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Comparative Study of Different Types of Combined Footing for Small Residential Building

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Abstract—*Foundation is one of the most important part of any structure, whether it be a light weight structure or heavy; like a simple house or a skyscraper, all require appropriate type of foundation. In case of heavy structures deep foundations are used (since top soil does not have sufficient strength to support it), whereas small structures utilise shallow foundation (due to low weight of structure). In India small houses (compared to residential apartment) of three story or less are most common dwelling for residents. The modern houses being constructed are mostly using RCC frame structure with shallow foundation (Isolated, combined or both). These foundations are usually constructed based on prior experience of the mason, that is why they are mostly constructed with easiest geometry (i.e., rectangular and square), rather than best suited as per structural analysis or economy (i.e., rectangular, square, circular, trapezoidal, etc.). In this paper a combined footing beneath two columns is analysed with three different geometry (rectangular, trapezoidal and strap) in CSi SAFE software. Dead load is calculated as per IS 875(Part I): 1987, live load as per IS 875 (Part II): 1987, design is done as per IS 456: 2000, IS 1904: 1986 and IS 1080: 1980. Seismic load is not considered as does not give highest value of load combination as per IS 875 (Part V): 1987. The software does analysis using Finite Element Method (FEM) to simulate various results such as bending moment, one-way shear, two-way shear, settlement, etc. and gives the value of reinforcement required as per above mentioned codes. These all factors combined make for the basis of this study.*

Keyword: *Bending moment, One-way shear, Two-way shear, Settlement, CSi SAFE software.*

1. INTRODUCTION

A small residential building (usually one or two stories tall), is the most common dwelling for people in India. Traditionally these structures were made of various different types of materials (like stone, brick, timber, etc.) depending upon its local availability, but now a days reinforced cement concrete (RCC) is becoming more common in all places. These type of RCC structures are anchored to earth using shallow foundations (since they are light structures). There is various type of shallow foundations that are used, like isolated footing, combined footing, matt/raft footing, etc. combined footing is further subdivided (as per geometry) into rectangular combined footing, trapezoidal combined footing, irregular shaped or it can be a strap footing.

A combined footing is one that is provided as a single footing below two or more columns. If it is provided under all the columns then it becomes matt footing. The most common use of combined footing is under two columns only as rectangular, trapezoidal, or strap footing; whichever best suits the situation. Hence it becomes important to better understand how the above-mentioned combined footing behave when put under same type of conditions (like soil bearing capacity, dead load, live load, spacing between columns, position of column, etc.). For comparison factors such as soil reaction, punching shear, settlement, etc. can be used. For the purpose of this paper two column system with these three types of combined footings are used and are analysed using Finite Element Method in CSi SAFE software.

2. OBJECTIVES OF WORK

A. To study the behaviour of different types of combined footing under similar loading and soil condition as per IS 875(Part I): 1987, IS 875 (Part II): 1987, design is done as per IS 456: 2000, IS 1904: 1986 and IS 1080: 1980.
B. To evaluate the values of soil reaction, punching shear and settlement. for all three types of foundation
C. To compare the maximum and minimum values of soil reaction, punching shear and settlement.

3. DESCRIPTION OF MODEL

1.	Size of columns	300x300 mm
2.	Spacing between columns	3 m
3.	Basic properties: a) Material • Grade of concrete used • Rebar • Soil bearing capacity	 M20 HYSD500 180 KN/m^2
4.	Depth of foundation	700 mm

5.	Live loads ● Column 1 (C1) ● Column 2 (C2)	 250KN 200KN
6.	Dead loads ● Column 1 (C1) ● Column 2 (C2)	 400KN 350KN
7.	Load combinations ● Service normal ● Strength (Ultimate)	 LL+DL (LL+DL) *1.5

4. MODELLING

MODEL 1: Rectangular Combined Footing

MODEL 2: Trapezoidal Combined Footing

MODEL 3: Strap Footing

Modelling done with the help of CSi SAFE software.

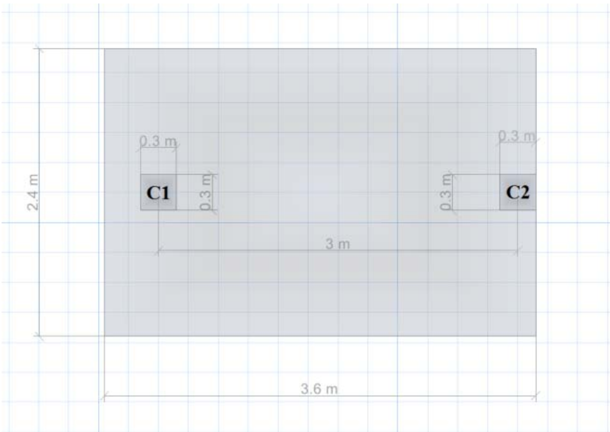


Figure 1. Plan view of model 1

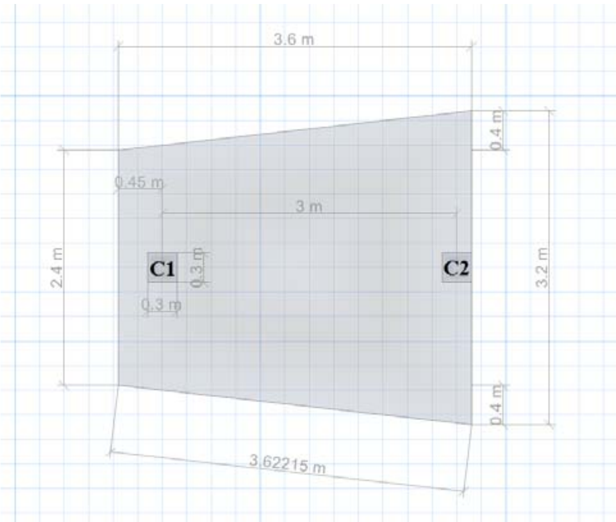


Figure 2. Plan view of model 2

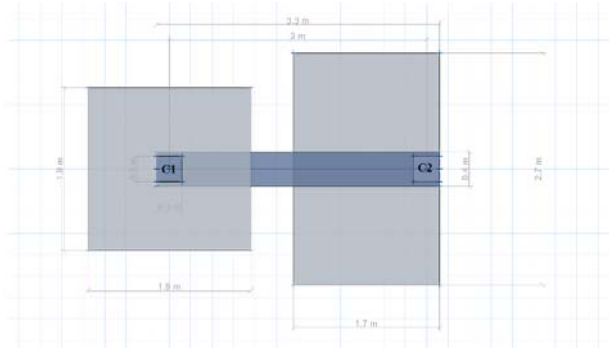


Figure 3. Plan view of model 3

5. ANALYSIS

5.1 Soil Reaction

Soil reaction is the upward thrust needed to be provided by the soil so as to support the weight of the structure acting on it through the foundation. Its value must be less than the soil bearing capacity at the place.

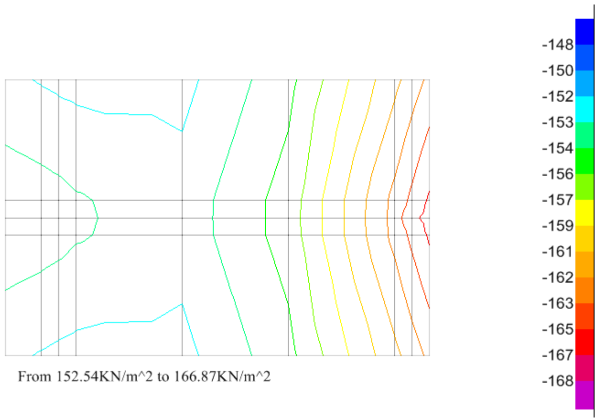


Figure 4. Soil Reaction for model 1

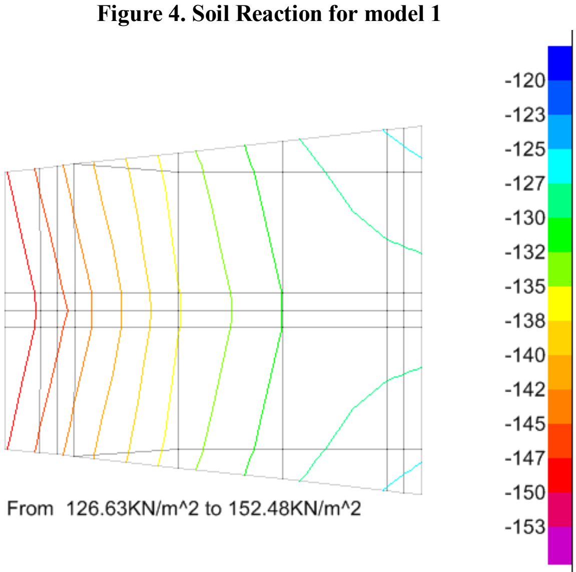


Figure 5. Soil Reaction for model 2

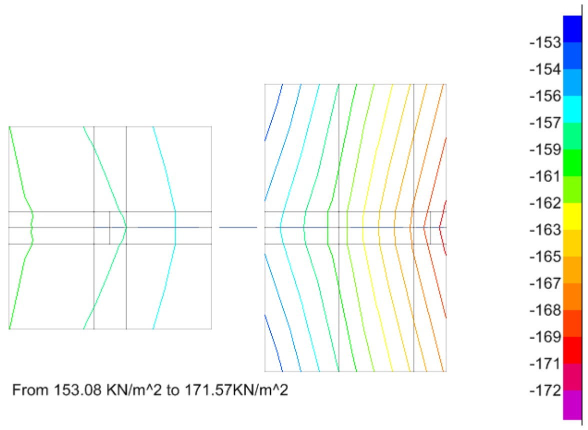


Figure 6. Soil Reaction for model 3

5.2 Settlement

Settlement is maximum downward displacement of foundation due to compaction of soil below due to the load acting on it. The maximum settlement of foundation should not exceed the maximum permissible value of 25mm.

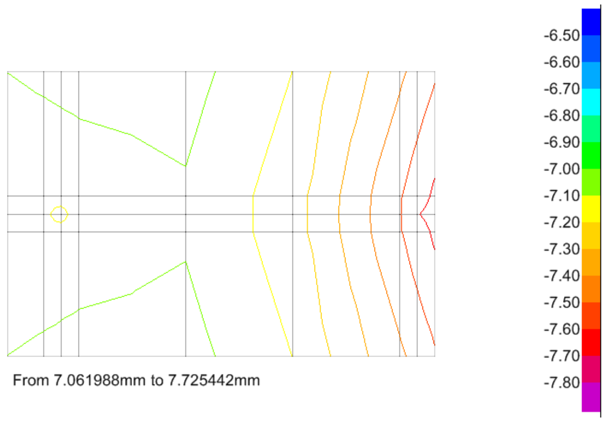


Figure 7. Settlement for model 1

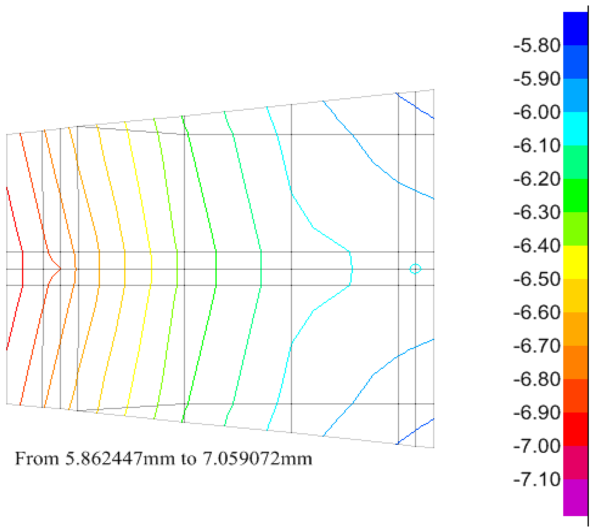


Figure 8. Settlement for model 2

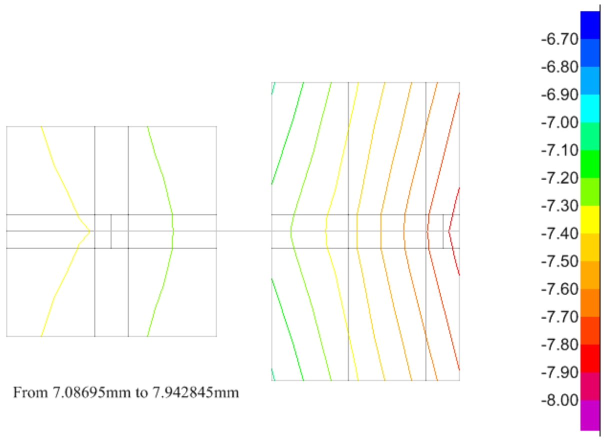


Figure 9. Settlement for model 3

5.3 Punching Shear

Punching shear is the maximum two-way shear acting on the foundation, due to this the column tries to punch through the foundation like a needle punching through paper. In CSi SAFE its value is represented by punching shear ratio whose value should be less than one.

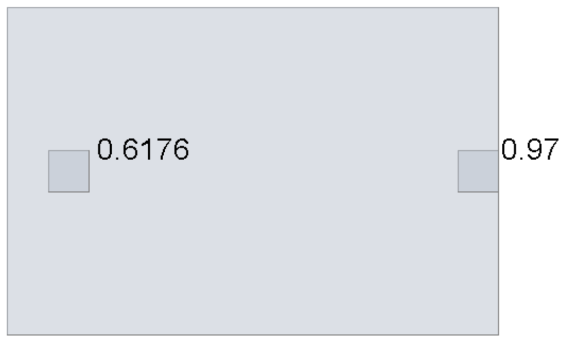


Figure 10. Punching Shear Ratio for model 1

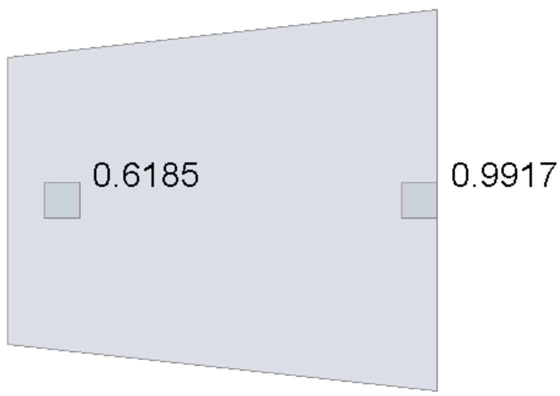


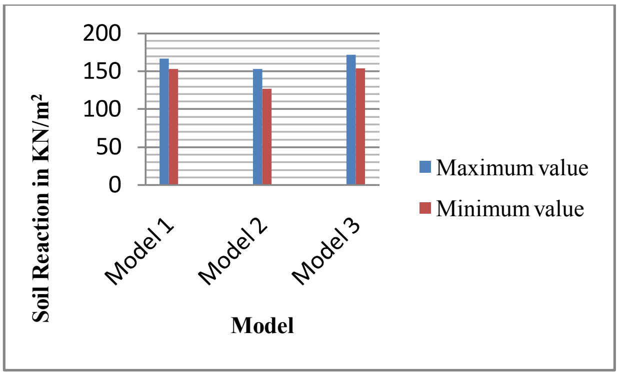
Figure 11. Punching Shear Ratio for model 2

Punching Shear Ratio not applicable for Strap footing.

6. RESULTS AND DISCUSSIONS

6.1 Soil Reaction

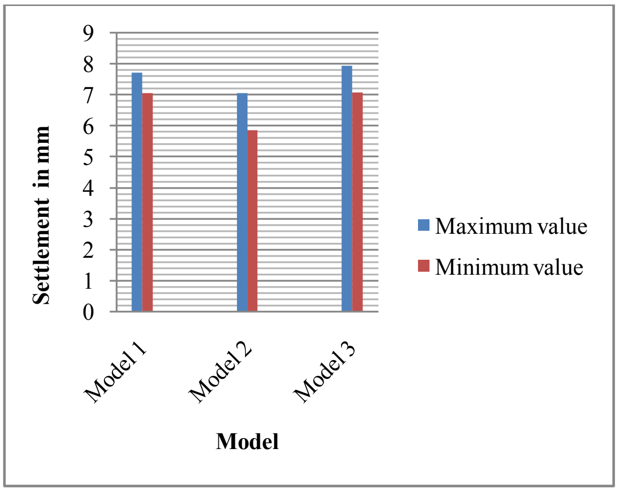
The maximum value of soil reaction for model 1, model 2 and model 3 are 166.87KN/m^2, 152.48KN/m^2 and 171.57KN/m^2 respectively and the minimum value of soil reaction for model 1, model 2 and model 3 are 152.54KN/m^2, 126.63KN/m^2 and 153.08KN/m^2 respectively as shown in Graph 1.



Graph 1. Model vs Soil Reaction

6.2 Settlement

The maximum value of settlement for model 1, model 2 and model 3 are 7.725mm, 7.059mm and 7.943mm respectively and the minimum value of soil reaction for model 1, model 2 and model 3 are 7.062mm, 5.863mm and 7.087mm respectively as shown in Graph 2.



Graph 2. Model vs Settlement

6.3 Punching Shear Ratio

The maximum value of punching shear ratio for model 1 and model 2 are 0.97 and 0.9917 respectively and the minimum value of soil reaction for model 1 and model 2 are 0.6176 and 0.6185. Punching Shear Ratio not applicable for Strap footing.

7. CONCLUSIONS

A. The maximum value of soil reaction occurs for model 3 which is 11.13% more than model 2 and 2.74% more than model 1. The minimum value of soil reaction occurs for model 2.

B. The maximum value of settlement occurs for model 3 which is 11.13% more than model 2 and 2.74% more than model 1. The minimum value of soil reaction occurs for model 2.

C. The maximum value of punching shear ratio occurs for model 2 and its minimum value is also higher than minimum value of model 1.

From above results it appears that model 3 gives maximum soil reaction and settlement but it also has minimum area and hence minimum material. Both model 1 and 2 are near limiting value in case of punching ratio while model 3 is completely safe. Hence it can be concluded that despite giving maximum values for soil reaction and settlement model 3 proves to be most economical and safe for such conditions.

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[10] IS 875 (Part II): 1987 code of practice for design loads (other than earthquake) for buildings and structures. part 2: imposed loads.

[11] IS 875 (Part V): 1987 code of practice for design loads (other than earthquake) for buildings and structures. part 5: special loads and load combinations.
[12] IS: 456:2000 Plain and Reinforced Concrete- Code of Practice.
[13] IS 1904: 1986 code of practice for design and construction of foundations in soils - general requirements.
[14] IS 1080: 1980 code of practice for design and construction of shallow foundations in soils (other than raft, ring and shell).