ANALYSIS OF PILED RAFT FOUNDATION USING MIDAS GTS NX

Sonia Saini*[1], Er. Tripti Goyal[2]

*[*1] M. Tech Student, Modern Institute of Engineering & Technology, Mohri (Haryana)*
[2]Head of Department, Civil Engineering, Modern Institute of Engineering & Technology, Mohri (Haryana)

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Abstract: - Foundation is the structural element which connects the superstructure to the ground beneath it. Generally foundations are of two types, first is shallow foundation such as a raft and the second is deep foundation such as a pile. Traditionally it is a common practice in foundation design to consider first the use of a shallow foundation system such as a raft and if the shallow foundation was not adequate, a fully piled foundation taking the entire design load was designed. Rafts cover the entire area of the structure and transmit the load to the underlying soil. They do not require any deep excavations for their construction. Pile foundations require deep excavations and transmit the load to hard strata at deeper depths. In some cases the raft is capable of taking the structural loads efficiently but can't control the settlements or differential settlements. In such a condition rather than increasing the thickness of the raft another alternative called the piled-raft foundation system can be adopted. The piles and raft act as a single unit in a pile-raft system.

From the laboratory experiments and 3D simulation of piled raft in Midas GTS NX, the reduction in settlements with increase in diameter becomes insignificant after a certain range of diameter. The variation of pile length shows more influence on the settlements than the variation of pile diameter. The use of piled raft as an alternate for raft foundation results in around 30% decrease in raft thickness, along with 20% decrease in the settlements when the raft thickness was reduced to 50cm from 70cm.In order to bring down the settlement of 78.7mm in 70cm raft foundation, the first alternative of using a piled raft of 50cm thickness resulted in the decrease of settlement by about 20%. The introduction of piles irrespective of the raft thickness results in considerable decrease in the foundation settlements. Use of piled raft can be used to reduce the settlements of the raft as well as the material resources by reduction in the raft thickness. Midas GTS NX proves to be efficient software in the analysis of piled raft foundation with a user friendly interface and can aid in the analysis of complex problems.

***Key Words*: Numerical modeling, piled raft, full-scale field tests, Midas GTS NX**

1. INTRODUCTION

Foundation is the structural element which connects the superstructure to the ground beneath it. Generally foundations are of two types, first is shallow foundation such as a raft and the second is deep foundation such as a pile. Traditionally it is a common practice in foundation design to consider first the use of a shallow foundation system such as a raft and if the shallow foundation was not adequate, a fully piled foundation taking the entire design load was designed. Rafts cover the entire area of the structure and transmit the load to the underlying soil. They do not require any deep excavations for their construction. Pile foundations require deep excavations and transmit the load to hard strata at deeper depths. In some cases the raft is capable of taking the structural loads efficiently but can't control the settlements or differential settlements. In such a condition rather than increasing the thickness of the raft another alternative called the piled-raft foundation system can be adopted. The piles and raft act as a single unit in a pile-raft system. In a piled raft system the raft takes most of the load while the pile controls the settlement or differential settlement.

The numerical calculations were performed using commercial software Midas GTS NX and concentrated on some specific aspects of numerical modeling applied to deep foundations, especially the influence of the soil constitutive model and the pile-soil interface elements on overall settlements.

Midas GTS NX is a FEM based modeling software. It includes CAD based 2D and 3D commands for modeling. GTS NX analyses foundation stability subjected to lateral pressure and differential settlements.

2. OBJECTIVES:-

1. To evaluate the engineering properties of soil.
2. To study the effect on displacements of raft with the introduction of piles.
3. To study the piled raft interactions with variations in thickness of raft.
4. To study the piled raft interactions with variation in length and diameter of piles.

3. EXPERIMENTAL INVESTIGATION:-

Three samples of soil at different elevations have been collected from study area. To analysis the piled raft foundations in Midas GTS NX, the foremost requirement is to determine the basic soil engineering properties of various soil types of that area. A series of test has been conducted to determine some pre-requisite properties of soil.

Determination of In-situ density, moisture content and dry density of various soil samples.

a) **In-situ density: -** The in-situ density is defined as the bulk density of soil measured at its actual depth. By conducting this test, it is possible to determine the field density of the soil. The moisture content is likely to vary from time and hence the field density also.

Table1:- calculation of In-situ density

S.No.	Observations	Soil 1	Soil 2	Soil 3
1.	Weight of casing and soil (w_1) gm	2790	2780	2660
2.	Weight of casing (w_2) gm	1115	1115	1115
3.	Volume of casing (v) cc	884	884	884
4.	In-situ density (γ_f) = $\left(\frac{w1-w2}{v}\right)$ g/cc	1.894	1.883	1.747

b) Natural moisture content: - The moisture content of soil also referred to as water content is an indicator of the amount of water present in soil. By definition, moisture content is the ratio of the mass of water in a sample to the mass of solids in the sample, expressed as a percentage.

Table 2:- calculation of natural moisture content

S. No.	Observations	Soil 1	Soil 2	Soil 3
1.	Weight of soil sample + container (w_1) gm	140	150	165
2.	Weight of oven dried sample + container (w_2) gm	135	145	160
3.	Weight of container (w_3) gm	21	21.2	21
4.	Moisture content (w) % = $\left(\frac{w1-w2}{w2-w3}\right) \times 100$	4.4	4	3.6

c) **Dry density: -** The relationship between the density of a sample of soil in a dry state and its moisture content for a given degree of compaction.

Table 3:- calculation of dry density

S. No.	Observations	Soil 1	Soil 2	Soil 3
1.	In-situ density (γ_f) g/cc	1.894	1.883	1.747
2.	Moisture content (w)	4.4	4	3.6
3.	Dry density (γ_d) g/cc= $\frac{\gamma_f}{1+w}$	1.814	1.81	1.686

d) **Relative density test (I_D):-** Relative density is considered as one of the most important index aggregate property of cohesion less soil as many engineering properties of cohesion less soil depends on relative density. It gives a better idea of denseness of soil than the void ratio. Relative density of soil indicates the expected behaviour of soil under loading.

Figure 1:- Relative density apparatus

Table 4:- calculation of relative density

S. No.	Observations	Soil 1	Soil 2	Soil 3
1.	Weight of mould (w_1) gm	10915	10915	10915
2.	Weight of mould + soil (w_2) gm	14730	14940	14930
3.	Volume of soil in loosest state = Volume of mould (v_1) cc	3000	3000	3000
4.	Minimum density (γ_{min}) = $\frac{w2-w1}{v1}$ g/cc	1.271	1.342	1.338
5.	Radius of mould (r) cm	7.5	7.5	7.5
6.	Settlement in soil after 8 min. of compaction (h) cm	4.057	3.440	3.904
7.	Volume of soil in compacted state (v_2) = $v_1 - \pi r^2 h$ cc	2283.43	2399.475	2310.54
8.	Maximum density (γ_{max}) = $\frac{w2-w1}{v2}$ g/cc	1.670	1.677	1.7375
9	Rel. density (I_d) % = $\frac{\frac{1}{\gamma min}-\frac{1}{\gamma dry}}{\frac{1}{\gamma min}-\frac{1}{\gamma max}} \times 100$	94.1	94.18	91.8

e) **Specific gravity test (G):-** Specific gravity is defined as ratio of mass of given volume of solids to the mass of an equal volume of water at 4° C. Specific gravity of both fine-grained and coarse-grained soils can be determined using Pycnometer method. It is used for determination of void ratio and particle size. Specific gravity of soils is determined using relation:

$$\text{Specific gravity (G)} = \frac{W2-W1}{(W2-W1)-(W3-W4)}$$

Table 5:- determination of specific gravity using Pycnometer

S.No.	Observations	Soil 1	Soil 2	Soil 3
1.	Weight of empty Pycnometer (w_1) gm	563.8	563.8	563.8
2.	Weight of Pycnometer + soil (w_2) gm	765.4	764.7	799.4

3.	Weight of Pycnometer + soil + water (w_3) gm	1567.9	1569.3	1593.4
4.	Weight of Pycnometer + water (w_4) gm	1449	1449	1449
5.	Specific gravity (G) = $\frac{W2-W1}{(W2-W1)-(W3-W4)}$	2.437	2.492	2.583

f) Direct shear test:- Shear strength of a soil is defined as its maximum resistance to shearing stresses just before reaching failure. Shear strength is the chief engineering property which controls the bearing capacity of soil, slope stability, stability of retaining structures and many other soil related problems. Normal stress of 0.5 kg/cm², 1 kg/cm², 1.5kg/cm² is applied in three different trials and shear load is applied at a shearing strain of 1.25mm/min. Readings are taken when the soil specimen fails. Shear strength of soil is expressed as:

$$s = c + \sigma \tan \phi$$

Figure 2:-Direct shear apparatus

Figure 3:- Shear failure of soil samples

Table 6:- Determination of shear strength parameters using direct shear test.

S. No.	Soil Condition	Normal Stress	Area of specimen	Load(kg)			Shear stress(kg/cm²)		
				Soil 1	Soil 2	Soil 3	Soil 1	Soil 2	Soil 3
1.	At natural Moisture Content	0.5	36	23.8	23.5	21.8	0.661	0.652	0.605
		1	36	41.9	37	37.5	1.163	1.027	1.041
		1.5	36	55	50.4	49.4	1.527	1.4	1.372

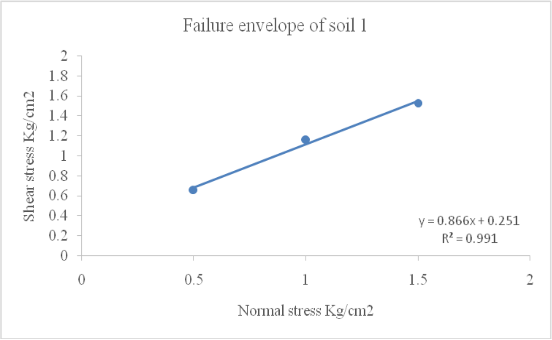

Figure *Error! No text of specified style in document.*:- **Failure envelope of soil 1**

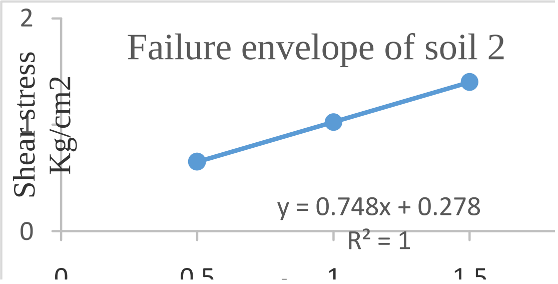

Figure 5:- Failure envelope of soil 2

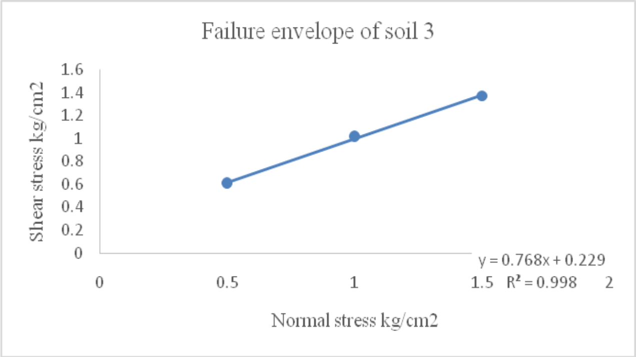

Figure 6:- Failure envelope of soil 3

Table 7:- Summary of experimental study

S.No.	Property	Soil 1	Soil 2	Soil 3
1.	Liquid limit (w_l)	-	23.167	23.085
2.	Plastic limit (w_p)	-	5.707	3.085
3.	Classification	SP	SM-SC	SM
4.	Field density (γ_f)	1.894	1.883	1.747
5.	Natural Moisture Content (w)	4.4	4	3.6
6.	Dry density (γ_d)	1.814	1.81	1.686
7.	Minimum density (γ_{min})	1.271	1.342	1.338
8.	Maximum density ($\gamma_{max.}$)	1.670	1.677	1.737
9.	Relative density (I_d)	94.1	94.18	91.8
10.	Specific Gravity (G)	2.437	2.492	2.538
11.	Cohesion (c)	25.1	27.8	22.9
12.	Angle of internal friction (ϕ)	40	36.7	37.52

4) NUMERICAL MODELLING:- In this analysis the displacements of rafts of different thickness have been analysed under the same load by varying the pile length and pile thickness. In the first case, a 70cm thickness raft is analysed for displacements under a load of 250kN/m². Displacements are obtained for the raft without piles and with 25 piles of 6.2 m length at varying diameter. In second case, the raft thickness has been reduced to 50cm and the displacements are obtained at varying pile length and diameter.

- ***Displacements of raft at various conditions:-***

a) Raft of thickness 70cm without any piles

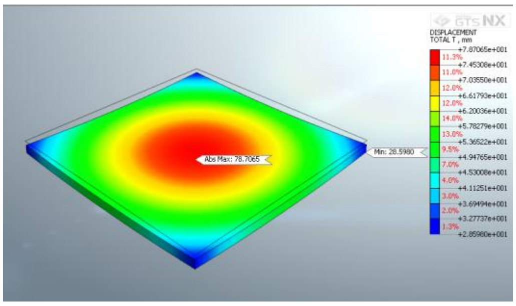

Figure 7:- Displacements of raft without any piles

b) Displacements of piled-raft with piles of length 6.2m:-

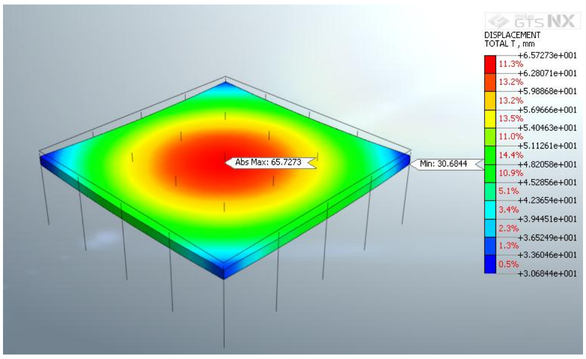

Figure 8:- Displacements of piled-raft with piles of length 6.2m and diameter 10cm

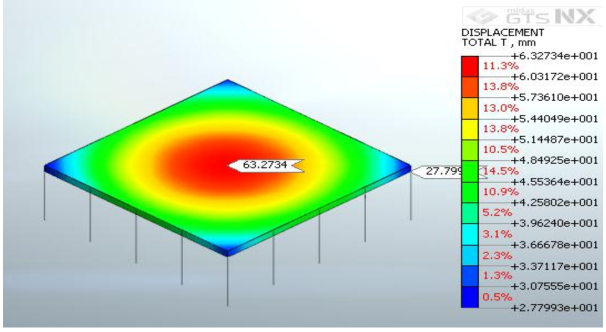

Figure9:- Displacements of piled-raft with piles of length 6.2m and diameter 15cm

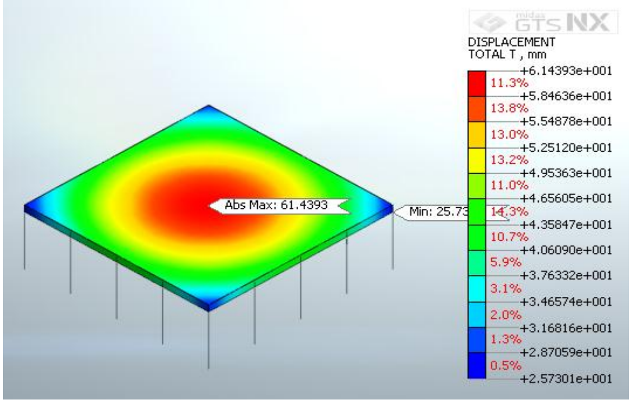

Figure10:- Displacements of piled-raft with piles of length 6.2m and diameter 20cm.

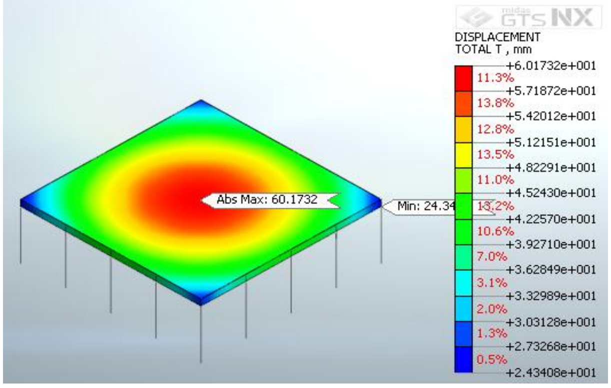

Figure11:- Displacements of piled-raft with piles of length 6.2m and diameter 25cm.

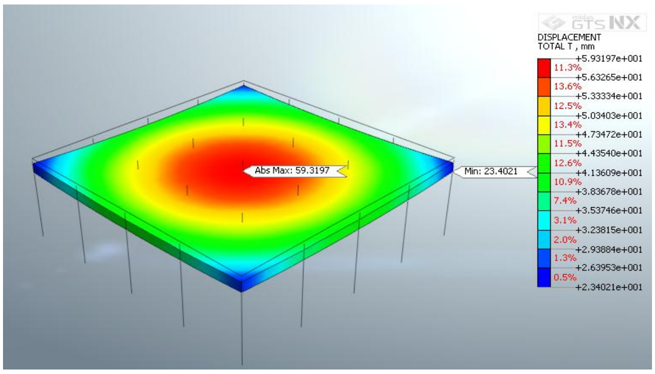

Figure 12:- Displacements of piled-raft with piles of length 6.2m and diameter 30cm.

Figure 13:- Settlements of 70cm thickness raft with 6.2m pile length at various diameters

c) Displacements of 70cm piled-raft with piles of length 9m

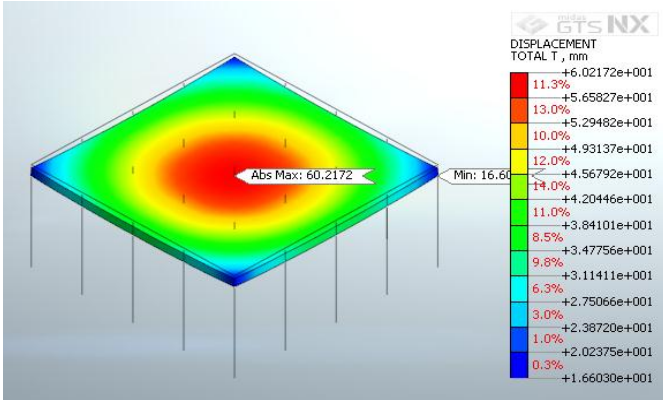

Figure 14:- Displacements of piled-raft with piles of length 9m and 30cm diameter.

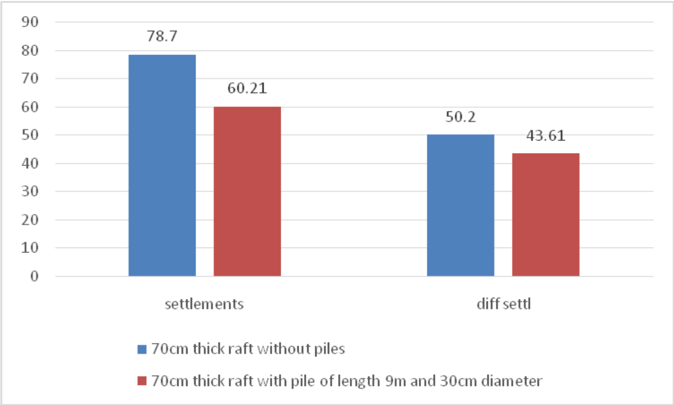

Figure 15:- Comparison of 70cm raft with and without piles

- **Raft of thickness 50cm**

d) Displacements of 50cmthickness raft without any piles

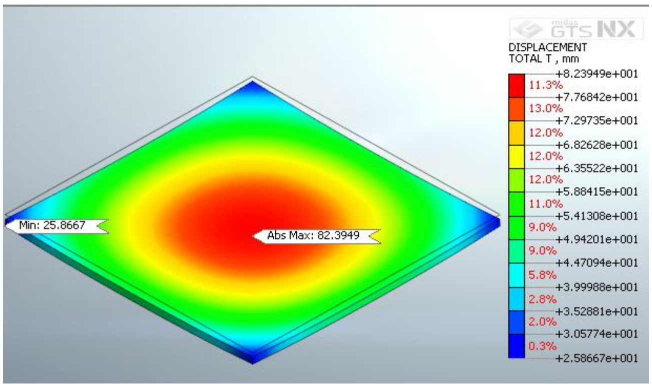

Figure 16:- Displacements of 50cm thickness raft without any piles

- **Displacements of 50cm thickness raft with piles of 6.2m length**

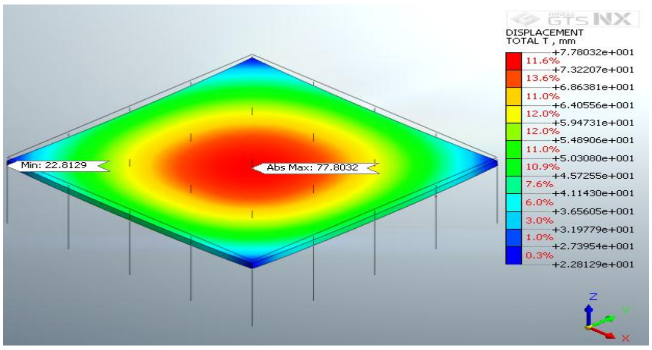

Figure 17:- Displacements of piled-raft with piles of length 6.2m and 10cm diameter

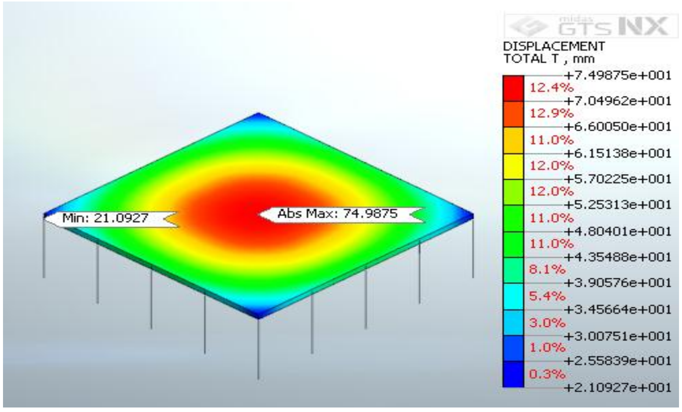

Figure 18:- Displacements of piled-raft with piles of length 6.2m and 15cm diameter

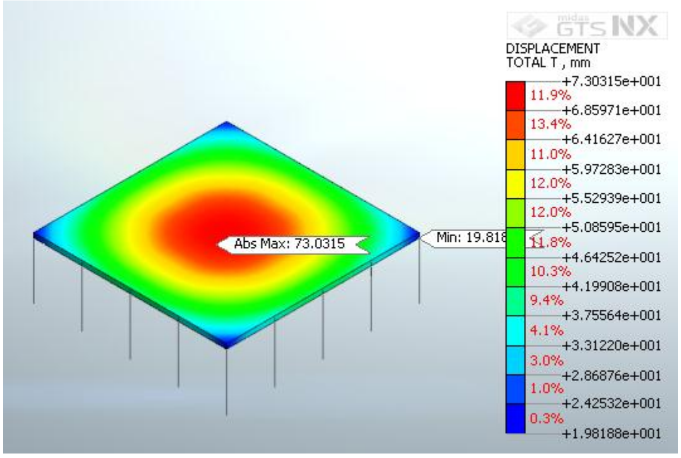

Figure 19:- Displacements of piled-raft with piles of length 6.2m and 20cm diameter.

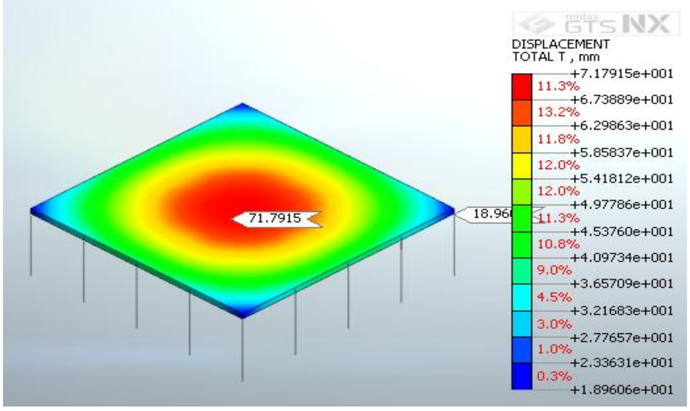

Figure 20:-Displacements of piled-raft with piles of length 6.2m and 25cm diameter.

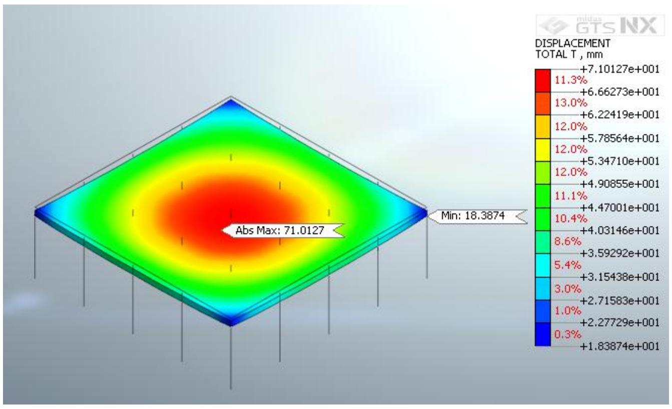

Figure21:- Displacements of piled-raft with piles of length 6.2m and 30cm diameter.

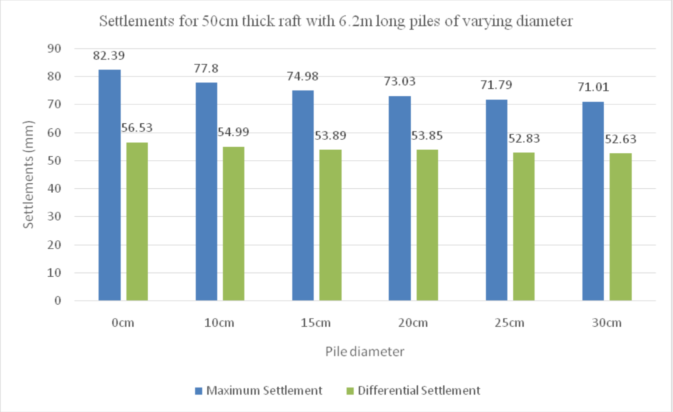

Figure 22:- Displacements of piled-raft with 50cm raft thickness and piles of length 6.2m at different diameter.

- **Displacements of piled-raft with raft of 50cm thickness and piles of length 7.5m**

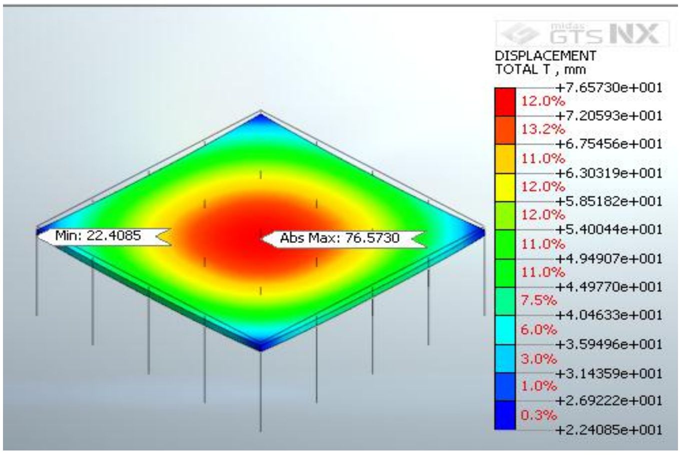

Figure 23:- Displacements of piled-raft with piles of length 7.5m and 10cm diameter.

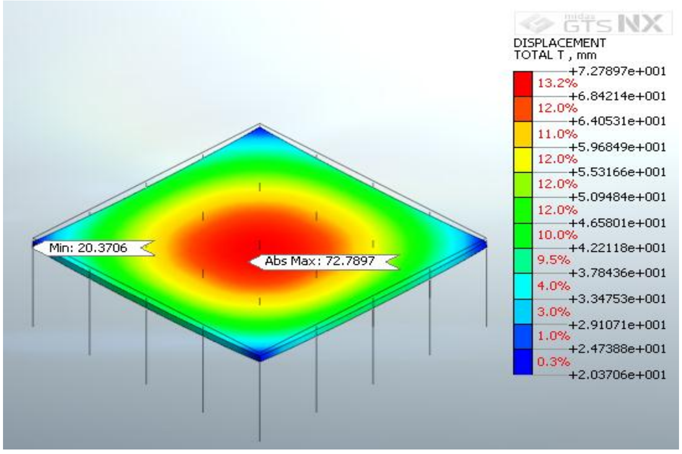

Figure 24:-Displacements of piled-raft with piles of length 7.5m and 15cm diameter.

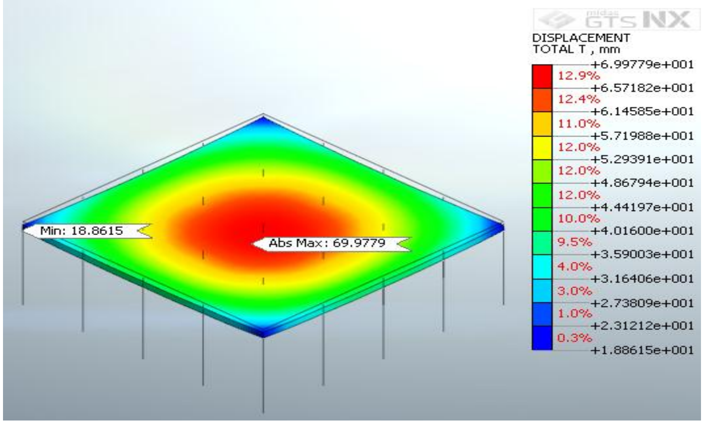

Figure 25:- Displacements of piled-raft with piles of length 7.5m and 20cm diameter.

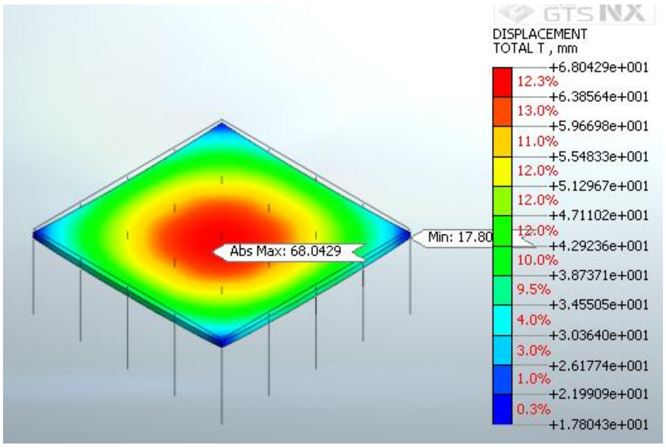

Figure 26:- Displacements of piled-raft with piles of length 7.5m and 25cm diameter.

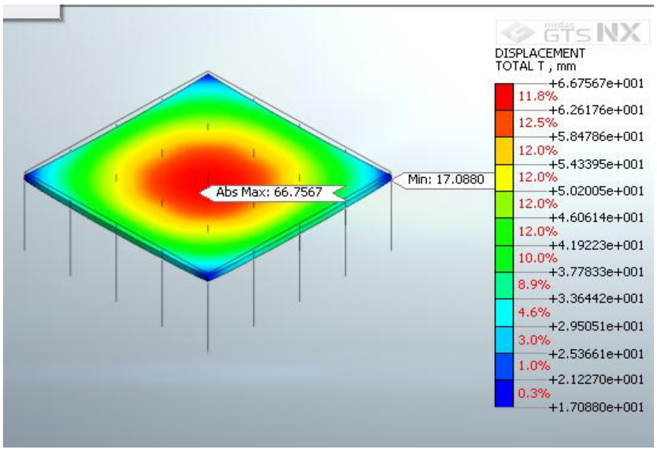

Figure 27:- Displacements of piled-raft with piles of length 7.5m and 30cm diameter

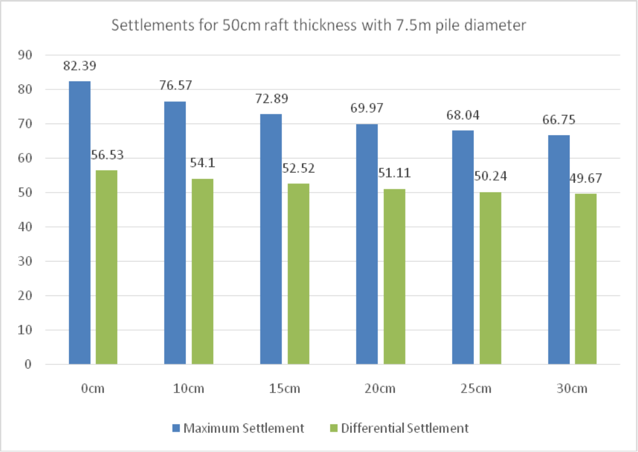

Figure 28:- Displacements of piled-raft with 50cm raft thickness and piles of length 7.5m at different diameter.

- **Displacements of piled-raft with raft of 50cm thickness and piles of length 9m**

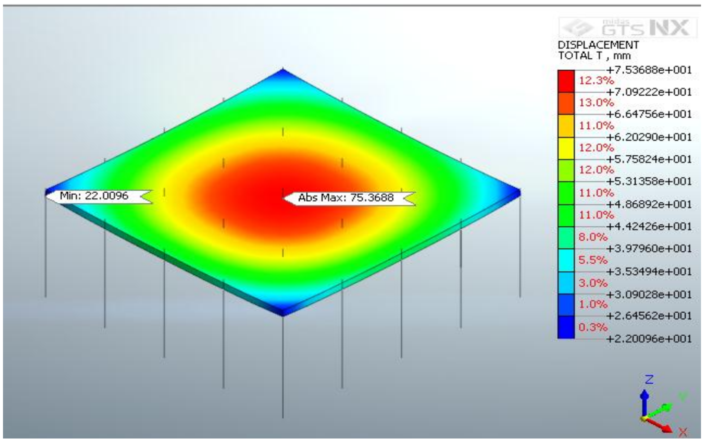

Figure 29:- Displacements of piled-raft with piles of length 9m and 10cm diameter.

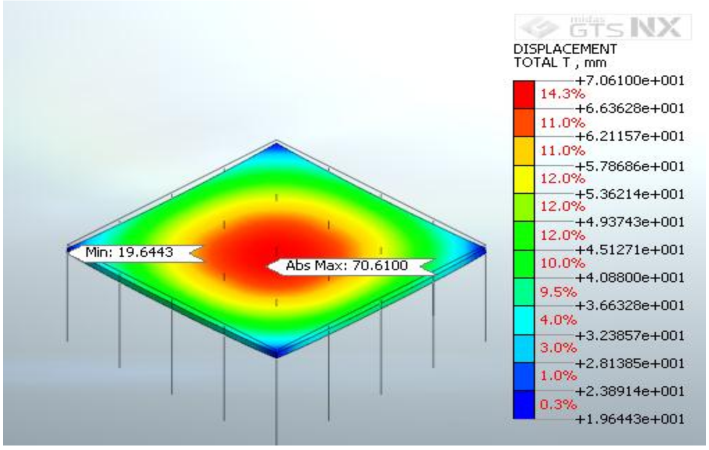

Figure 30:- Displacements of piled-raft with piles of length 9m and 15cm diameter.

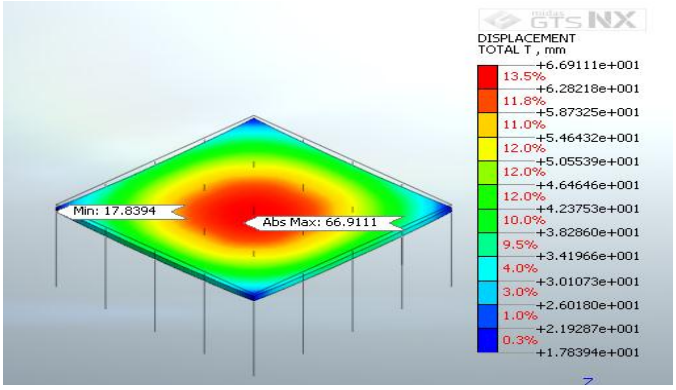

Figure 31:- Displacements of piled-raft with piles of length 9m and 20cm diameter.

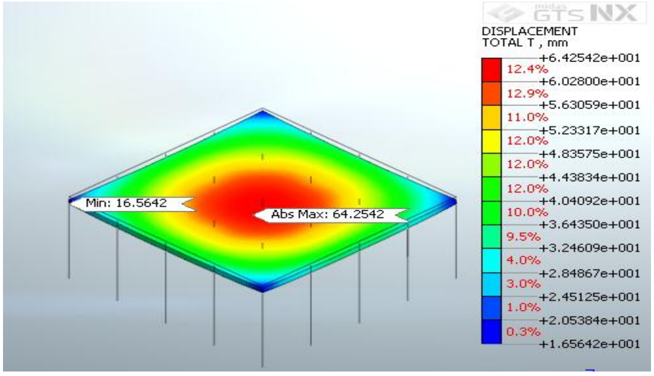

Figure 32:- Displacements of piled-raft with piles of length 9m and 30cm diameter.

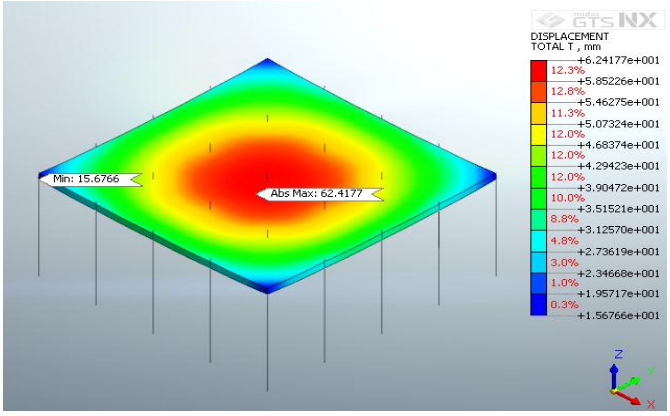

Figure 33:- Displacements of piled-raft with piles of length 9m and 30cm diameter.

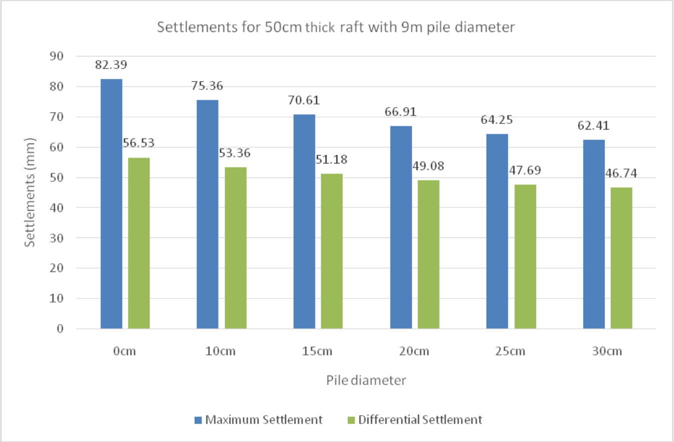

Figure 34:- Displacements of piled-raft with 50cm raft thickness and piles of length 9m at different diameter.

- **Raft of thickness 90cm**

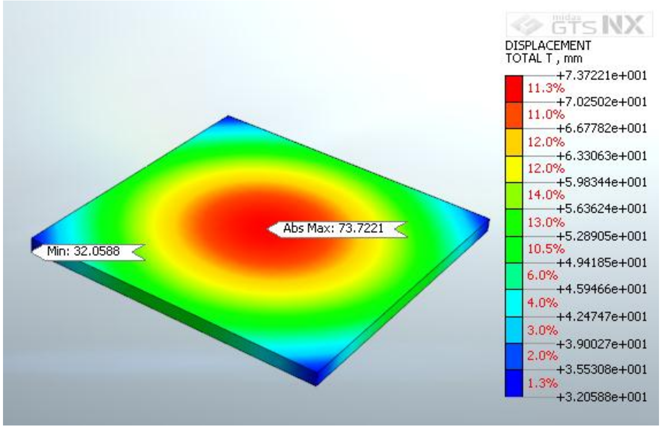

Figure 35:- Displacements of 90cm thickness raft without any piles.

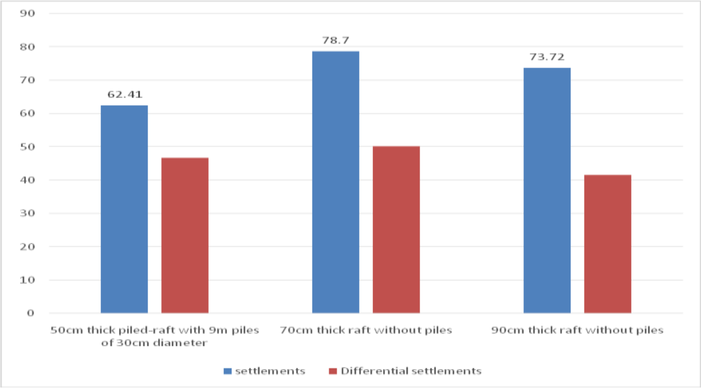

Figure 36:- Displacements of rafts of various thicknesses.

7. CONCLUSIONS

1. The introduction of piles irrespective of the raft thickness results in considerable decrease in the foundation settlements.

2. Use of piled raft can be used to reduce the settlements of the raft as well as the material resources by reduction in the raft thickness.
3. Midas GTS NX proves to be efficient software in the analysis of piled raft foundation with auser friendly interface and can aid in the analysis of complex problems.

8. FUTURE SCOPE OF WORK

1. The behaviour of the piled raft foundation can be analysed for the increments in the pressure load on the raft.
2. The foundation system can be analysed with a change in the number of piles and their different arrangements.
3. In the present study the settlements corresponding to a uniformly distributed pressure load were studied. The analysis can also be performed for the case where the load is acting at the location of structural columns.

REFERENCES

1. Poulos, H. G. "Piled raft foundations: design and applications'' *Geotechnique* 51, No. 2, 95-113 (2001).
2. W. Allen. Mark "Effective use of Finite Element Analysis in Geotech Engineering"
3. Goel Tarun, Sonthwal Vinod "A review on slope stability analysis by strength reduction method using MIDAS GTS" *International Journal of Innovative Research in Science, Engineering and Technology* Vol. 6, Issue 8, August 2017 (2017)
4. Poulos, H. G. "Methods of analysis of piled raft foundations'' *International Society of Soil Mechanics and Geotechnical Engineering* (2001)
5. Poulos H. G. "The piled raft foundation for the Burj Dubai – design and performance'' *IGS-Ferroco Terzaghi Oration* (2008)
6. E.Y.Oh, Huang M, Surarak C "Finite element modelling for piled raft foundation in sand" *EASEC-11, Taipei, Taiwan* (2008)
7. Poulos H.G., J.C. Small and H. Chow "Piled Raft Foundations for Tall Buildings" *Geotechnical Engineering Journal of the SEAGS & AGSSEA* (2011)
8. Koch Edina, Szep Janos, Ray Richard "Modeling of Combined Pile Raft Foundation by Midas-GTS and Axis 3-D Software" (2011)
9. Sharma V.J, Vansanvala S.A, Solanki C.H "Composite piled raft foundation with intermediate cushion in layered soil under seismic forces"*ComputationalMethods in Civil Eng*., Vol. 3, 2 (2012) 15-28 (2012)
10. Srilakshmi G, Moudgalya N S Darshan "Analysis of piled raft foundation using finite element method" *International Journal of Engineering research and science & technology* ISSN 2319-5991 Vol. 2, No. 3 (2013)
11. Nguyen Chung Dinh Dang, Jo Seong-Bae, Kim Dong-Soo "Design method of piled-raft foundations under vertical load considering interaction effects" *Computers and Geotechnics* Volume 47, January 2013, Pages 16–27 (2013)
12. Radhika. R, .Jeyapriya S.P, Soundrapandiyan P "Parametric Study and Numerical Analysis of Piled Raft Foundation on Soft Clay" *International journal for research in emerging science and technology,* volume-2, issue-4, April-2015 (2015)
13. Batali Loretta "Numerical modelling of piled raft foundations. Modelling particularities and comparison with field measurements*" International Conference on Soil Mechanics and Geotechnical Engineering*, Seoul 2017(2017)