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(RESEARCH ARTICLE)

Analysis and effect of lateral forces on Micropiles

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Abstract

Micro piles are small diameter pile (less than 300mm). Micro piles are generally used when there are difficult ground conditions, such as natural or man-made obstructions, sensitive ground with adjacent structures, limited access/low headroom. Micro piles are small diameter drilled and grouted friction piles. Each pile includes steel elements that are bonded into the bearing soil or rock – usually with cement grout. The bearing stratum is logged during installation drilling to assure that bearing capacity is adequate. This chapter presents a summary of various parameters defining the computational models. The bearing capacity and spring constant values for different pile diameter and different length is studied in this paper. Also, lateral pressure is also checked on the pile. The software SAFE 2016 used for the analysis of model.

Keyword: Micropile; Leadroom; Lateral pressure; Analysis

1 Introduction

Micro piles are small diameter piles (less than 300 mm) can be installed in almost any type of ground where piles are required with design load (3 Tons to 500 Tons). The first use of micro piles dates back to the early 1950's in Italy, where new methods of underpinning for existing structures were needed to restore structures and monuments damaged during World War II (Lizzi, 1982). Dr. Fernando Lizzi is commonly recognized as the inventor of micro piles in the form of the root. Dr. Lizzi was a civil engineer and Technical Director with the Italian specialty foundation contractor Fondedile and obtained the first patents for root piles in Italy in 1952. This early form of micro pile technology was used extensively in Europe for the restoration of various structures and monuments. Fondedile introduced micro piles into North America in 1973 by performing a number of projects, mainly in the Northeastern United States. By the mid 1970's a number of US specialty foundation contractors previously engaged in drilled and grouted anchor work had developed their own variants of the technology. There was slow growth of the technology in the time period between the mid 1970's and the mid 1980's with Fondedile closing their North American venture for economic reasons. (Bruce and Juran, 1997) There has been a rapid growth in the specification and use of micro piles in the United States since the mid 1980's to early 1990's partly as a result of FHWA research efforts, trade association promotion efforts and the development of various publications offering standardized design and specification guidelines. In the early 1990's, the Intermodal Surface Transportation Efficiency Act (ISTEA) provided massive funding for the rehabilitation of highway infrastructure in the United States. As part of this effort, the FHWA undertook a number of research and development projects associated with specialty geotechnical construction to encourage innovation in geotechnical applications and produced several design manuals including the first on micro piles. This was the beginning of the surge in micro pile use in the United State. In 2006 and 2007 respectively, the

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design code sections for micro piles thus making way for further expansion of applications in both building and highway construction. micro piles currently are widely specified and used in all construction sectors worldwide.

1.1 Types of micropiles

Micro piles are generally classified firstly according to design application and grouting method. The design application dictates the function of micro pile while the grouting method defined the grout/ground bond capacity.

1.2 Types according to design application

In the design application, there are two types of application. The first type is where the micro pile is directly loaded either axially or laterally and the pile reinforcement resists the majority of the applied load. Examples of such application are shown in Figure (1). This type of pile is used to transfer structural loads to deeper, more competent or stable stratum and may be used to restrict the movement of the failure plane in slopes. The loads are primarily resisted by the steel reinforcement structurally and by the grout/ground bond zone geotechnically.

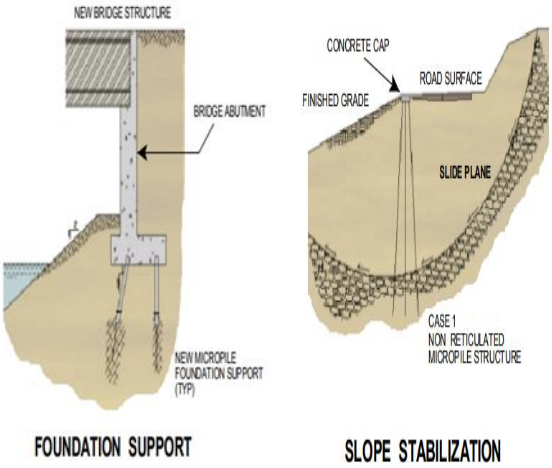


Figure 1 Directly Loaded Micro Piles

1.3 Types according to grout used

Second type of design application is where the micro pile reinforces the soil to make a reinforced soil composite that resist the applied load and KN as reticulated pile network. This application of micro pile serves to circumscribe and internally strengthen the reinforced soil composite. The method of grouting is generally the most sensitive construction control over grout/ground bond capacity and varies directly with the grouting method. The second part of the micro pile classification is based primarily on the method of placement and pressure under which grouting is used during construction.

Type A classification indicates that grout is placed under gravity head only. Sand-cement mortars, as well as neat cement grouts, can be used because the grout column is not pressurized.

Type B indicates that neat cement grout is placed into the hole under pressure as the temporary steel drill casing is withdrawn. Injection pressures typically range from 0.5 to 1 MPa, and are limited to avoid hydro-fracturing the surrounding ground or causing excessive grout takes, and to maintain a seal around the casing during its withdrawal, where possible.

Type C indicates a two-step process of grouting: primary grout is placed under pressure 1.0 – 2.0 MPa, causing hydro fracturing of surrounding ground. Prior to the hardening of the primary grout (typically 15 to 25 minutes), secondary grout is injected usually via tube a manchette.

Type D indicates a two-step process of grouting similar to Type C with modifications to the secondary grouting. Primary grout is placed under pressure and after hardening of the initially placed, additional grout is injected via tube a manchette at a pressure of 2 to 8 MPa. A packer may be so that specific levels can be treated several times, if required.

Type E is drill and inject grout through continuously – threaded, hollow – core steel bar, initial grout has high w/c ratio, which is replaced with thicker structural grout (lower w/c ratio) near completion of drilling.

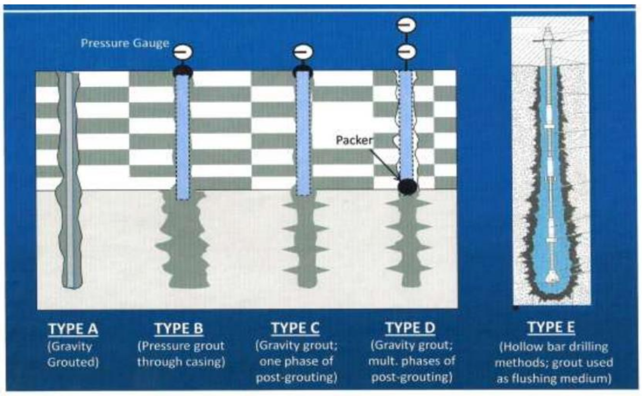


Figure 2 Micro piles Classification Based on Grouting Method

1.4 Drilling techniques

The drilling method is selected on the basis of causing minimal disturbance to the ground and nearby sensitive structures and able to achieve the required drilling performance. In all drilling methods, drilling fluid is used as a coolant for the drill bit and as a flushing medium to remove the drill cuttings. Water is the most common drilling fluid compared to other drilling fluid such as drill slurries, polymer, foam and bentonite. Another type of flushing medium is using compressed air.

1.5 Grouting

Grouting operations have a major impact on the micro pile carrying capacity and the details of the grouting vary somewhat throughout the world, depending on the origins of the practice and the quality of the local resources. In general, the grout mixture consists of cement, water and in certain cases additives such as sand and super plasticizers may be added to achieve the required working conditions.

1.6 Reinforcements

Generally, there are three types of reinforcement for micro piles and consist of single reinforced bar, reinforcement bars or steel pipe. Reinforcement bars is primarily deformed high-tensile strength steel bar and is typically placed in groups to increase structural capacity. They are available up to 40mm in diameter with yield strength of up to 500 MPa. Steel pipe is mainly used ex-oil API (American Petroleum Institution) pipe which are high tensile strength steel pipe.

2 Problem statement

In the present dissertation work, it is proposed carry out analysis and effect of lateral forces on micro piles. The structural capacity of 100mm, 150mm, 200mm diameter is calculated for different length of pile with soil bearing capacity 300kN/m^3, 400kN/m^3,500kN/m^3.

2.1 The axialcapacity of micro pile.

The "pile spring constant" can be calculated from the pile material's Modulus of Elasticity, area of pile and length of pile.

Table 1 Calculation of Spring Constant of Pile

Diameter Of Pile (mm)	100
Length Of Pile (m)	5
Grade Of Concrete Used (N/mm2)	30
E (Modulus of Elasticity) (kN/mm2)	27386127.88
Cross Section Area of Pile (A)(m2)	0.00785

Pile Spring (K)	
K=EA/L (kN/m)	42996.22076

The ultimate bearing capacity of soil is

$$Qu = Qpc + Qf$$

Here

Qpc = Point load capacity of soil= Cu x NC x Ap

Qf = Skin friction of single pile= α x Cu x Aps

Table 2 Calculation of Bearing of Pile

Bearing Capacity of Pile	
Point Load Capacity Qpc=Cu*Nc*Ap	
Diameter of pile (mm)	100
Cu (kN/m^3)	300
Nc	9
Ap (mm^2) (3.14/4*d^2)	0.00785
Point Load Capacity (kN)	21.195
Skin Friction of Single Pile Qf=α*Cu*Aps	
α	0.9
Length of pile (m)	5
area (m^2) (3.14*d*l)	1.57
Skin Friction of Single Pile (kN)	423.9

Nominal allowable tensile strength of pile

Pt allowable = 0.55 * Fy(steel) * (Abar)

Abar – Area of steel provided in the pile.

Fy (steel) - *Ultimate tensile strength of Steel*

The maximum tensile force should be less than the allowable force

2.2 Pile spring constant and bearing capacity.

Table 3 For 300kN/m3 Soil Type

Sr No.	Length of pile (m)	Pile Diameter (mm)	Pile Spring Constant (kN/m)	Bearing Capacity of Pile (kN)
1	5	100	42996.22	445.095
		150	96741.5	683.539
		200	171984.9	932.58

2	10	100	21498.11	869
		150	48370.75	1319.39
		200	85992.44	1780.4
3	15	100	14332.07	1292.895
		150	32247.17	1955.239
		200	57328.29	2628.18
4	20	100	10749.06	1716.795
		150	24185.37	2591.089
		200	42996.22	3475.98

Table 4 For 400kN/m3 Soil Type

Sr No.	Length of pile (m)	Pile Diameter (mm)	Pile Spring Constant (kN/m)	Bearing Capacity of Pile (kN)
1	5	100	42996.22	593.46
		150	96741.5	911.385
		200	171984.9	1243.4
2	10	100	21498.11	1158.7
		150	48370.75	1759.19
		200	85992.44	2373.8
3	15	100	14332.07	1723.86
		150	32247.17	2606.985
		200	57328.29	3504.24
4	20	100	10749.06	2289.06
		150	24185.37	3454.785
		200	42996.22	4634.64

Table 5 For 500kN/m3 Soil Type

Sr No.	**Length of pile (m)**	**Pile Diameter (mm)**	**Pile Spring Constant (kN/m)**	**Bearing Capacity of Pile (kN)**
1	5	100	42996.22	741.825
		150	96741.5	1139.23
		200	171984.9	1554.3
2	10	100	21498.11	1448.3
		150	48370.75	2198.98
		200	85992.44	2967.3
3	15	100	14332.07	2154.825
		150	32247.17	3258.731

		200	57328.29	4380.3
4	20	100	10749.06	2861.325
		150	24185.37	4318.481
		200	42996.22	5793.3

3 Modeling

3.1 G+15 STORY BUILDING IN ETAB.

The G+15 story building modelled in Etab. The corner column considered for the analysis of micro pile. The following combination mentioned in table 3 are checked for micro piles.

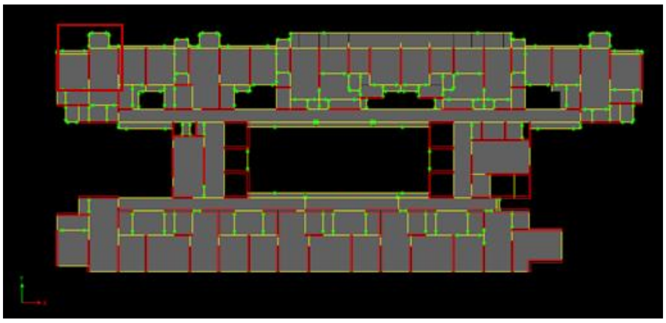


Figure 3 Typical Plan of Building

The marked shear wall i.e., corner and middle shear wall considered for the analysis of the micropiles.

Table 6 Models to Be prepared

Sr No.	Length Of Pile	SBC Of Soil	Pile Diameter
1	5m	300kN/m^3	100 mm
			150 mm
			200 mm
2	10m	300kN/m^3	100 mm
			150 mm
			200 mm
3	15m	300kN/m^3	100 mm
			150 mm
			200 mm
4	20m	300kN/m^3	100 mm
			150 mm
			200 mm
5	5m	400kN/m^3	100 mm
			150 mm
			200 mm
6	10m	400kN/m^3	100 mm

			150 mm
			200 mm
7	15m	400kN/m³	100 mm
			150 mm
			200 mm
8	20m	400kN/m³	100 mm
			150 mm
			200 mm
9	5m	500kN/m³	100 mm
			150 mm
			200 mm
10	10m	500kN/m³	100 mm
			150 mm
			200 mm
11	15m	500kN/m³	100 mm
			150 mm
			200 mm
12	20m	500kN/m³	100 mm
			150 mm
			200 mm

3.2 Stages in safe

3.2.1 Assign spring constant to pile

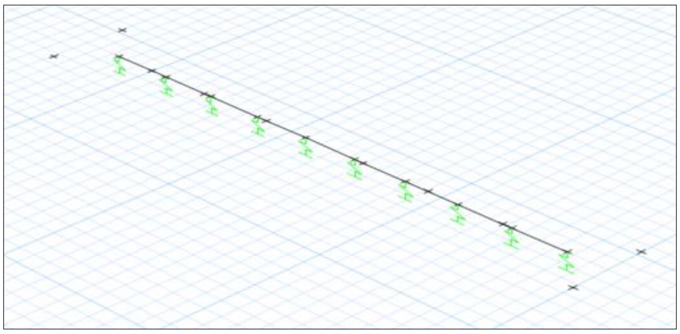


Figure 4 Spring Constant of Micro Piles

3.2.2 Check the Forces for Load Combination

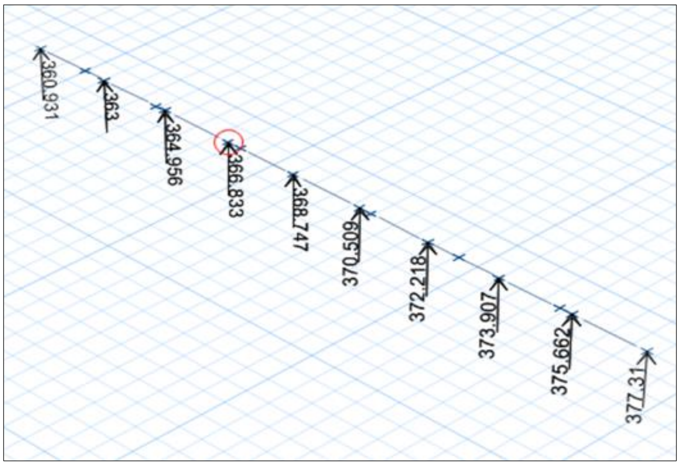


Figure 5 Upward reaction of Micro Piles

3.2.3 Earthquake forces in X and Y direction.

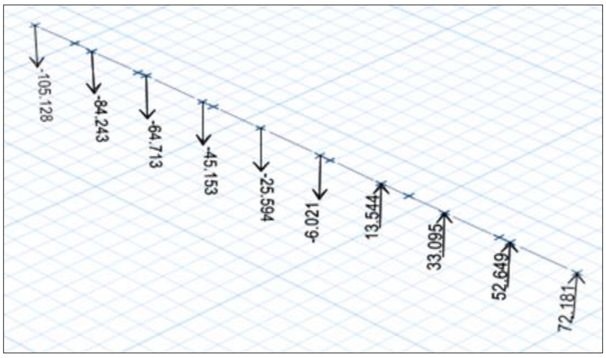


Figure 6 Upward and downward reaction of Micro Piles for earthquake force in Y direction

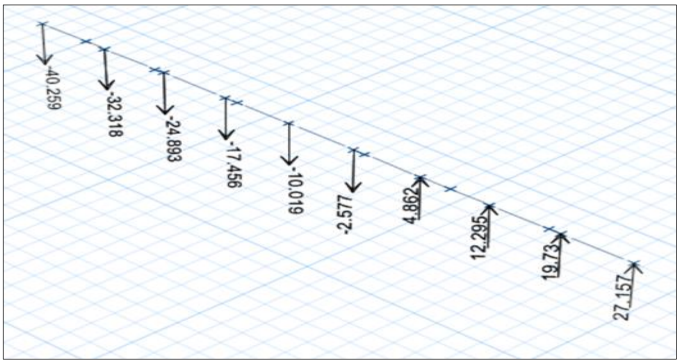


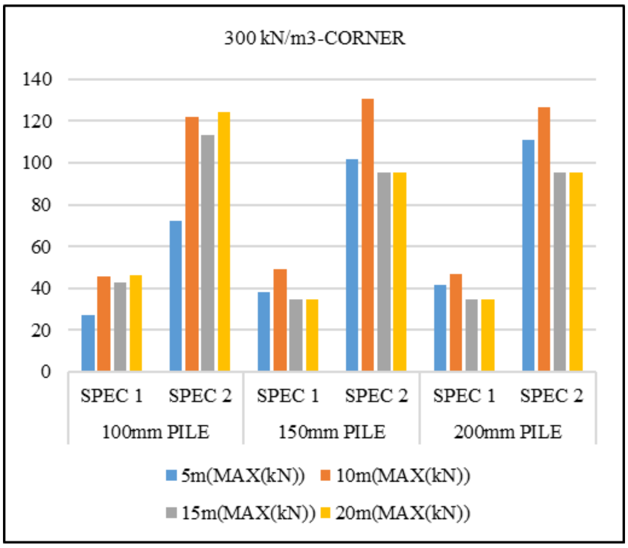
Figure 7 Upward and downward reaction of Micro Piles for earthquake force in X direction**.**

4 Results and discussion

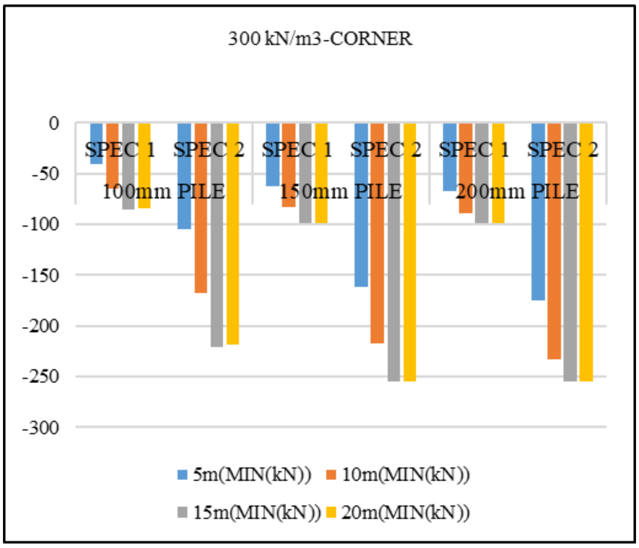
4.1 Torsional reaction on micropile

4.1.1 Result for corner wall

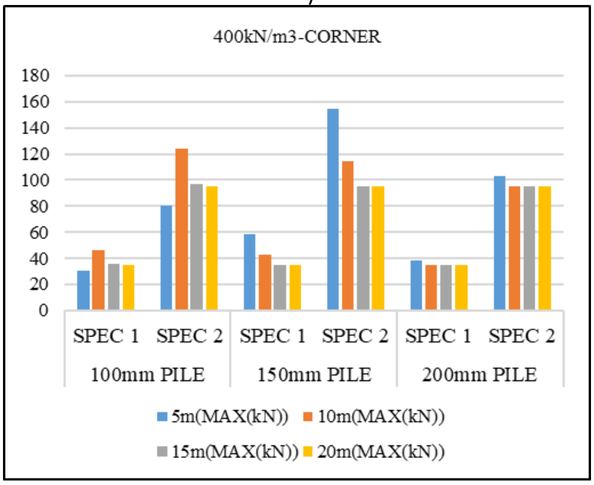
The following graph is showing the maximum and minimum torsional reaction on the micro pile.



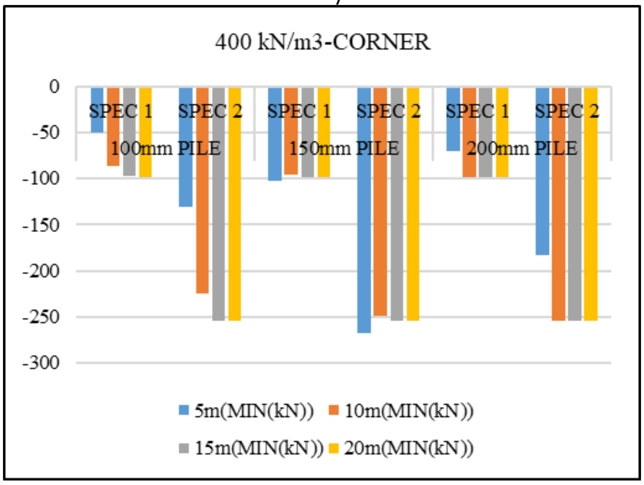
Graph 1 Maximum reaction on micro pile with SBC 300kN/m3.



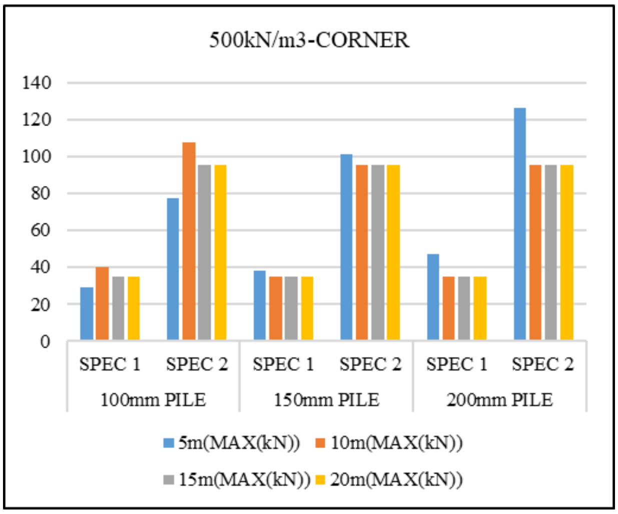
Graph 2 Minimum reaction on micro pile with SBC 300kN/m³.



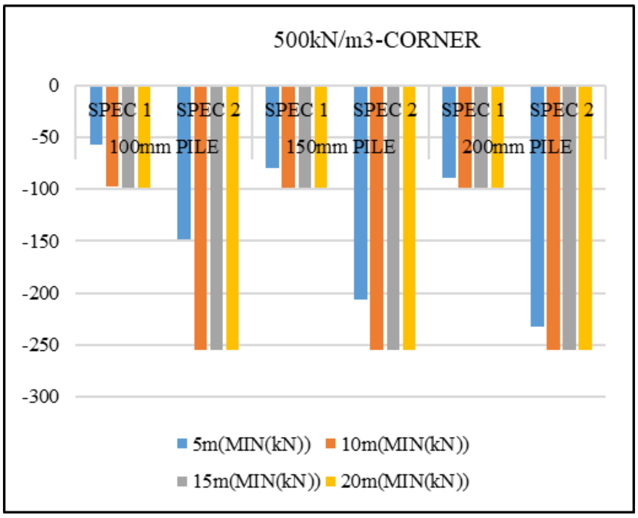
Graph 3 Maximum reaction on micro pile with SBC 400kN/m³



Graph 4 Minimum reaction on micro pile with SBC 400KN/M³

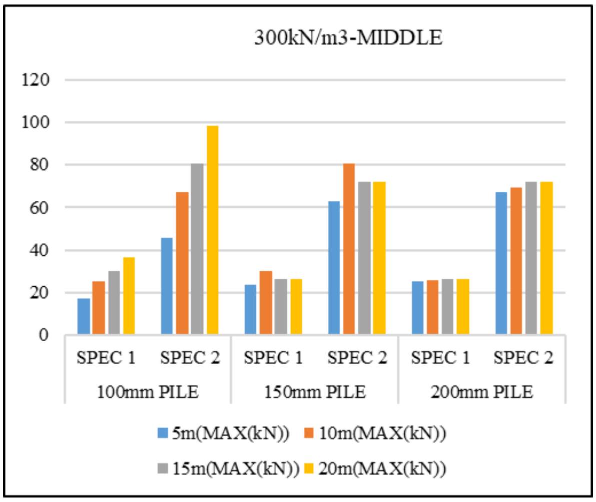


Graph 5 Maximum reaction on micro pile with SBC 500KN/M³.

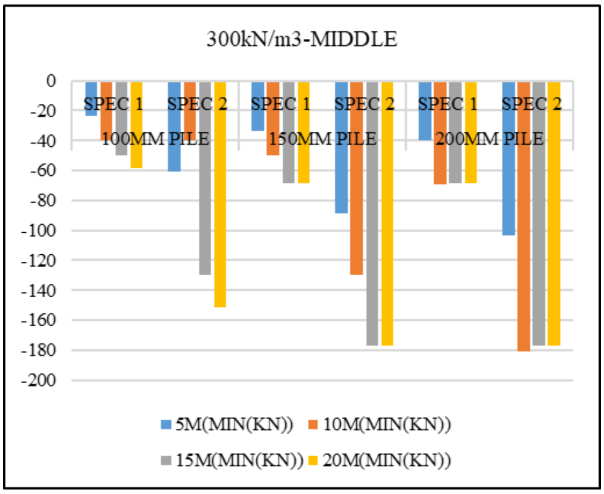


Graph 6 Minimum reaction on micro pile with SBC 500KN/M3.

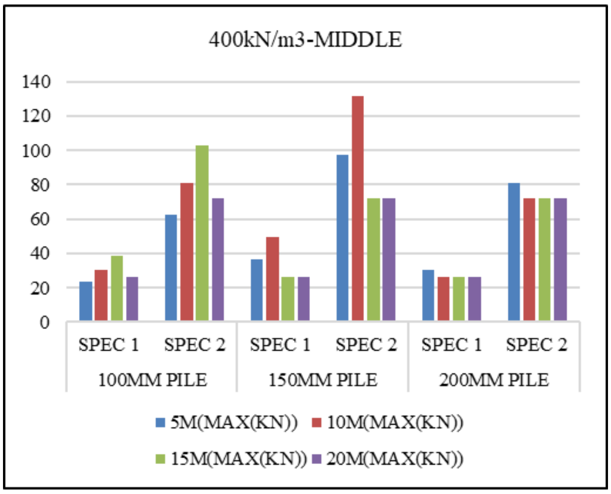
4.2 Result for middle wall



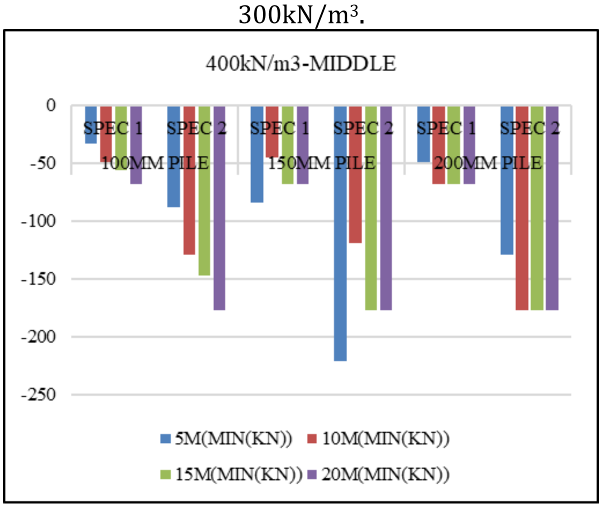
Graph 7. Maximum reaction on micro pile with SBC 300kN/m³



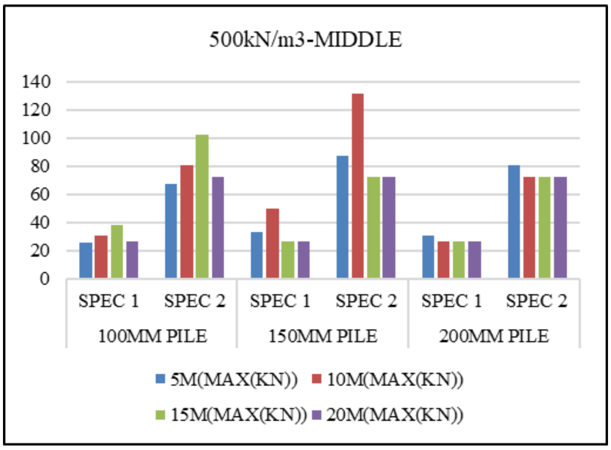
Graph 8 Minimum reaction on micro pile with SBC 300kN/m³.



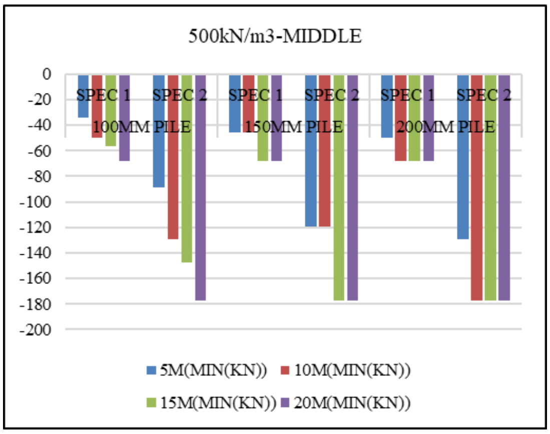
Graph 9 Maximum reaction on micro pile with SBC 400kN/m3.



Graph 10 Minimum reaction on micro pile with SBC 400kN/m3.



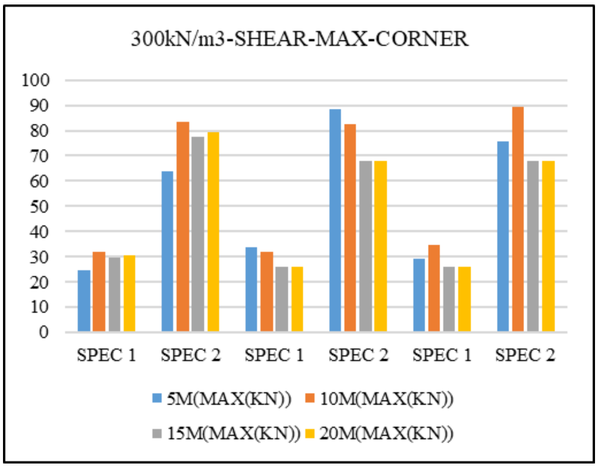
Graph 11 Maximum reaction on micro pile with SBC 500kN/m3.



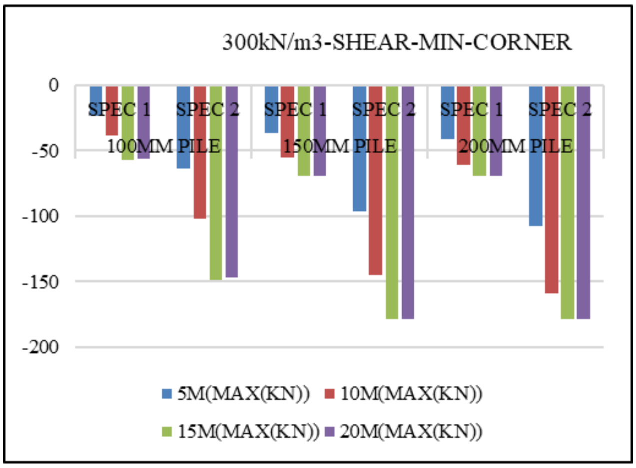
Graph 12 Minimum reaction on micro pile with SBC 500kN/m3.

4.3 Shear forces on micropile.

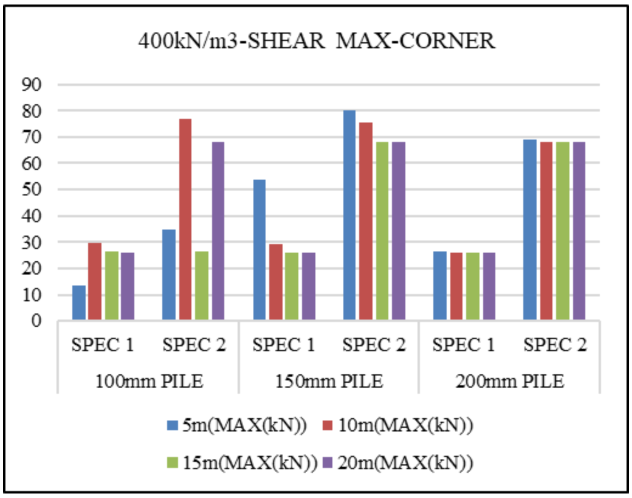
4.3.1 Result for corner wall



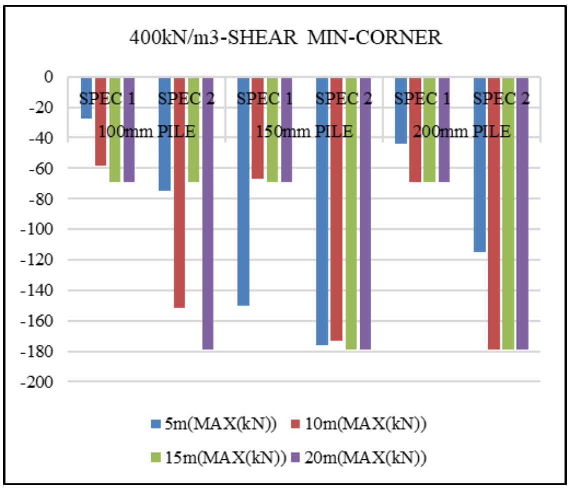
Graph 13 Maximum shear force on micro pile with SBC 300kN/m3



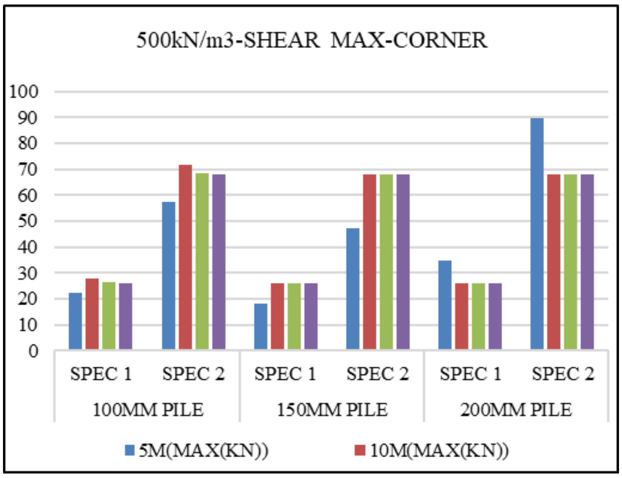
Graph 14 Minimum shear force on micro pile with SBC 300kN/m3.



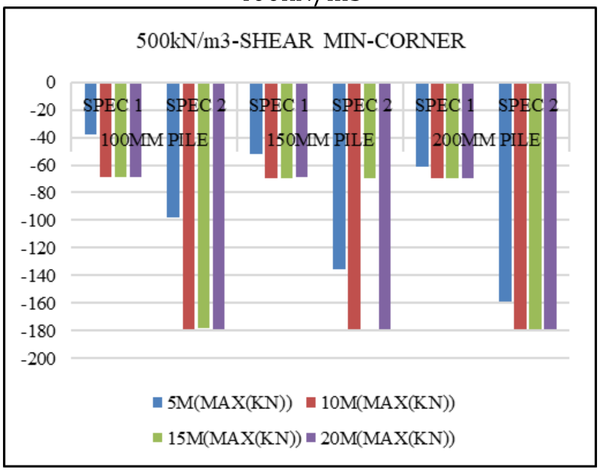
Graph 15 Minimum shear force on micro pile with SBC 400kN/m3



Graph 16 Minimum shear force on micro pile with SBC 400kN/m3

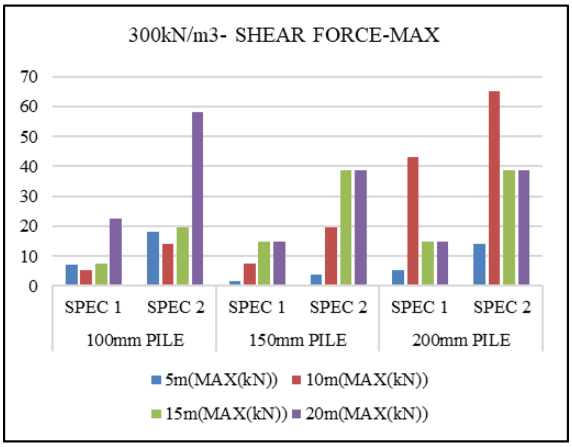


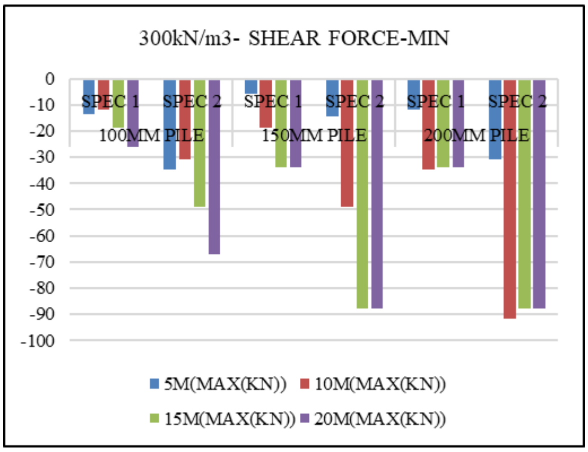
Graph 17 Maximum shear force on micro pile with SBC 500kN/m3.



Graph 18 Minimum shear force on micro pile with SBC 500kN/m3

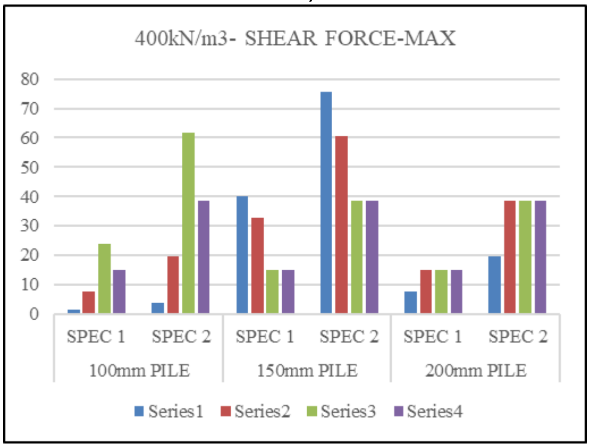
4.3.2 Result for middle wall

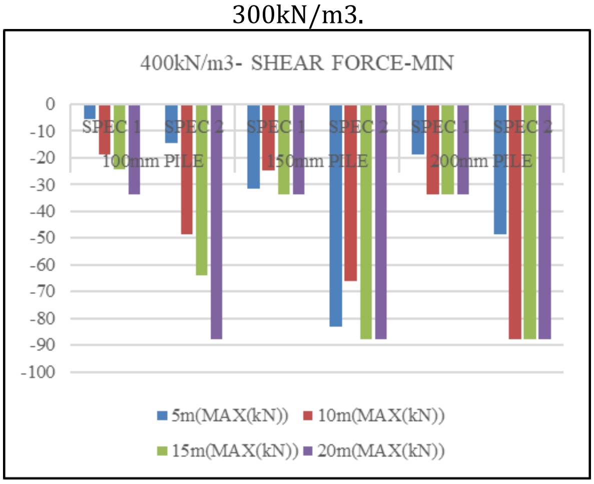




Graph 19 Maximum shear force on micro pile with SBC 300kN/m3

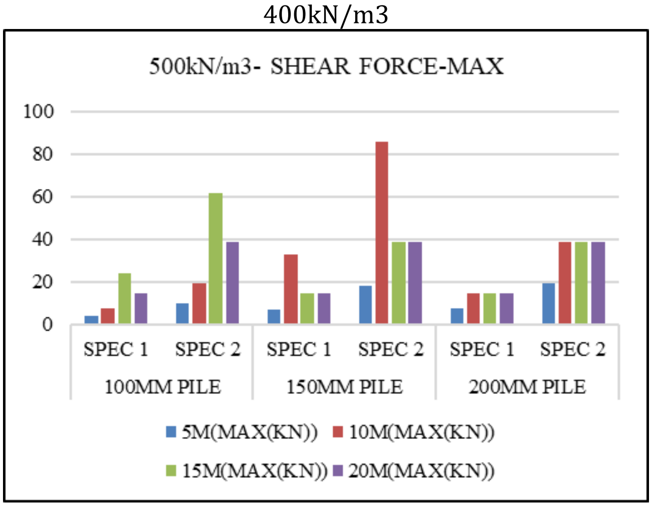
Graph 20 Minimum shear force on micro pile with SBC 300kN/m3.

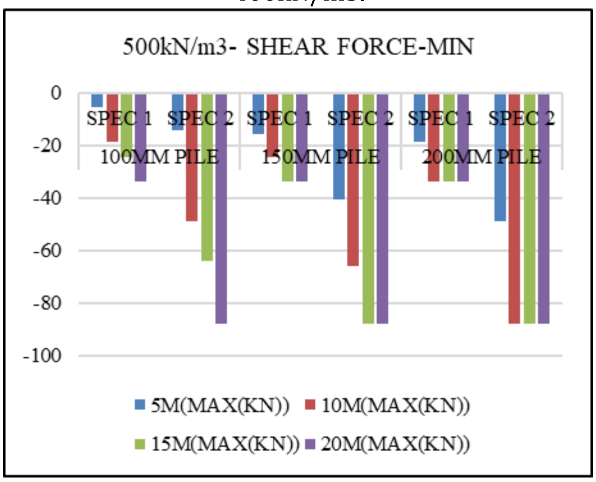




Graph 21 Maximum shear force on micro pile with SBC 400kN/m3

Graph 22 Minimum shear force on micro pile with SBC 400kN/m3.



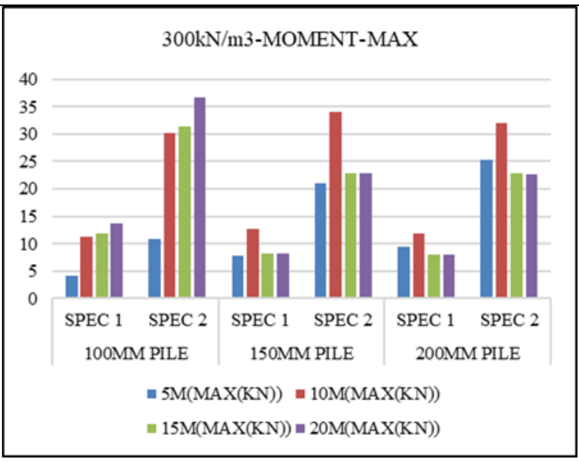


Graph 23 Maximum shear force on micro pile with SBC 500kN/m3.

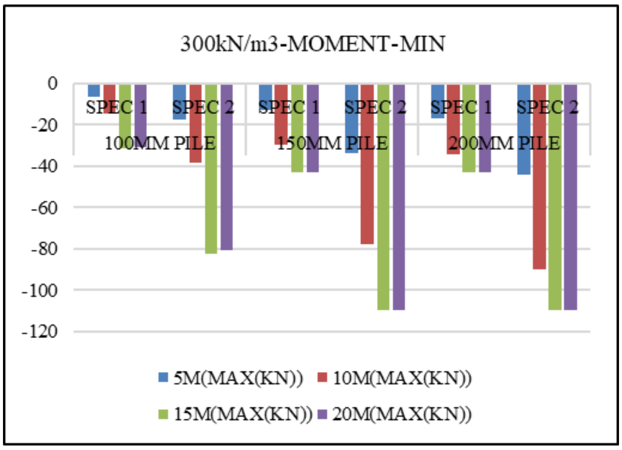
Graph 24 Minimum shear force on micro pile with SBC 500kN/m3.

4.4 Moments on micropile

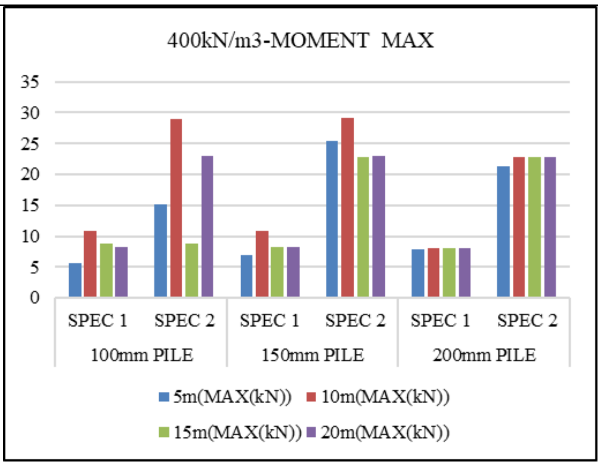
4.4.1 Result for corner wall



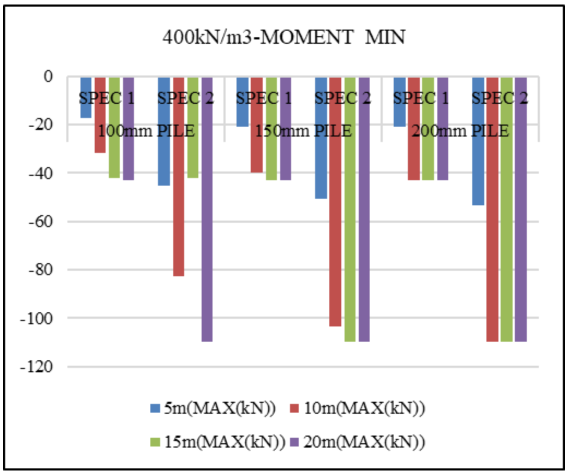
Graph 25 Maximum moment on micro pile with SBC 300kN/m3.



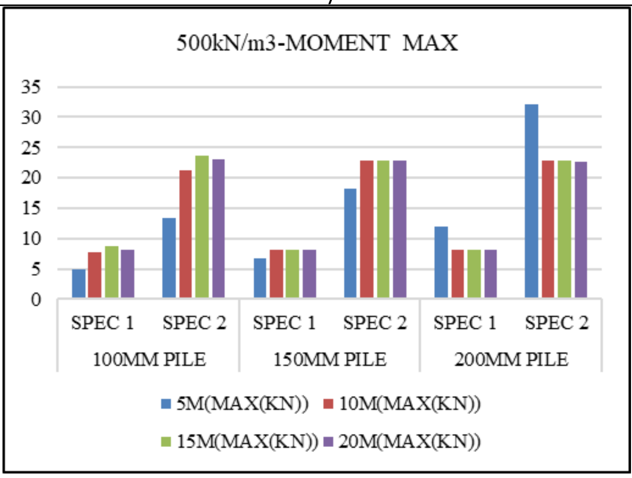
Graph 26 Minimum moment on micro pile with SBC 300kN/m3.



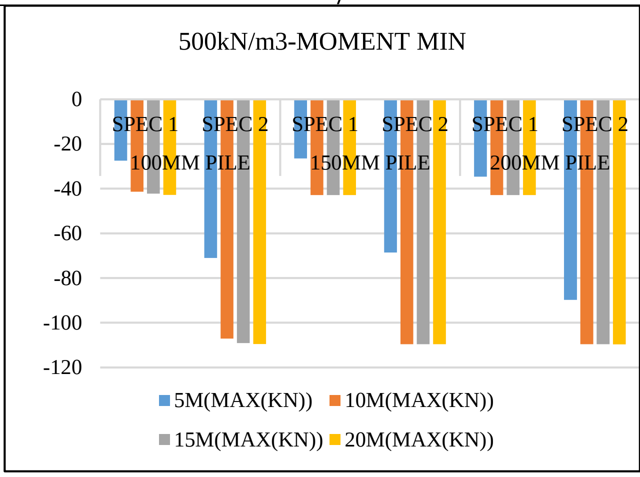
Graph 27 Maximum moment on micro pile with SBC 400kN/m3.



Graph 28 Minimum moment on micro pile with SBC 400kN/m3

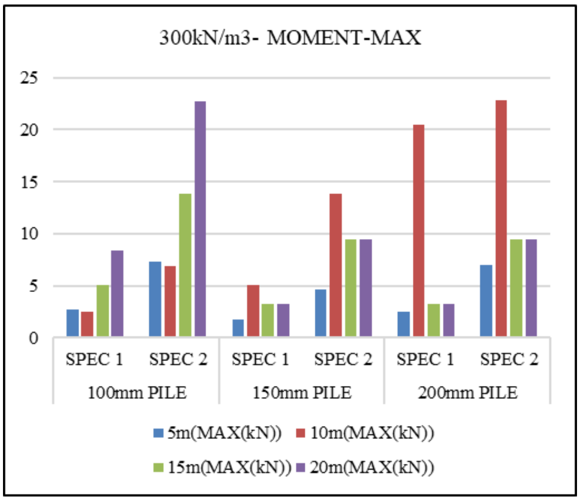


Graph 29 Maximum moment on micro pile with SBC 500kN/m3

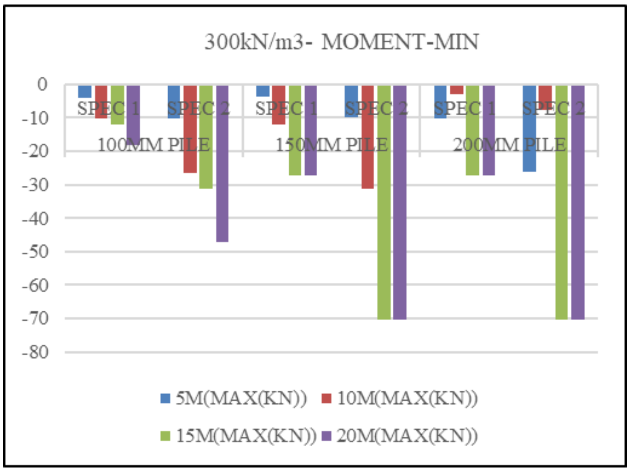


Graph 30 Minimum moment on micro pile with SBC 500kN/m3

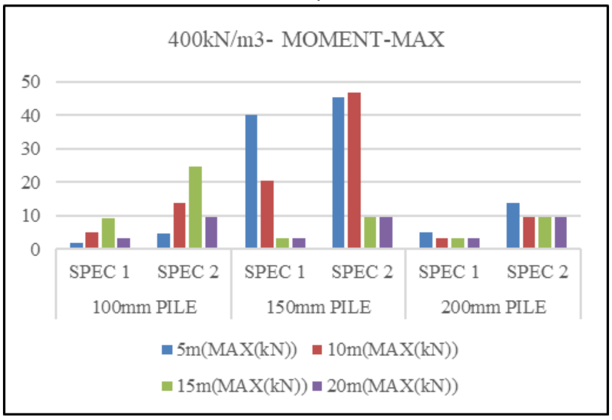
4.4.2 Result for middle wall



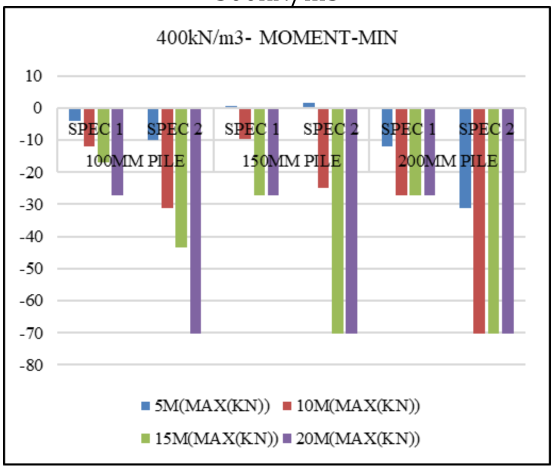
Graph 31 Maximum moment on micro pile with SBC 300kN/m3.



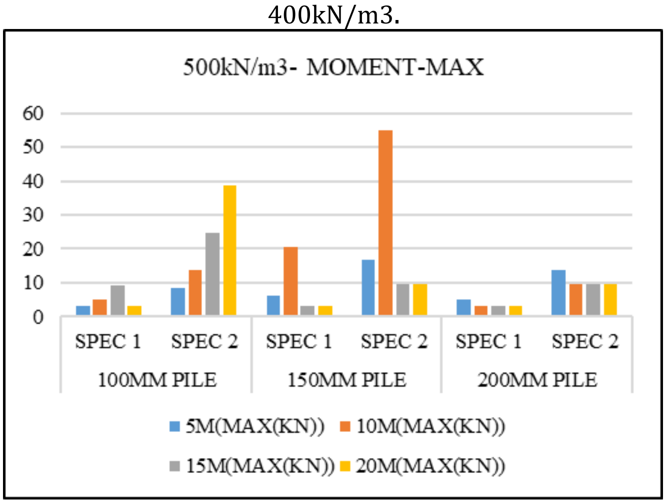
Graph 32 Minimum moment on micro pile with SBC 300kN/m3



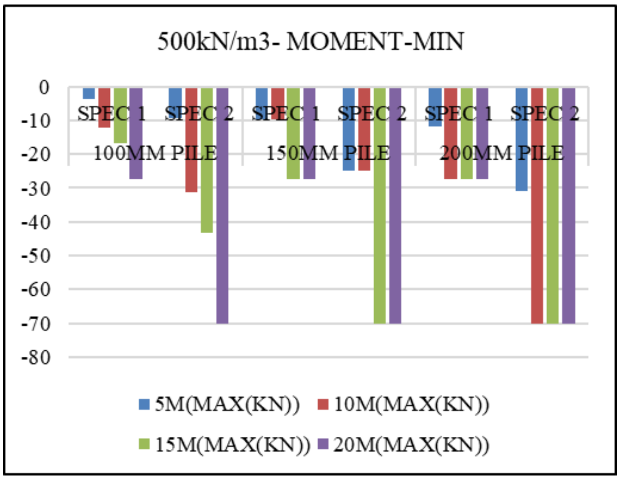
Graph 33 Maximum moment on micro pile with SBC 400kN/m3.



Graph 34 Minimum moment on micro pile with SBC 400kN/m3.



Graph 35 Maximum moment on micro pile with SBC 500kN/m3



Graph 36 Minimum moment on micro pile with SBC 500kN/m3.

5 Conclusion

- Spring constant of micropile increases with increase in diameter of pile.
- Capacity of micropile increases with increase in length of pile and bearing capacity of soil.
- The compressive forces, tensile forces, moment and shear force are constant if the number of micropiles are same and it is irrespective of the diameter of pile.
- Maximum shear forces for SBC 300kN/m3 are varying from 9% to 23%, for 400kN/m3 is 6% to 51%, for 500Kn/m3 is 16% to 51% for middle shear wall and for corner shear wall SBC 300kN/m3 is varying from 77% to 75%, for 400kN/m3 is 34% to 98%, for 500Kn/m3 is 69% to 79%.
- Maximum moment for SBC 300kN/m3 is varying from 12% to 53%, for 400kN/m3 is 8% to 68%, for 500Kn/m3 is 15% to 68% for middle shear wall and for corner shear wall SBC 300kN/m3 is varying from 29% to 71%, for 400kN/m3 is 30% to 96%, for 500Kn/m3 is 56% to 83%.
- Minimum shear forces for SBC 300kN/m3 are varying from 45% to 16%, for 400kN/m3 is 16% to 75%, for 500Kn/m3 is 16% to 55% for middle shear wall and for corner shear wall SBC 300kN/m3 is varying from 41% to 60%, for 400kN/m3 is 40% to 96%, for 500Kn/m3 is 38% to 88%.
- Minimum moment for SBC 300kN/m3 is varying from 10% to 66%, for 400kN/m3 is 14% to 44%, for 500Kn/m3 is 13% to 44% for middle shear wall and for corner shear wall SBC 300kN/m3 is varying from 21% to 40%, for 400kN/m3 is 38% to 48%, for 500Kn/m3 is 61% to 80%.

Future scope

- Check the results for the combine micro pile result.
- Comparison with the open foundation and pile foundation to the micropile foundation.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest in publishing the paper.

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