Finite Element Analysis of Piled Raft Foundation

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***Abstract* -A piled raft foundation is fairly a new concept in which the total load coming from the superstructure is partly shared by the raft through contact with soil and the remaining load is shared by piles through skin friction. Due to the three dimensional nature of the load transfer, piled-raft foundations are regarded as very complex systems involving many interaction factors such as pile-to-pile, pile-to-raft, raft-to-soil and pile-to-soil. The foundation design becomes economical when both the criteria of bearing capacity and settlement are satisfied in an optimum way. In the case of sand the permissible settlement for the foundation is less than that of foundation resting on clay. Therefore the applicability of piled raft to support moderately loaded buildings on sand and predominantly sandy soils gains importance, further more understanding of load sharing between piles and raft is very much important for the piled raft in sand particularly when the piles are driven because the driving of piles improves the state of compaction of the sand. Even though lot of works has been carried out in piled raft, not much of a work has been carried out on the behavior of piled raft with varying pile length and in most of the conventional designs, piles in the foundation have uniform lengths. In case of plaza like structures wherein the raft thickness as well as the pile length can be varied depending upon the capacity requirements, it becomes necessary to understand the effect of variation in pile length on settlement reduction and load sharing behavior of piled raft.**

***IndexTerms* - ANSYS, Finite element method, Pile, Piled raft foundation, Raft, Settlement, Ultimate load.**

I. INTRODUCTION

One of the most important aspects of a civil engineering project is the foundation system. Foundation is the lower portion of the building, usually located below the ground level, which transmits the loads of the superstructure directly to the underlying soil or rock, resulting in a soil-structure interaction. The foundation method which is most suitable depends on the properties of the soil and the functional requirements of the building. Designing the foundation system carefully and properly, will surely lead to a safe, efficient and economic project overall. The foundation must satisfy two fundamental requirements. Firstly, it must provide an adequate factor of safety against failure of the supporting strata. Secondly, any resulting settlement, and in particular differential settlement, should not be detrimental or interfere with the function of the structure.

Foundations can be split into two main systems, shallow foundations and deep foundations. Shallow foundations are constructed relatively close to the ground level. Shallow foundations can only be used where the soil at that level is capable of adequately supporting the load. A deep foundation is used to transfer loads from a structure above ground through the upper weak strata of soil or through water, onto stiffer or a suitable hard bearing soils or rock. According to Terzaghi, a foundation is shallow if its depth is equal to or less than its width and deep when it exceeds the width. Until quite recently, these systems were used separately like shallow foundations such as rafts and deep foundations such as piles. These systems when implemented alone, will fulfill the designrequirements; however, in most cases they become over safe and economically not efficient. Furthermore, in some cases when being used alone they can cause some important problems. On the other hand, when the conditions are suitable, these systems can be combined and one can have a more efficient, safe and economical design. Thus, piled raft foundation system is one of those combined systems.

In designing raft foundations, engineers frequently encounter situations in which the bearing capacity of the raft is quite adequate, but the settlements are estimated to be excessive. In such cases, the combined use of a raft, along with a limited number of piles, could be an economical counter measure in which the piles are used to reduce the settlements to an acceptable level. A piled raft foundation is a new concept in which the total load coming from the superstructure is partly shared by the raft through contact with soil and the remaining load is shared by piles through skin friction. In conventional piled foundation, it is assumed that the raft does not carry any load even if raft is in contact with ground. Also in conventional piled foundation, as the contribution of raft is ignored, long piles are provided which extends up to the deep strata. On the other hand, if only raft has to carry the total load coming from the superstructure, very thick raft is needed which increase the cost of the foundation. In general, the raft alone can provide the required bearing capacity but it cannot control the settlement. Therefore, the piles are crucial to reduce the settlement of the raft. The behaviour of a piled raft foundation is affected by some factors like; the number of piles, spacing between piles, configuration of piles, diameter and length of piles, the nature of loading, raft thickness and applied load level. Some researches have been made on piled raft foundations giving special attention to these effects. The effectiveness of piled rafts 3 in reducing average and differential settlements has been confirmed not only on favorable ground conditions but also on unfavorable ground conditions with ground improvement techniques.

The combined system can be based on various design philosophies which can be classified as follows:

1. Concept of settlement reducing pile: In this philosophy, piles are located only to reduce the total settlement and for the piles, the factor of safety values against bearing capacity is taken as unity.

2. Piled raft concept: This is a newly adopted concept in which a significant portion of the total load is carried by the raft contrarily to the conventional design. Piles are designed to work at 70-80% of the ultimate load capacity.
3. Differential settlement control: In this philosophy, placing piles under the raft strategically, in a limited number, will enhance the ultimate load capacity of the foundation and decrease both the settlement and the differential settlement.

In traditional foundation design, it is customary to consider first the use of shallow foundation such as a raft. If it is not adequate, deep foundation such as a fully piled foundation is used instead. In the former, it is assumed that load of superstructure is transmitted to the underlying ground directly by the raft. In the latter, the entire design loads are assumed to be carried by the piles. In recent decades, another alternative intermediate between shallow and deep foundation, what is called piled raft foundation or settlement reducing piles foundation, has been recognized by civil engineers. Due to combining raft and piles in one system, piled-raft foundations are regarded as very 4 complex systems. The complexity of this type of foundations is caused by the presence of many interaction factors involved in the system such as pile-to-pile, pile-to-raft, raft-toraft and pile-to-soil interactions. Figure 1 shows various interaction factors involved in piled raft

II.SOFTWARE USED

Finite element method is considered to be the best tool for analyzing the structures recently many software's uses this method for analyzing and designing. The most popular and the easiest to learn is ANSYS software. It is a general purpose finite element modeling package for numerically solving a wide variety of mechanical problems. All users, from designers to advanced experts, can benefit from ANSYS structural analysis software. The fidelity of the results is achieved through the wide variety of material models available, the quality of the elements library, the robustness of the solution algorithms and the ability to model every product from single parts to very complex assemblies with hundreds of components interacting through contacts or relative motions. ANSYS FEA tools also offer unparalleled ease of use to help product developers focus on the most important part of the simulation process, understanding the results and the impact of design variations on the model.

Scope of study

The scope of this research based project is to understand the concept of piled raft foundation also to stimulate piled raft foundation usinf FEAto evaluate the deflection and deformmation developed under structural load conditions using different combination of piles. Also to determine the influence of pile length and pile shape . Piled raft foundation has a better scope for both research and applications in the field,

III STRUCTURE MODELLING

Modelling

ANSYS Version 14.5 was used to develop a three-dimensional finite-element model representing the sample. Model is as shown below. The number of piles are 16. Pile length is 3 m and 6m, thickness of raft is .6m and spacing of piles is 1.2 m which is kept constant. Outer Pile diameter all are 0.4 m and inner pile diameter are .5m . All the specimens are modeled in three dimensional spaces in ANSYS 14.5. The soil interaction volume is taken as cross section of 15.6m x 26mx26m.

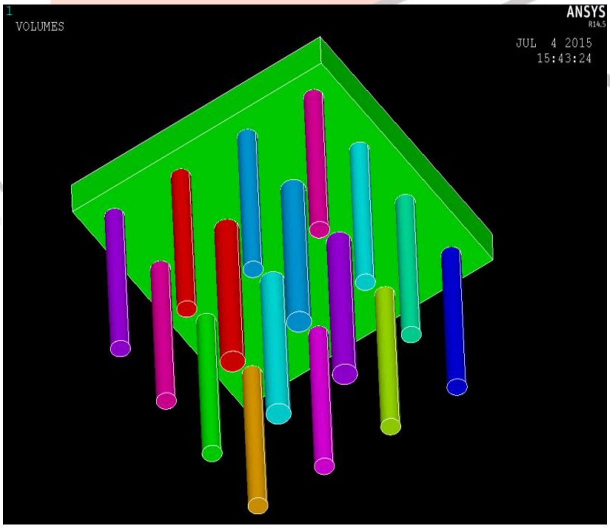


Fig.1. Conventional piled raft foundation

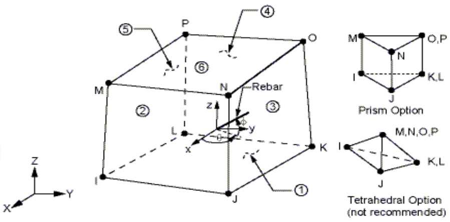
Table1. MATERIAL PROPERTIES

Properties	Piled Raft	Soil (Medium Sand)
E	$2.5*10^7$ kPa	$4*10^4$ kPa
μ	0.15	0.3
ρ	2500 kg/m^3	1900 kg/m^3
C	-	5kPa
Φ	-	35^o
ψ	-	10.5^o

IV . ELEMENT LIBRARY

SOLID65

SOLID65 is used for the 3-D modeling of solids with or without reinforcing bars (rebar). The solid is capable of cracking in tension and crushing in compression. The element is defined by eight nodes having three degrees of freedom at each node:translations in the nodal x, y, and z directions. Up to three different rebar specifications may be defined.



SOLID45

SOLID45 is used for the 3-D modeling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities.

TARGE170

TARGE170 is used to represent various 3-D "target" surfaces for theassociated contact elements .The contact elements themselves overlay the solid, shell, or line elements describing the boundary of a deformable body and are potentially in contact with the target surface, defined by TARGE170.

CONTACT174

CONTA174 is an 8-node element that is intended for general rigid-flexible and flexible-flexible contact analysis. In a general contact analysis, the area of contact between two (or more) bodies is generally not known in advance. CONTA174 is applicable to 3-D geometries. It may be applied for contact between solid bodies or shells.

CONTACT175

CONTA175 may be used to represent contact and sliding between two surfaces (or between a node and a surface, or between a line and a surface) in 2-D or 3-D. The element is applicable to 2-D or 3-D structural and coupled field contact analyses.

BEAM188

BEAM188 is suitable for analyzing slender to moderately thick beam structures . the element is based on Timoshenko beam theory which includes shear deformation effects . the element provides for unrestrained warping of cross sections

V. ANALYSIS RESULTS

Composite Square Piled Raft

Pile size is .4x .4m with a length of 3 m (outer pile) and inner piles have .5x,5 m size with a length of 6m .

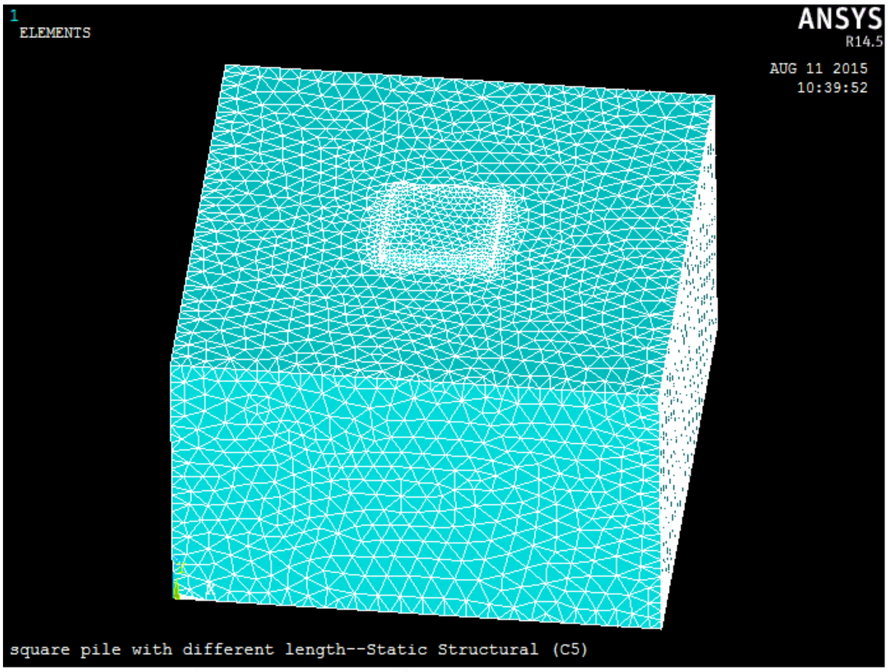


Fig.2.Meshed full model

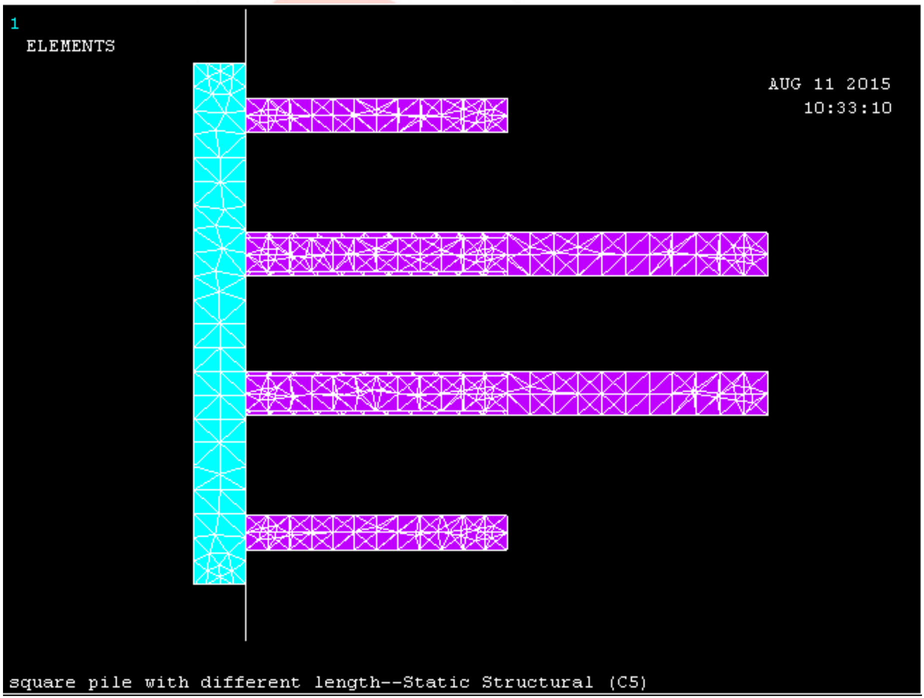


Fig.3.Meshed pile raft

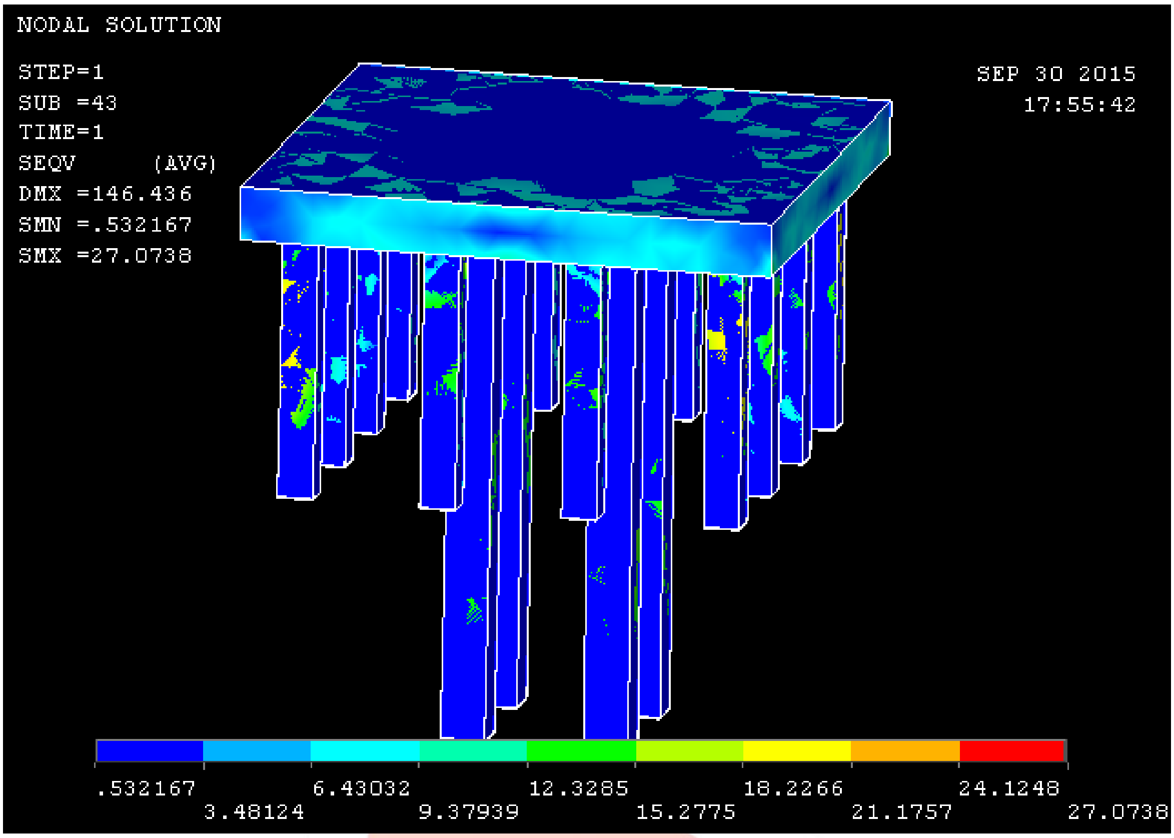


Fig.4.Pile raft stress

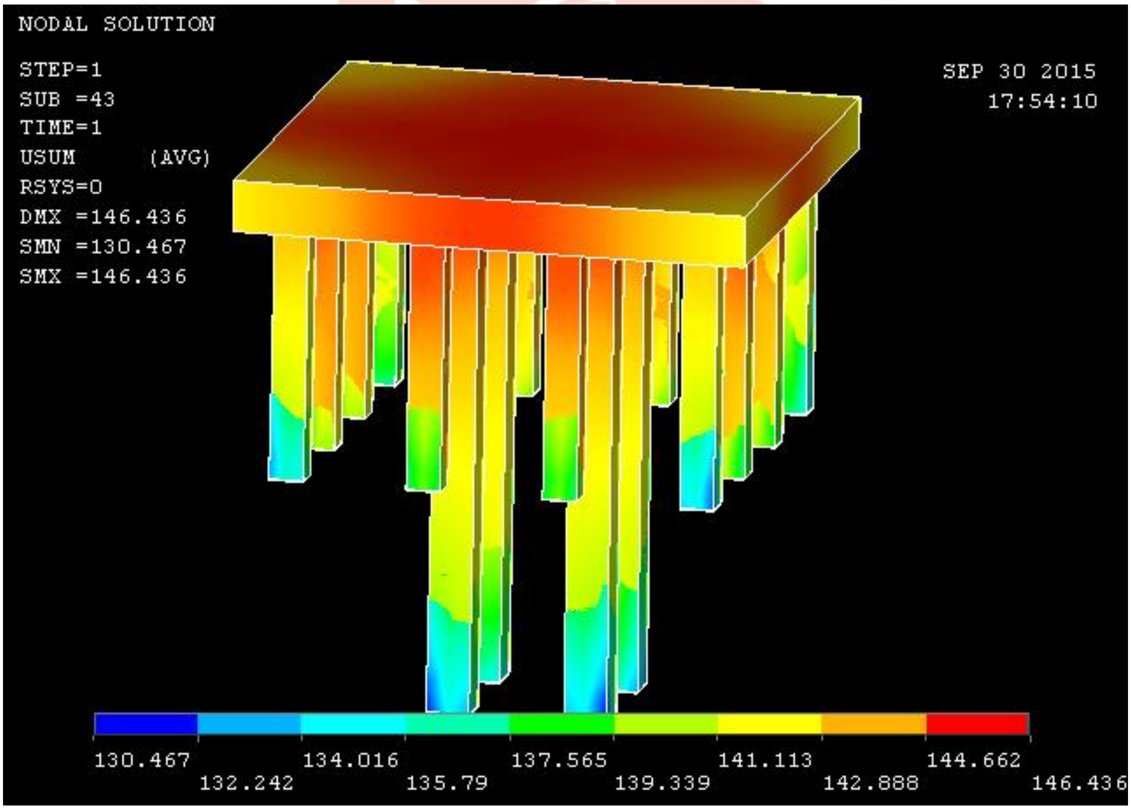


Fig.5.Pile raft total deformmation

Conventional Square Piled Raft

Pile size is .4x .4m with a length of 3 m (outer pile) and inner piles have .5x,5 m size with a length of 3m .

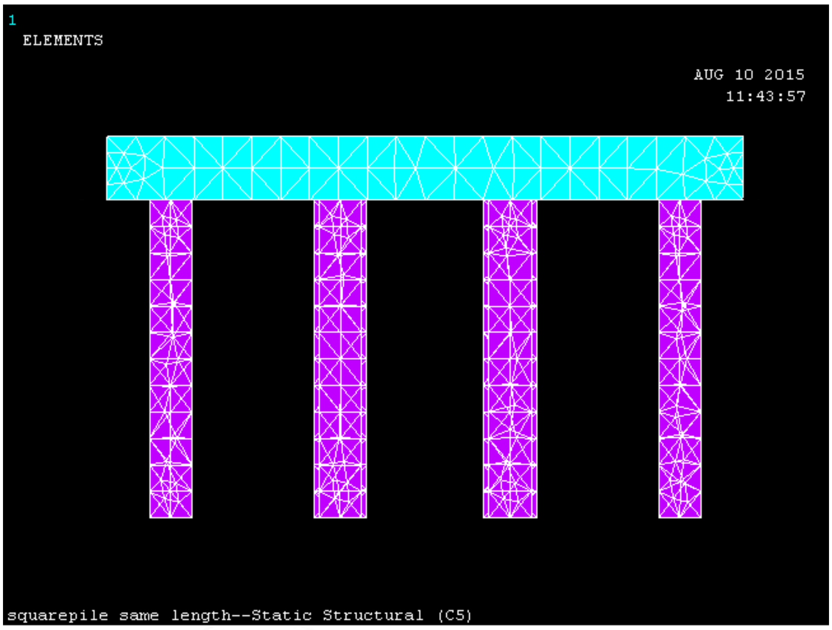


Fig.6. Meshed conventional piled raft

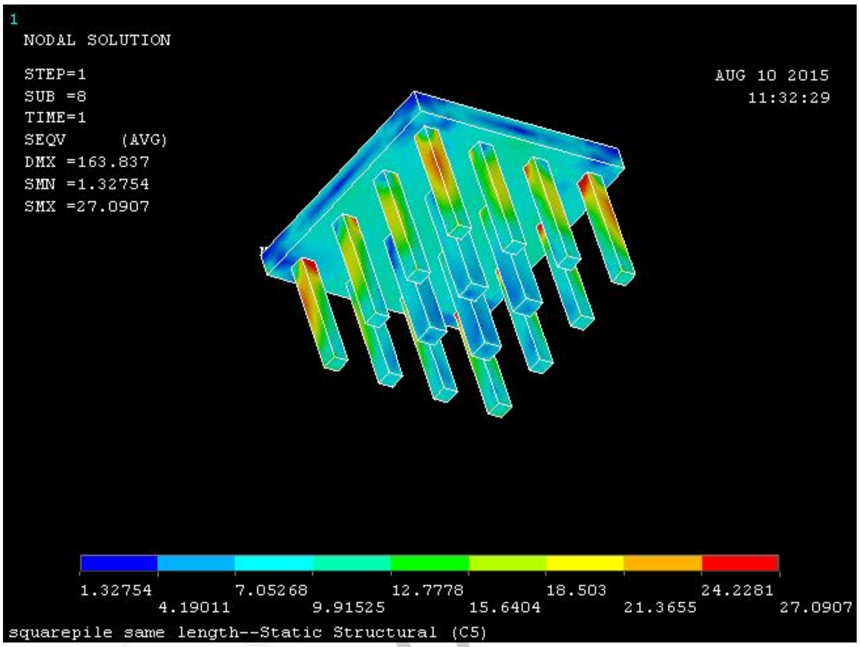


Fig 7 . Stress dig of piled raft

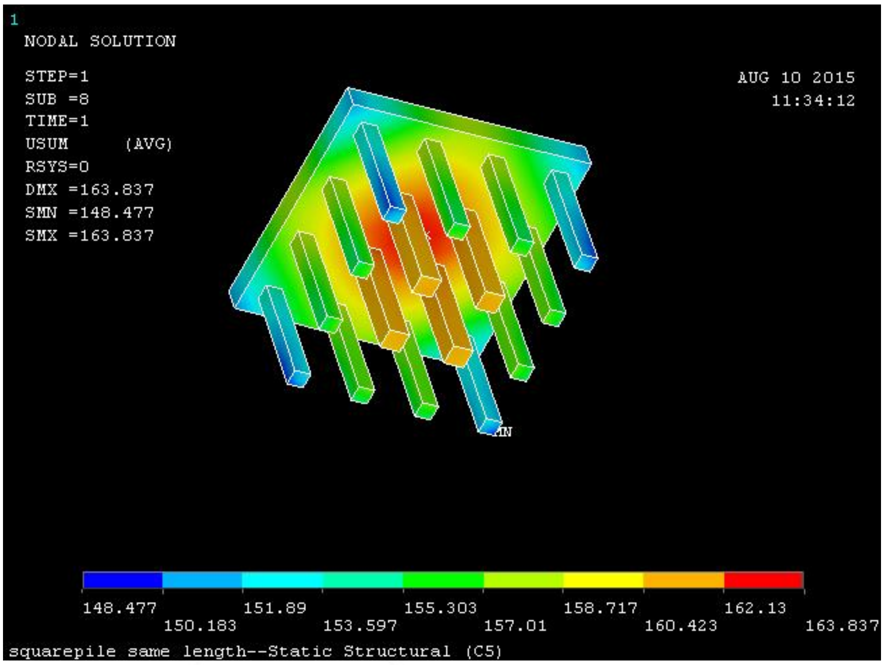


Fig 8 .Displacement dig of piled raft

Conventional Circular Piled Raft

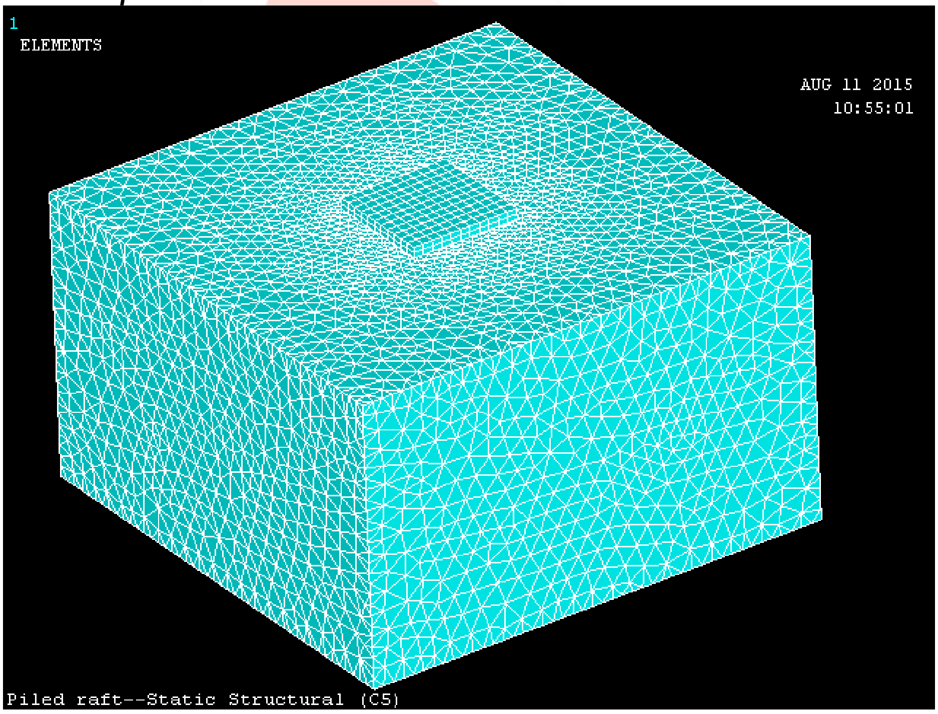


Fig 9. Meshed Diagram

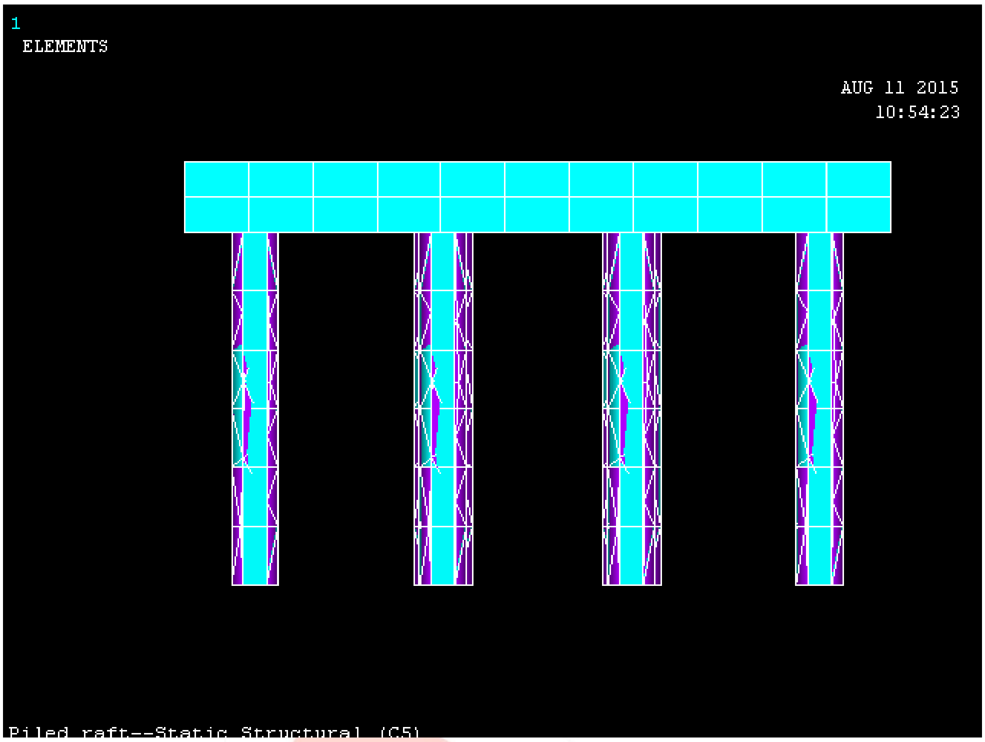


Fig 10. Meshed Diagram Of Piled Raft

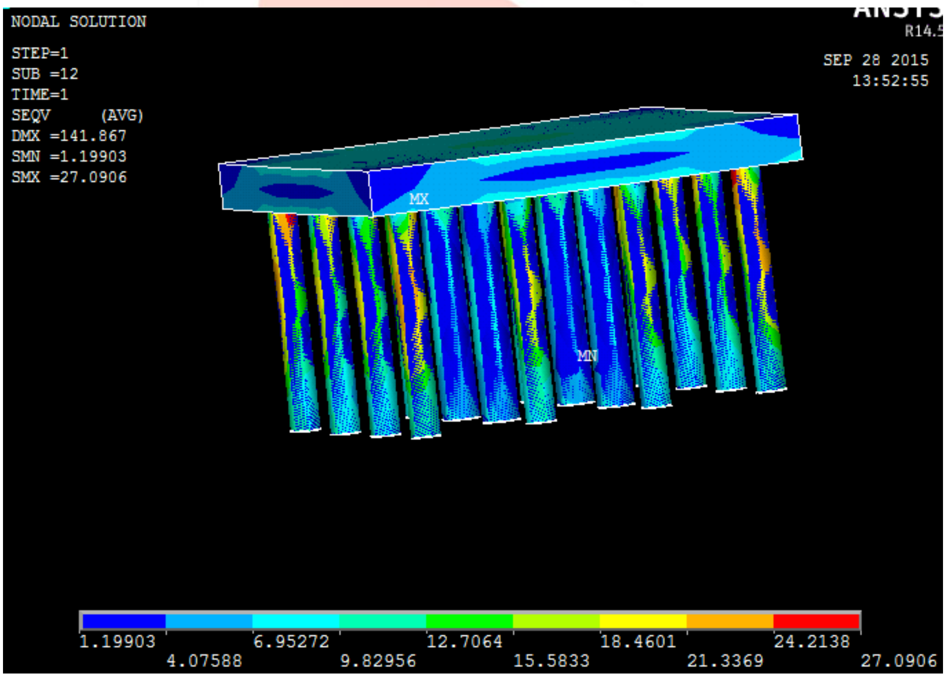


Fig 11. Stress dig of piled raft

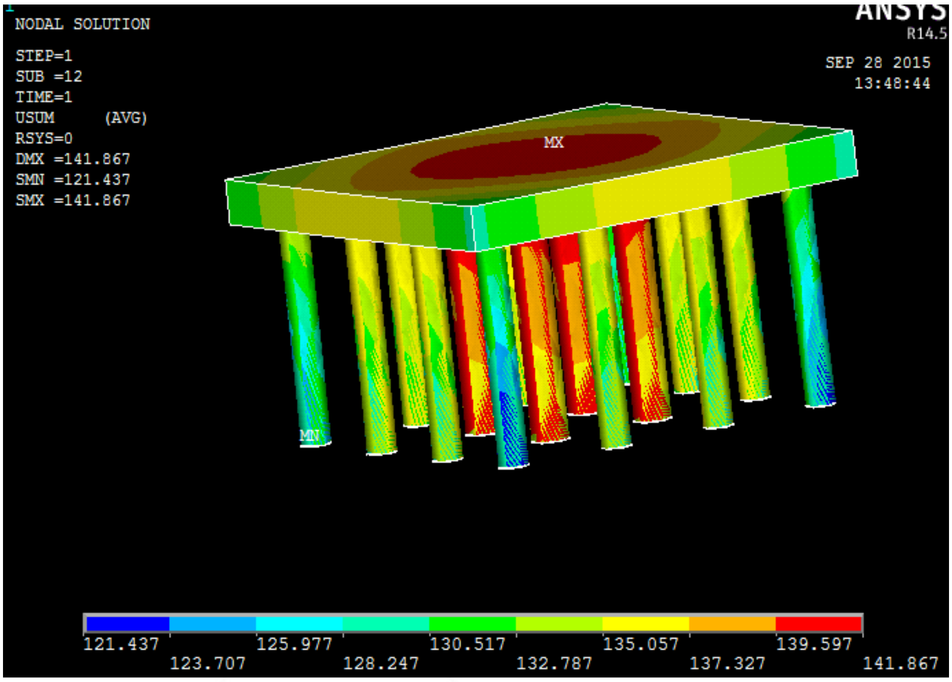


Fig 12. Displacement Dig Of Piled Raft

Composite Piled Raft

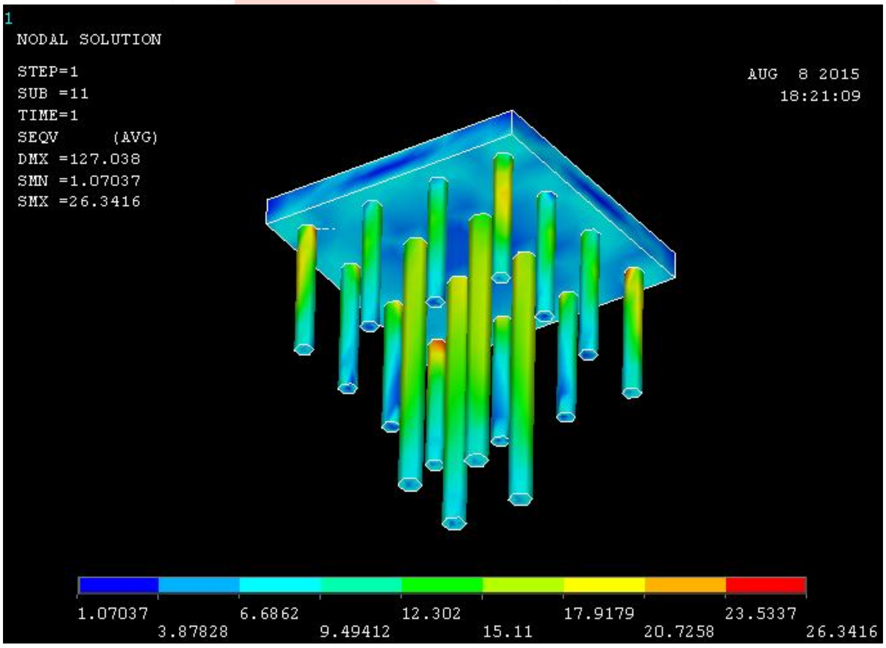


Fig 12. Stress dig of piled raft

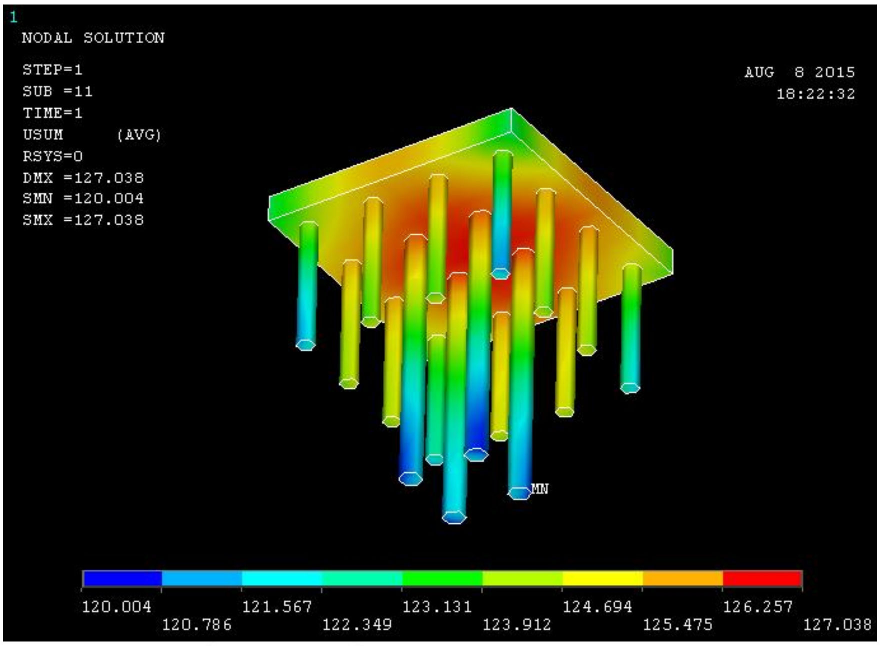


Fig 14. Displacement Dig Of Piled Raft

Table 3 Summary of analysis of piled raft foundation

Serial. No.	PILED RAFT COMBINATION	ULTIMATE LOAD	STRESS	DISPLACEMENT
1	CONVENTIONAL SQUARE PILE RAFT	5.84X10^7	27.0907	163.87
2	COMPOSITE SQUARE PILE RAFT	5.89X10^7	27.0738	146.999
3	CONVENTIONAL CIRCULAR PILE RAFT	4.95X10^7	27.0906	141.93
4	COMPOSITE CIRCULAR PILE RAFT	4.95X10^7	26.3416	127.038

VI. CONCLUSIONS

- A pile diameter combination of .5m and .4m is best suggested combination based on ultimate load and settlement . From it is clear that , providing larger inner pile diameter with smaller outer pile diameter leads to good results.
- Providing same length for both inner and outer pile increases settlement. Whereas providing shorter outer pile and longer inner pile reduces settlement.
- Providing square piles increases settlement whereas circular piles reduces settlement compare to square piles , therefore pile shape has much significance on ultimate load carrying capacity of foundation.

Hence ,the piled raft foundation has a better scope for both research and applications in the field

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REFERENCES

[1] M.Huang , C.Surarak And A.S. Balasurbamaniam (2008), "Finite Element Modeling For Piled Raft Foundation In Sand ", *Eleventh East Asia Pacific Conference On Structural Engineering And Construction (Easec-11*); Building A Sustainable Environment ;Taipei ;Taiwan Pp1-

[2] P.Wulandari(2009), 'Analysis Of Piled Raft Foundations In Clayey Soils Using Finite Element And Analytical Methods" ,*Journal Of Geotechnical And Geo Environmental Engineering* , Vol 127 No:1 Pp1024-1090

[3] Andre Ryltenius, "Fem Modeling Of Piled Raft Foundations In 2D And 3D", *Journal Of Geotechnical And Geo Envirnomental Engineering ,Vol 127,no:1,asce.Pp 17-24*

[4] Desai.A.K, Solanki C.H(2014)"*international Journal Of Advance Research In Science And Engineering , Vol No :3 Issue No:3 March 2014*

[5] A.Eslami ,M.Veiskarami.M.M.Eslami (2011) "Study On Optimized Piled Raft Foundations Performance With Connected And Non Connected Piles Three Case Histories " *International Journal Of Civil Engineering* .Pp1-12

[6] S.R.Gandhi, D.K.Maharaj(1998) "Pile Raft Foundation For Tall Buildings"*International Journal Of Earth Sciences And Engineering , Vol1 ,Pp 113-115*

[7] Zkaria Mohammed Omemam(2012), " Load Sharing Of Piled Raft Foundations In Sand Subjected To Vertical Loaads", *Science Verse Science Direct Ocean Engineering ,Vol.53.Pp153-163*

[8] G.Alireza Roshan ,Issa Shooshpasha (2014) "Numerical Analysis Of Piled Raft Foundations In Soft Clay ", *International Journal For Numerical And Analytical Methods In Geomechanics,vol 22,pp777-790*

[9] G.Srilakshmi and Darshan Moudgalya (2013), "Analysis Of Piled Raft Foundation using FEM ", *International Journal Of Engineering Research Science And Technology, Vol 2*

[10] Jean sebastian lebeau (2008) " The Behavior Of Piled Raft In Clay Soils" *science verse –science direct –ocean engineering* ,vol53,pp153-163

[11] Small J C and Zhang H H (2002), "Behavior of Piled Raft Foundations under Lateral and Vertical Loading", *The International Journal of Geo mechanics*, Vol. 2, pp. 29-45.

[12] Jaeyeon Cho, Jin-HyungLee, SangseomJeong and JaehwanLee (2012),"The Settlement Behavior of Piled Raft In Clay Soils", *Science Verse – Science direct- Ocean Engineering*, Vol. 53, pp. 153-163.

[13] Joseph E Bowles (1997), *Foundation Analysis and Design, McGraw- Hill Companies*, 5th Edition, New York.

[14] JinHyung Lee, Youngho Kim and Sangseom Jeong (2010), "Three-Dimensional Analysis of Bearing Behavior of Piled Raft on Soft Clay", *Science direct - Computers and Geotechnics*, Vol. 37, pp. 103-114.

[15] Luca de Sanctis and Alessandro Mandolini (2006), "Bearing Capacity of Pr on Soft Clays", *Journal of Geotechnical And Geo environmental Engineering*, Vol. 132, pp. 1600-1610.

[16] Seo, Y-K., Choi, K-s. and Jeong, S-G. 2003. Design Charts of Piled Raft Foundations on Soft Clay. Proceedings of The Thirteenth (2003) *International Offshore and Polar Engineering Conference,* Honolulu, Hawaii, USA, May 25-30. pp. 753-755.

[17] Oh E Y N, Huang M, Surarak C and Balasubramaniam A S (2008) , "Finite Element Modeling For Piled Raft Foundation in Sand", *Eleventh East Asia-Pacific Conference on Structural Engineering & Construction (EASEC-11) ; Building a Sustainable Environment*; *Taipei; Taiwan*, pp. 1-8.

[18] Emilios M Comodromos, Mello C Papadopoulou and Ioannis K Rentzeperis (2009), "Pile Foundation Analysis and Design Using Experimental Data And 3-D Numerical Analysis", *Science direct - Computers and Geotechnics*, Vol. 36 , pp. 819-836

[19] Srilakshmi G and Chethan Gowda R K (2012), "Analysis of Piled raft foundation by Finite Element method", *Dissertation report to VTU Belgaum*

[20] Srilakshmi G and Rekha (2011), "Analysis of Mat Foundation Using Finite Element Method", *International Journal of Earth Sciences and Engineering*, Vol. 4, pp. 113- 115.

[21] Poulos H G, Small J C and Chow H (2011), "Pile Raft Foundation For Tall Buildings",*Geotechnical Engineering Journal of the SEAGS & AGSSEA*, Vol. 42, pp. 78-84