JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

COMPARATIVE ANALYSIS OF RAFT, PILE & PILED RAFT FOUNDATION USING SAFE SOFTWARE

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Abstract : Raft foundation is essentially a continuous slab resting on the soil that extends over the entire footprint of the building, thereby supporting the building and transferring its weight to the ground. A pile foundation a series of columns constructed or inserted into the ground to transmit loads to a lower level of subsoil. A pile is a long cylinder made up of a strong material, such as concrete. Piles transfer the loads from structures to hard strata, rocks, or soil with high bearing capacity. Piled raft foundations is a combination of pile with raft slab. They are typically used for large structures, and in situations where soil is not suitable to prevent excessive settlement. A raft foundation is often used when the soil is weak, as it distributes the weight of the building over the entire area of the building, and not over smaller zones (like individual footings) or at individual points (like pile foundations). This reduces the stress on the soil. Pile foundation is needed in areas where the structures constructed are large & heavy and the soil underlying is weak. In areas where settlement issues are common due to soil liquefaction or water table issues, pile foundation is a better choice. Pile raft foundations can help transfer loads through weak, compressible strata or water onto stronger, more compact, less compressible and stiffer soil or rock at depth. The addition of piles to a raft increases the effective size of a foundation and can help resist horizontal loads.

The analysis of raft, pile and piled raft foundation is been carried out on a G+20 residential structure by using structural software safe 16. Seismic analysis of building is done for a zone factor II earthquake. The paper on studying the G+20 structure for pile, raft and piled raft, it has been observed that the pile raft foundation has reduced the settlement as compared to the raft foundation and it has less upward soil bearing load as compared to the pile foundation.

***IndexTerms*- Settlement, soil bearing pressure, superimposed load ,stresses, Piles with Raft foundation**

I. INTRODUCTION

Superstructures are supported by foundations, which move their load to a layer of soil or rock with ample bearing power. In most cases, a pile or raft base is used. A combined pile raft base, on the other hand, is a hybrid form of foundation in which some of the load is carried by the pile and the rest by the raft. When the total area covered by the column is greater than 75%, a raft base is used to move the load from the superstructure to the soil in the form of a continuous slab. Pile is a cylinder-shaped, strong material made of concrete and steel that transfers load from the superstructure to hard strata at a specific level below the ground surface. The ultimate loading of the structure is taken by the raft foundation; when the ultimate loading is taken by the raft, the allowable value for differential settlement in the raft rises. To minimise differential settlement, piles are embedded in the raft foundation. As a result, in a combined pile raft base, the raft foundation bears the overall load of the structure while the pile foundation reduces settlement. A mixture of shallow and deep foundations may also be a cost-effective construction strategy.

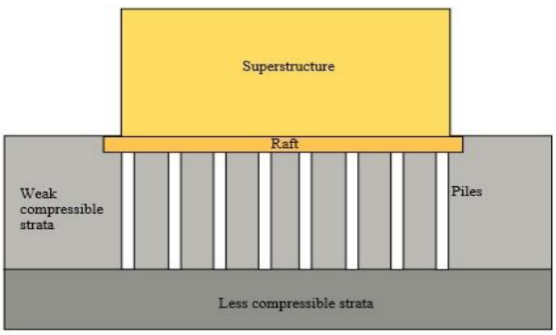

Fig 01: Piles with raft foundation.

II. PROBLEM STATEMENT

Many High rise structure has a big problem related to the foundation because of external forces acts on it like earthquake and continuous winds. But nowadays there is also a major problem related to the construction is availability of space. High rise building require more strong foundation. Raft foundation when designed for tall buildings require more area of land. Which becomes unsuitable of construction. Soil condition also have a major impact on type of foundation. So for a design of G+20 storey structure a foundation is required which not only requires less space but also reduce the settlement of structural foundation. Pile foundation when used it has a major issue of Grouping of piles. For a particular column the group of pile is to be designed. But when the load of column increases the number of piles in the group also increase which creates the problem of asymmetric pile cap location and overlapping of piles. These issues makes the pile foundation unsuitable for a structure where the distance between columns is less. For such condition the pile raft foundation is considered where the total number of columns and their total load is combined and the for that total load the number of piles are designed. Here the distance between the piles centre to centre is equal and more number of piles can be placed within the permissible space. That is why the pile raft foundation is more suitable for a structure with less ground space for foundation and distance between column is less.

In this for pile foundation a total number of 301 piles are placed at a distance of 1450mm and more to reduce the overlapping of piles. But in Pile raft a total of 361 piles are placed with a centre to centre distance of spacing to be 1450mm without overlapping for a pile dia of 500mm.

III. METHOD OF MODELLING AND ANALYSIS

To examine the behaviour of piled raft foundation ETABS 2018 and SAFE-16 is used. First Investigation of the site location is done where the bearing capacity of soil is 100 kN/m^2 and taking the SBC of soil in that area and study of the properties of the soil is done. Using ETABS software the 20 storey building is analysed then by importing the super structural loads using the SAFE software the raft foundation, Pile foundation and Piled raft foundation is modelled and analysed.

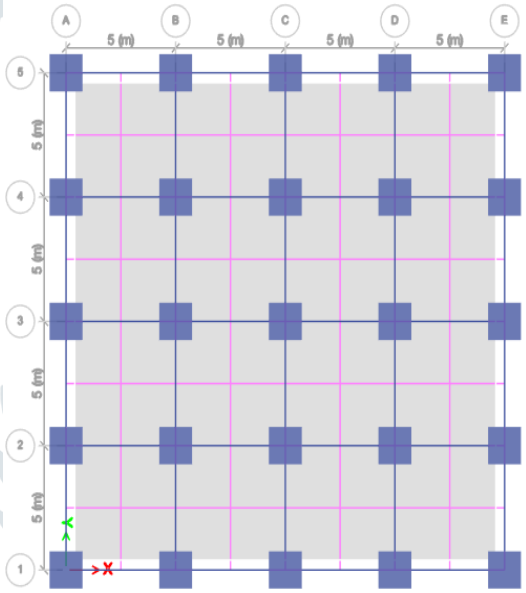

Fig 02: Plan Of structure.

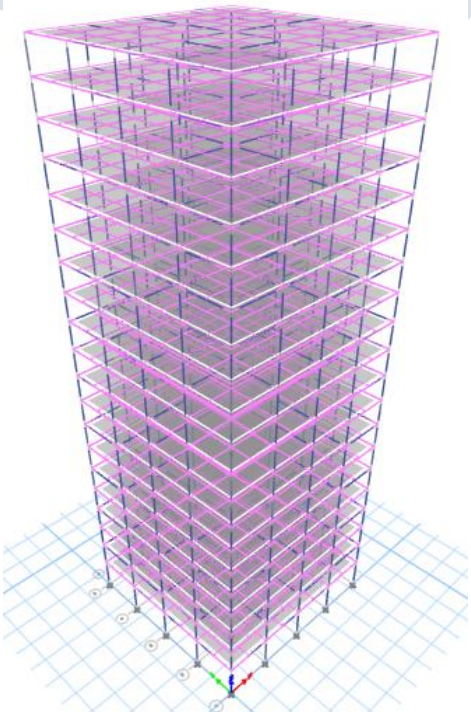

Fig 03: 3D Model Of Structure.

A) MATERIAL PROPERTIES

Plan of Building:- 20m X 20m
Total Height of Building:- 60m
Floor Height:- 3m

B) MATERIAL PROPERTIES

Grade of Concrete:- M25
Grade of Steel:- Fe500

C) SECTION PROPERTIES

Beam:- 300mm X 500mm
Column:- 1500mm X 1500mm
Slab:- 150mm
Pile size:- 500mm
Thickness of Raft:- 1500mm
Thickness of Raft of Pile raft:- 1000mm
Thickness of Pile cap:- 1000mm
Distance between piles:- 1450mm
Depth of Pile 10m

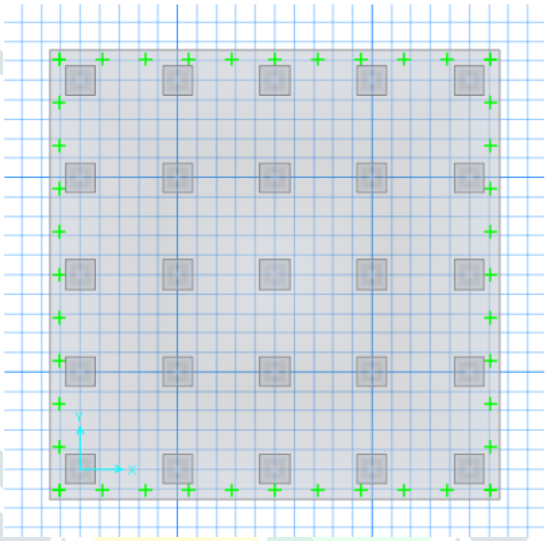

Fig 04: Finite Element Model of Raft Foundation

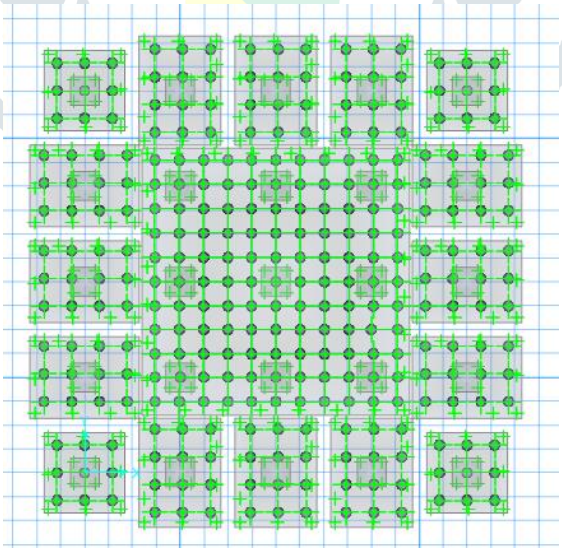

Fig 05: Finite Element Model of pile Foundation

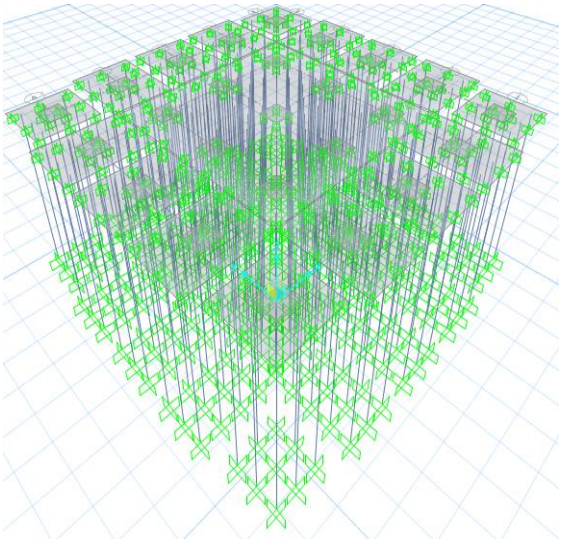

Fig 06: 3D model of Pile Foundation

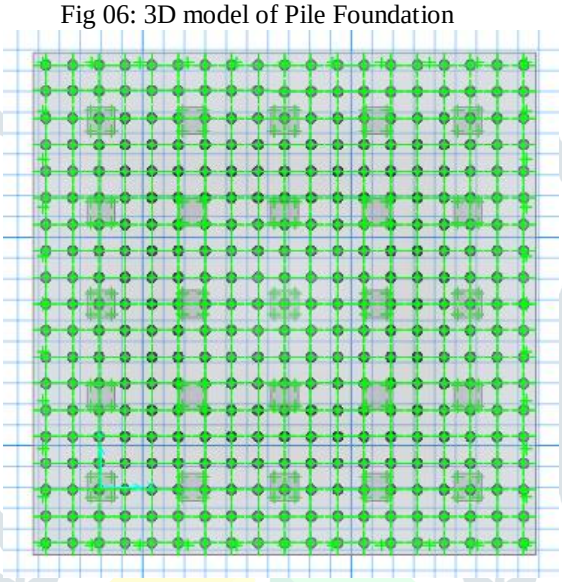

Fig 07: Finite Element Model of pile raft Foundation

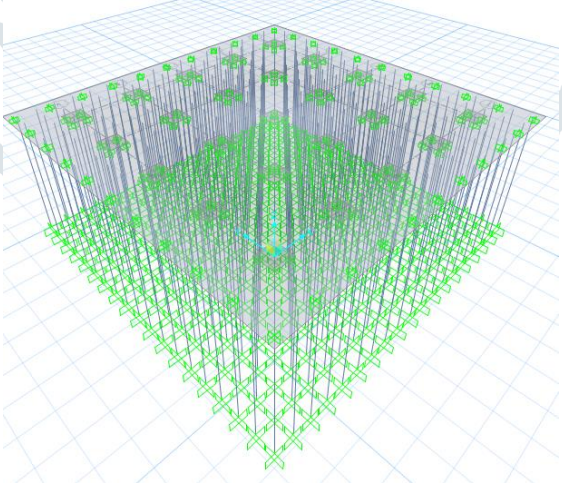

Fig 08: 3D model of Pile Raft Foundation

D) SUPPORT PROPERTIES

Soil Subgrade Properties
SBC of Soil:- 100 kN/m^2
Subgrade Modulus (Compression) :- 5X10^3 kN/m^3

E) MODEL LOADING

This section provides model loading information, including load patterns, load cases, and load combinations.

Load Pattern

1) DEAD LOAD
2) LIVE LOAD
3) EQ IN X Direction
4) EQ IN Y Direction

Load Calculation

1) Wall Load

0.23 m (thickness of wall) x (3-0.45) m (height of storey-depth of beam) x 20 kN/m^3 (density of brick) = 11.73 kN/m

2) Slab Load

25 kN/m^3 (density of Concrete) x 0.15m (thickness of slab) = 3.75 kN/m^2

Adding Floor Finish 1.5 kN/m^2

3) Live load:- 3 kN/m^2

4) Seismic parameters

Seismic Zone Factor (Z) = II =(0.1)
Response Reduction Factor = 5 Special moment resting frame (SMRF)
Site Factor = II
Importance Factor = 1

Load Combination

1) LOAD COMB 101 1.5(DL+LL)
2) LOAD COMB 102 1.5(EQX+DL)
3) LOAD COMB 103 1.5(-EQX+DL)
4) LOAD COMB 104 1.5(EQY+DL)
5) LOAD COMB 105 1.5(-EQY+DL)
6) LOAD COMB 106 1.2EQX+1.2DL+1.2LL
7) LOAD COMB 107 -1.2EQX+1.2DL+1.2LL
8) LOAD COMB 108 1.2EQZ+1.2DL+1.2LL
9) LOAD COMB 109 -1.2EQZ+1.2DL+1.2LL
10) LOAD COMB 110 .9DL+1.5EQX
11) LOAD COMB 111 .9DL-1.5EQX
12) LOAD COMB 112 .9DL+1.5EQY
13) LOAD COMB 113 .9DL-1.5EQY
14) LOAD COMB 201 (DL+LL)
15) LOAD COMB 202 (EQX+DL)
16) LOAD COMB 203 (-EQX+DL)
17) LOAD COMB 304 (EQZ+DL)
18) LOAD COMB 305 (-EQZ+DL)

IV. RESULT AND DISCUSSION

1) Settlement of Foundation

For Raft Foundation

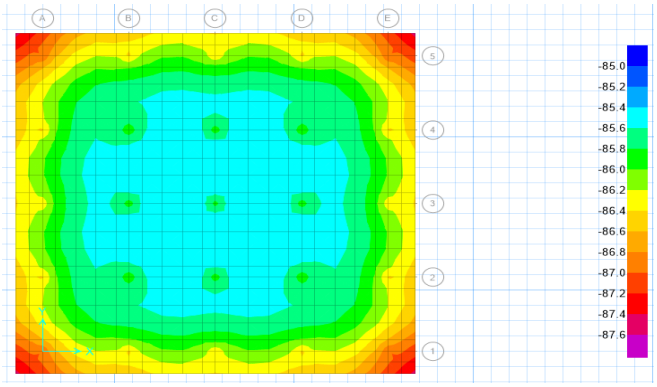

Fig 09: Raft foundation Settlement

The permissible limit of Settlement of mat foundation as per IS 456:2000 is 60mm to 100mm in clay soil. The result obtained from the settlement deformed shape shows that the maximum settlement is 87.6mm and at the corners of the MAT slab

For Pile Foundation

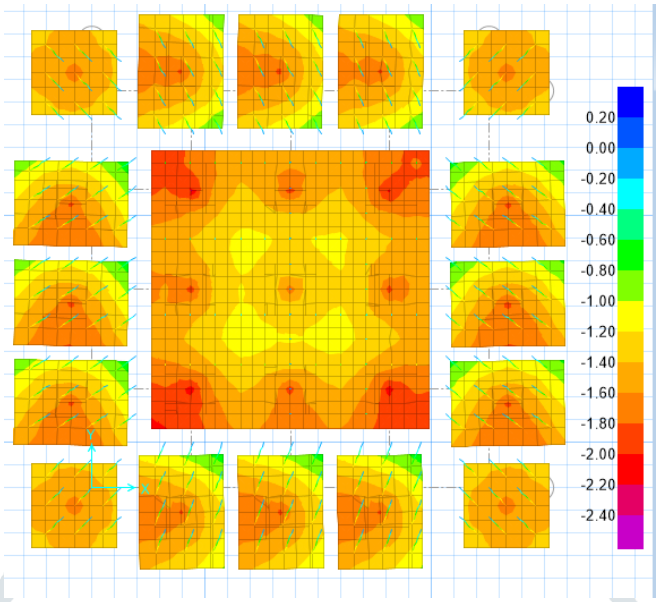

Fig 10: Pile foundation Settlement

The permissible limit of settlement of pile foundation As per IS 456:2000 is 2% of the dia of pile in clay soil The permissible limit for 500mm dia. pile will be 10mm. The result obtained from analysis shows that the settlement is below 2mm.

For Pile Raft Foundation

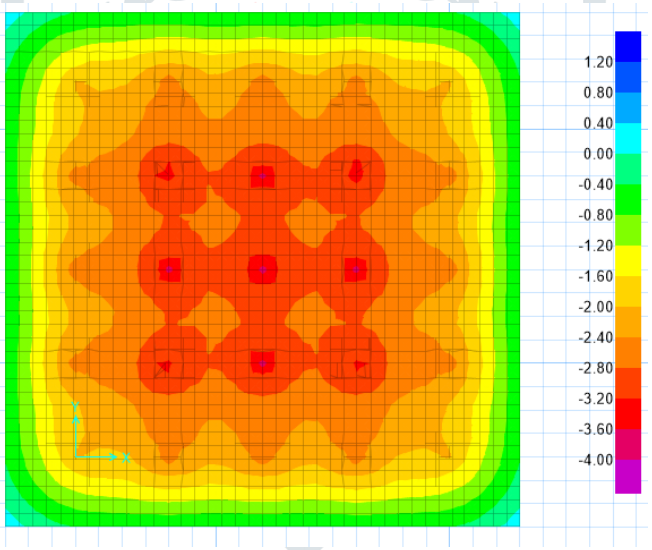

Fig 11: Pile Raft foundation Settlement

Here the overall settlement of the piled raft foundation is less than 4 mm so the foundation doesn't have more settlement and is under the permissible limits

Table 1:- Settlement of Foundation.

Sr. No.	Type of Foundation	Settlement	Permissible settlement
1	Raft Foundation	87.6mm	60mm
2	Pile Foundation	2mm	10mm
3	Pile Raft Foundation	4mm	10mm

As seen from above table the pile and pile raft foundation are in the permissible limit but the raft foundation has settlement more than the permissible limit.

2) Soil Pressure Reaction.

For Raft Foundation

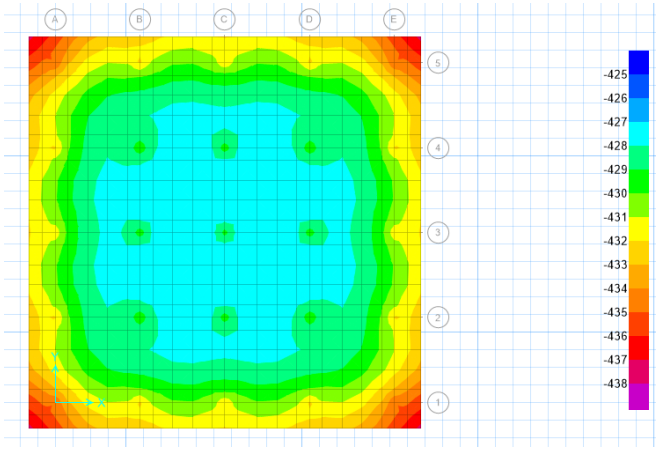

Fig 12: Raft foundation Soil Pressure Reaction

As we assumed the SBC of soil To be 100kN/m2 so the upward pressure exerted by the soil is 100kn/m^2. The allowable pressure for the safe design of foundation should be below 100kN/m^2 but the pressure is more than 400kN/m^2. So raft foundation is unsafe in soil pressure.

For Pile Foundation

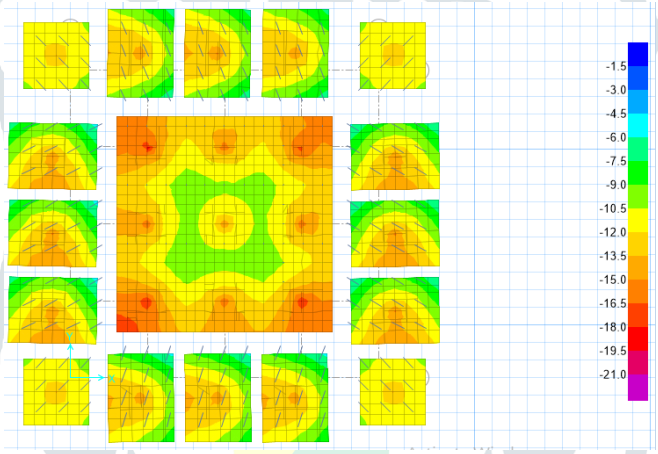

Fig 13: Pile foundation Soil Pressure Reaction

The allowable pressure for the safe design of foundation should be below 100kN/m2 and the result is found to be below 20kN/m2

For Pile Raft Foundation

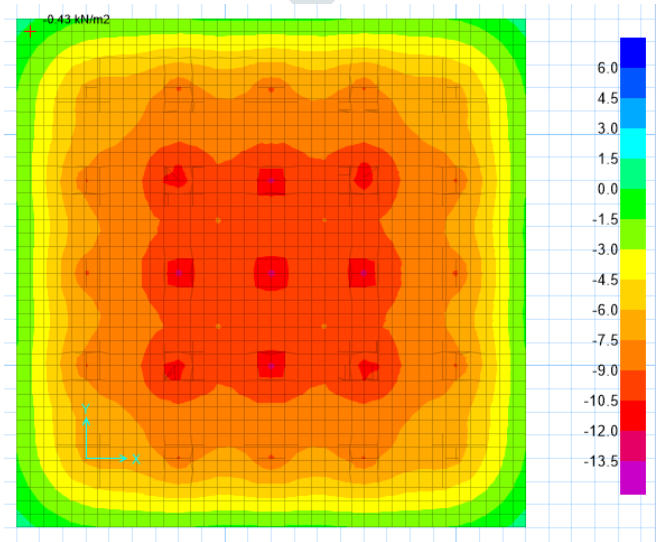

Fig 14: Pile Raft foundation Soil Pressure Reaction

The allowable pressure for the safe design of foundation should be below 100kN/m2 and the result is found to be below 15kN/m2

The Soil upward pressure reduces as the load of the structure is completely transferred by piles and the raft only governs the settlement of the structure in soil

Table 2:- Soil Pressure Reaction

Sr. No.	Type of Foundation	Soil upward pressure	SBC of Soil
1	Raft Foundation	400 kN/m^2	100kN/m^2
2	Pile Foundation	20 kN/m^2	100kN/m^2
3	Pile Raft Foundation	15 kN/m^2	100kN/m^2

Here Raft foundation has soil upward pressure more than the SBC of soil, whereas the pile and pile raft foundation has the soil upward pressure below the SBC of soil. But the pile raft has lower soil pressure than pile foundation which gets reduced because of the pressure of combine raft in pile raft foundation.

3) Punching Shear

For Raft Foundation

For the safe design of the foundation the punching shear ratio should be 1 or less than 1.The analysis result were found that the Punching shear has the ratio of less than 0.72. So the foundation is safe in punching shear

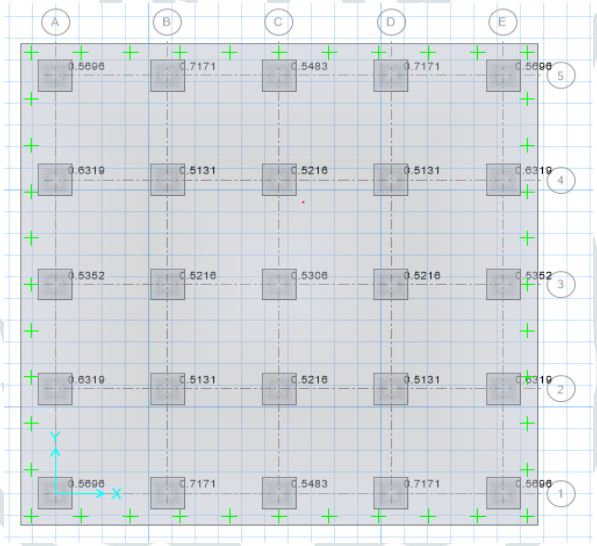

Fig 15: Raft foundation Punching Shear

For Pile Foundation

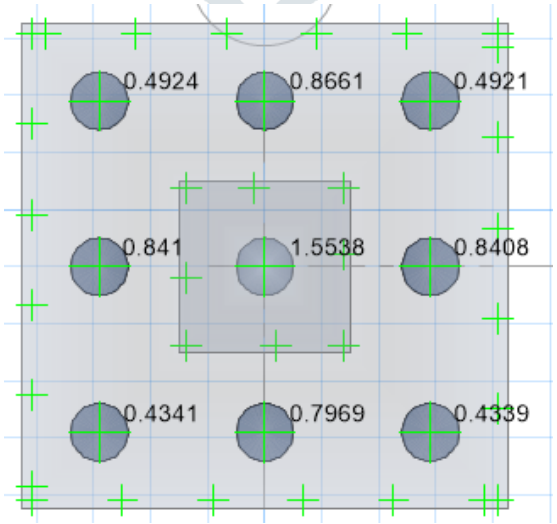

Fig 16: Pile foundation Punching Shear for 9 pile group.

Here the punching shear for pile is less than 1 for but when pile is just below the column the punching shear ration is more than 1

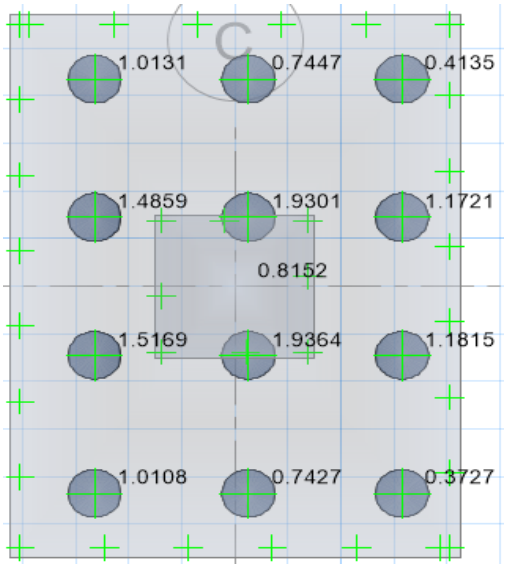

Fig 17: Pile foundation Punching Shear for 12 pile group

Here the punching shear for pile is more than 1 for but pile cap is less than 1

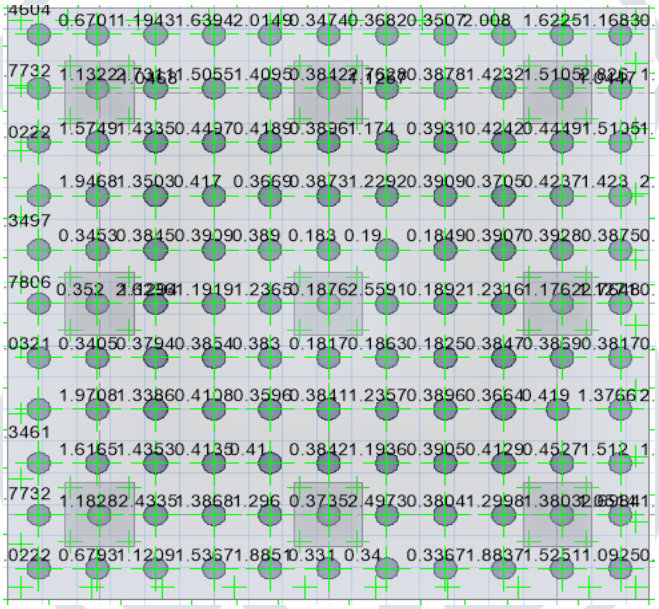

Fig 18: Pile foundation Punching Shear for 121 pile group

Here the punching shear for all the piles are different and are in the range of 0.2 to 2
In pile foundation two types of punching shear is checked. One is by the column to the pile cap and other is by the pile to the pile cap.
The location where the pile is just below the column have added punching shear which comes to be more than 1. But for all the other piles the punching shear for the piles are less than 1.
For Pile Raft Foundation

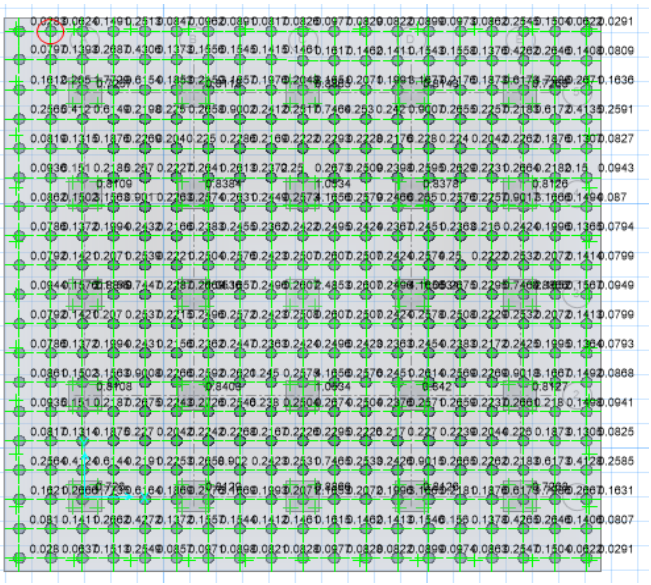

Fig 19: Pile raft foundation Punching Shear for 361 pile

Here the overall punching shear ratio for Maximum number of piles is less than 1 from the analysis of the punching shear the shear reinforcement in the piled raft foundation is not required in design.

Table 3:- Punching shear ratio

Sr. No.	Type of Foundation	Max. Punching shear ratio	Permissible ratio
1	Raft Foundation	0.72	1
2	Pile Foundation	2	1
3	Pile Raft Foundation	1	1

From the above table it is shows that the raft and pile raft foundation has less punching shear values as compared to the pile foundation. The pile foundation fails in the punching shear ratio check.

V. CONCLUSION

As opposed to a single pile foundation or a Raft foundation, the Pile with Raft foundation is more cost effective. When piles are added below the raft in the current work piled with raft base, the load sharing of pile and raft results in gradual reduction of soil settlement. Using SAFE tools to analyse the foundation of a multi-story residential house, we have come to the conclusion that:

• The raft foundation fails in the settlement condition and has settlement above the permissible limit.

• Pile foundation fails in punching shear as the punching shear ration of pile was found be more than 1 and it was around the ratio of 2

• In soil bearing pressure the raft foundation was having the 4times the upward soil pressure than the SBC of soil. Whereas the pile foundation and pile raft were having low upward soil bearing pressure. Here also the pile has more bearing pressure than pile raft foundation.

• From the overall results it was concluded that the pile raft foundation is safe in all the criterias whereas the raft and pile fails in either condition.

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