17.64	14.6	16

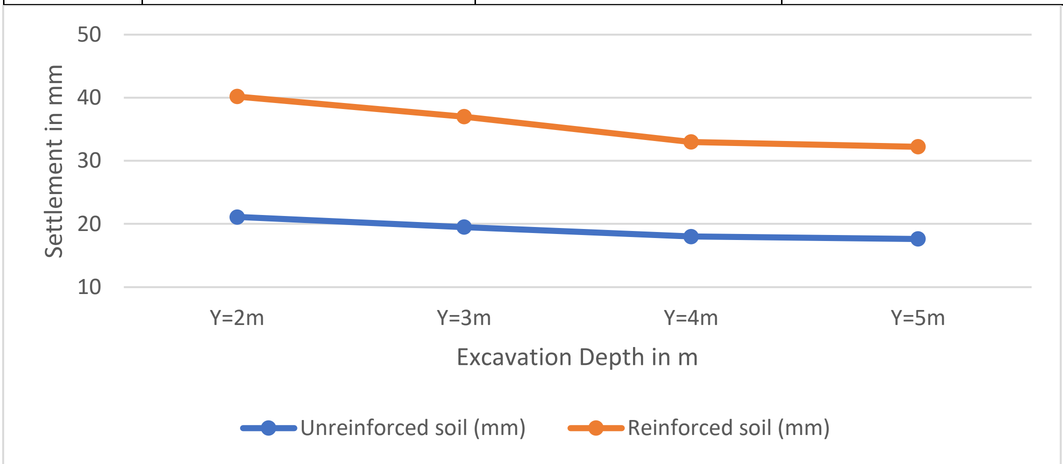

Fig.5: Effect of excavation at X=2m on Settlement of foundation soil

From Fig. 4 and Fig. 5 it is clearly observed the effect of using geogrid for the existing foundation soil. Ultimate bearing capacity values are enormously increased by using geogrids as reinforcement to the soil in an average of 25%. Similarly maximum settlement values are decreased by using geogrids in an average of 13%.

Effect of Neighbouring excavation at X=3m on Bearing capacity and Settlement of Existing Foundation Soil with and without Geogrid.

Table 3 and Fig.6 represents the effect of using geogrids by comparing the results of bearing capacity of existing foundation soil for various depth of excavation at a horizontal distance of X=3m from edge of footing to excavation.

Table 3: Effect of excavation at X=3m on Bearing capacity of foundation soil

Y	Unreinforced soil (kN/m^{2})	Reinforced soil (kN/m^2)	% of increase in bearing capacity
Y=2m	113	152	26
Y=3m	112	140	20
Y=4m	112	129	13
Y=5m	111	127	12

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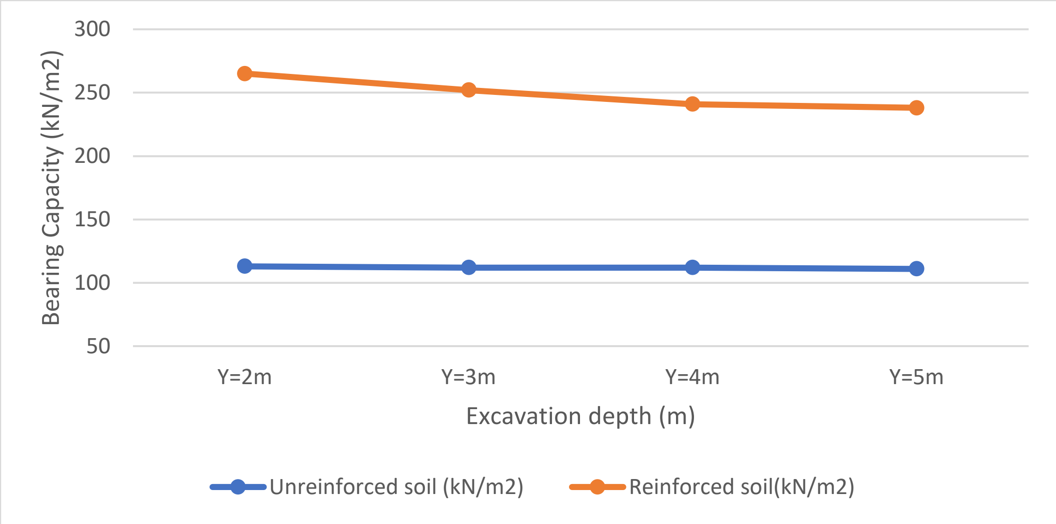

Fig. 6: Effect of excavation at X=3m on Bearing capacity of foundation soil

Table 4 and Fig.7 represents the effect of using geogrids by comparing the results of settlement of existing foundation soil for various depth of excavation at a horizontal distance of X=3m from edge of footing to excavation.

Table 4: Effect of excavation at X=3m on Settlement of foundation soil

Y	Unreinforced soil (mm)	Reinforced soil (mm)	% of decrease in settlement
Y=2m	19.27	17.1	13
Y=3m	19.82	16.8	12
Y=4m	18.46	15.4	14
Y=5m	17	14.9	16

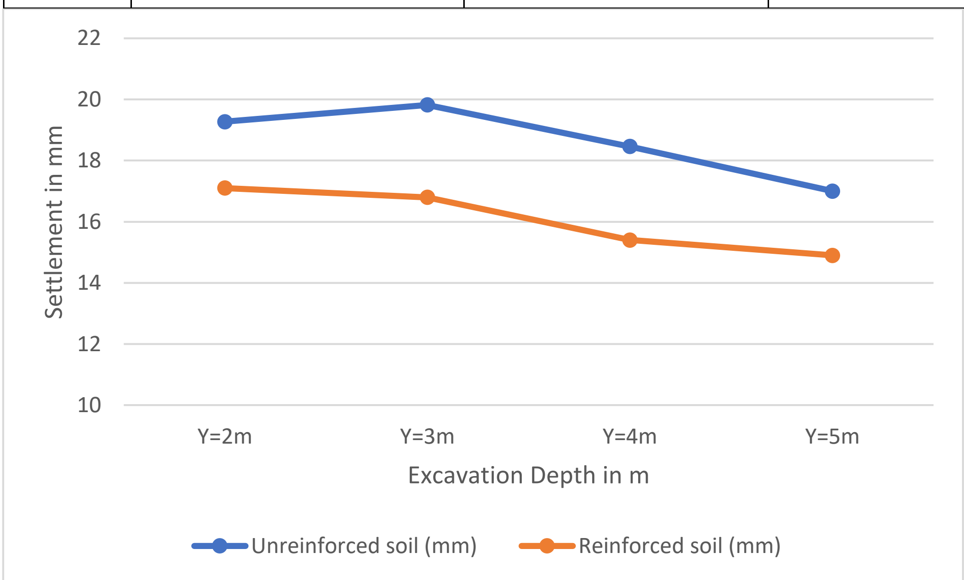

Fig. 7: Effect of excavation at X=3m on Settlement of foundation soil

From Fig. 6 and 7 it is clearly observed the effect of using geogrid for the existing foundation soil. Ultimate bearing capacity values is enormously increased by using geogrids as reinforcement to the soil in an average of 18%. Similarly maximum settlement values are decreased by using geogrids in an average of 14%.

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Effect of Neighbouring excavation at X=4m on Bearing capacity and Settlement of Existing Foundation Soil with and without Geogrid.

Table 5 and Fig.8 represents the effect of using geogrids by comparing the results of bearing capacity of existing foundation soil for various depth of excavation at a horizontal distance of X= 4m from edge of footing to excavation.

Table 5: Effect of excavation at X=4m on Bearing capacity of foundation soil

Y	Unreinforced soil (kN/m^2)	Reinforced soil (kN/m^2)	% of increase in bearing capacity
Y=2m	121	156	22
Y=3m	120	144	16
Y=4m	120	133	10
Y=5m	120	129	7

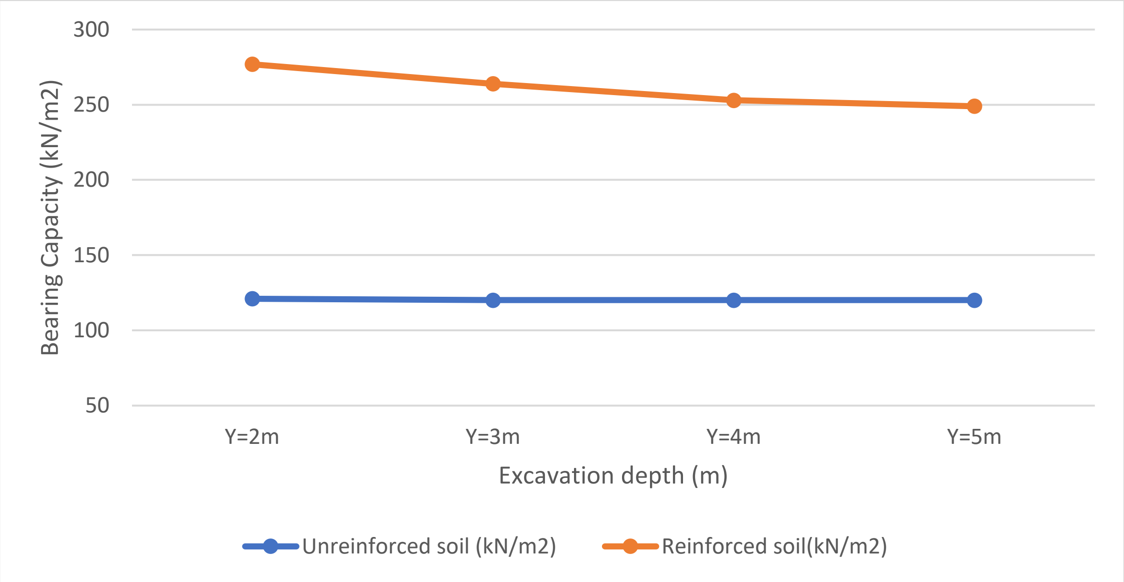

Fig. 8: Effect of excavation at X=4m on Bearing capacity of foundation soil

Table 6 and Fig.9 represents the effect of using geogrids by comparing the results of settlement of existing foundation soil for various depth of excavation at a horizontal distance of X=4m from edge of footing to excavation.

Table 6: Effect of excavation at X=4m on Settlement of foundation soil

Y	Unreinforced soil (mm)	Reinforced soil (mm)	% of decrease in settlement
Y=2m	18.18	15.1	13
Y=3m	18.82	15.8	14
Y=4m	17.45	14.4	15
Y=5m	15	13	15

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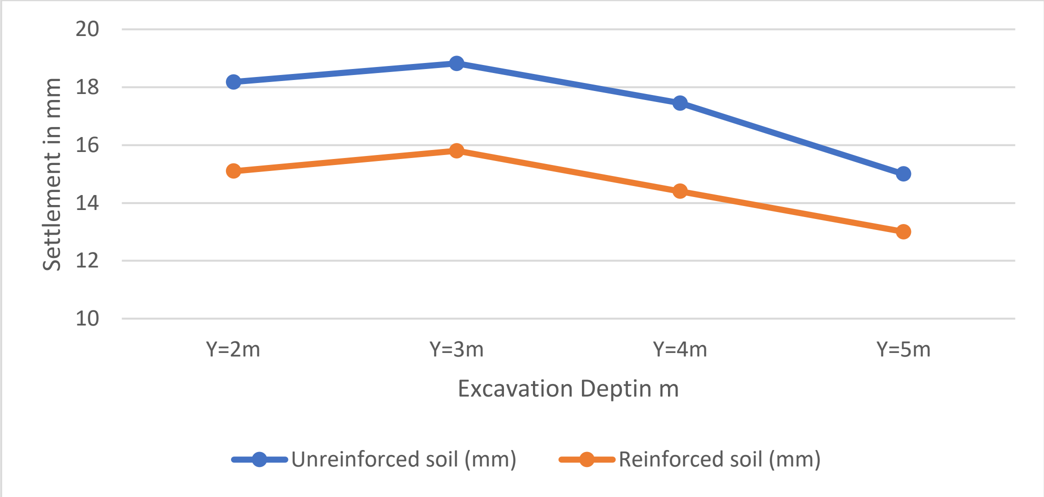

Fig. 9: Effect of excavation at X=4m on Settlement of foundation soil

From Fig. 8 and 9 it is clearly observed the effect of using geogrid for the existing foundation soil. Ultimate bearing capacity values is enormously increased by using geogrids as reinforcement to the soil in an average of 14%. Similarly maximum settlement values are decreased by using geogrids in an average of 14%.

Effect of Neighbouring excavation at X=5m on Bearing capacity and Settlement of Existing Foundation Soil with and without Geogrid.

Table 7 and Fig.10 represents the effect of using geogrids by comparing the results of bearing capacity of existing foundation soil for various depth of excavation at a horizontal distance of X= 5m from edge of footing to excavation.

Table 7: Effect of excavation at X=5m on Bearing capacity of foundation soil

Y	Unreinforced soil (kN/m^2)	Reinforced soil (kN/m^2)	% of increase in bearing capacity
Y=2m	121	159	24
Y=3m	121	149	18
Y=4m	120	137	12
Y=5m	120	132	9

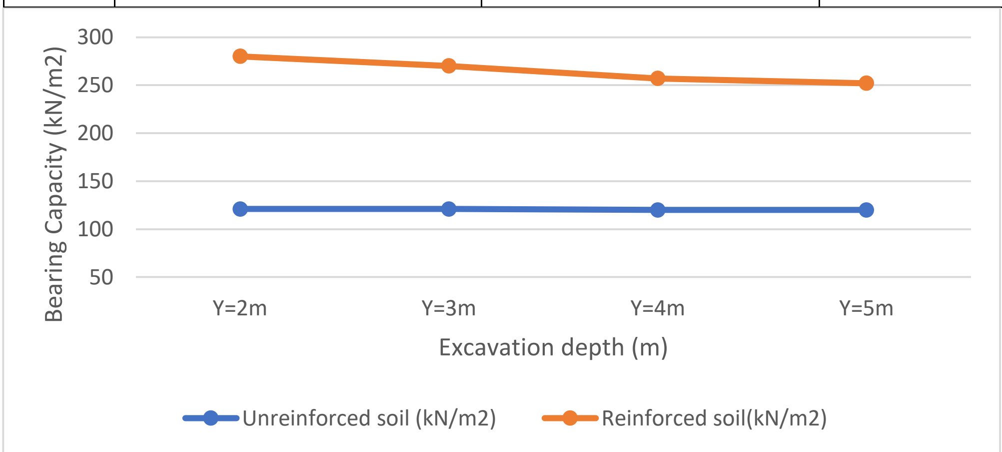

Fig. 10: Effect of excavation at X=5m on Bearing capacity of foundation soil

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Table 8 and Fig.11 represents the effect of using geogrids by comparing the results of settlement of existing foundation soil for various depth of excavation at a horizontal distance of X=5m from edge of footing to excavation.

Table 8: Effect of excavation at X=5m on Settlement of foundation soil

Y	Unreinforced soil (mm)	Reinforced soil (mm)	% of decrease in settlement
Y=2m	18.45	15.4	14
Y=3m	17.9	15.8	15
Y=4m	16.27	14.2	13
Y=5m	14.81	13.6	12

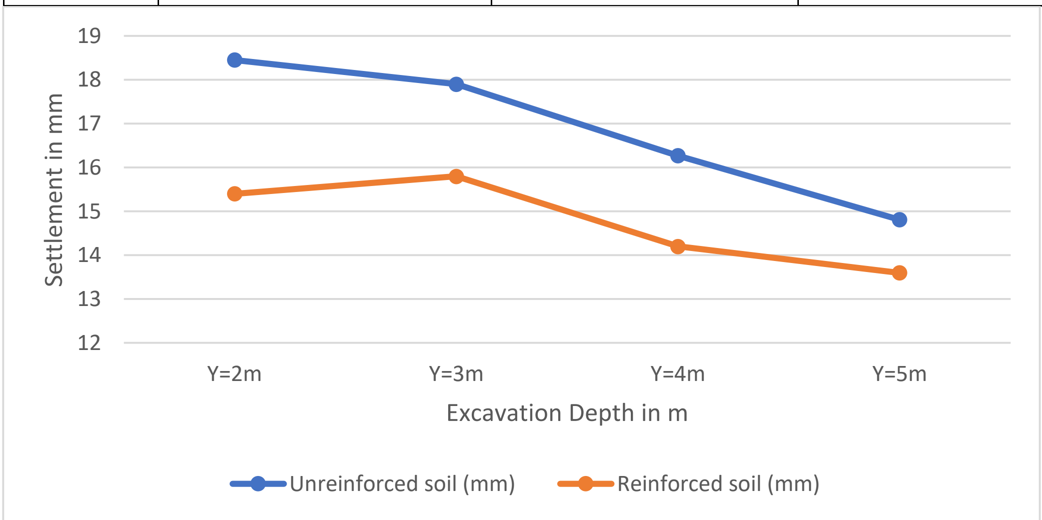

Fig. 11: Effect of excavation at X=5m on Settlement of foundation soil

From Fig. 10 and 11 it is clearly observed the effect of using geogrid for the existing foundation soil. Ultimate bearing capacity values is enormously increased by using geogrids as reinforcement to the soil in an average of 16%. Similarly maximum settlement values are decreased by using geogrids in an average of 14%.

CONCLUSIONS

The present study investigated the influence of adjacent excavation on the behaviour of existing strip foundations reinforced with geogrids using finite element modelling in PLAXIS 2D. Based on the numerical investigation, the following conclusions can be drawn:

1. Adjacent excavation significantly influenced the response of strip foundations by reducing the ultimate bearing capacity and increasing foundation settlement, particularly at smaller excavation distances and greater excavation depths.
2. Geogrid reinforcement effectively improved the engineering performance of the foundation soil by increasing the ultimate bearing capacity by approximately 14–27% while reducing settlement by 11–16% under the excavation conditions considered.
3. The improvement in performance is attributed to the tensile reinforcement provided by the geogrid, which enhanced stress redistribution within the soil and improved confinement beneath the foundation.
4. The effectiveness of geogrid reinforcement was observed for all excavation configurations, indicating its suitability as a practical ground improvement technique for protecting existing foundations during nearby excavation activities.

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5. Overall, the numerical study demonstrates that geogrid reinforcement can substantially improve the stability and serviceability of existing strip foundations, providing a reliable solution for foundation rehabilitation and safe urban excavation practices.

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