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Structural Analysis of Isolated Footing with and without Strap Beam

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Abstract—*Isolated footing is the most common type of foundation used for small residential building. Sometimes these are used in conjunction with strap beam (hence converting them into strap footing) for better distribution of load among the neighbouring columns. These are especially useful in case of columns lying on property line and eccentrically loaded columns. This paper aims to analyse these two configurations of footings by comparing bending moment, one-way shear, two-way shear and settlement for their better understanding and usage. In this paper a simple two column system is used, one of which lies on property line. Load on the columns, loading conditions and soil properties are kept constant throughout the paper. CSi SAFE software is used for analysis of the models which makes use of FEM (Finite Element Method) for simulation of results. For the purpose of this paper dead load and live load are considered from IS 875(Part I): 1987 and IS 875 (Part II): 1987 respectively. For designing IS 456: 2000, IS 1904: 1986 and IS 1080: 1980 have been used. Seismic load is not considered as does not give highest value of load combination as per IS 875 (Part V): 1987.*

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

1. INTRODUCTION

Small residential building (usually one or two stories tall) are most commonly made of reinforced cement concrete (RCC) as construction material and RC frame structures are used. These structure rest of shallow foundations usually not deeper than 1.5m below ground level. There is various type of shallow foundations that are used for such structures, like isolated footing, combined footing, matt/raft footing, etc. Out of all these types of shallow foundations isolated footing is most common, since it is easy to construct as compared to other shallow foundations.

An isolated footing may be concentrically loaded or eccentrically loaded (due to moment or column lying at (or near) property line). In such cases another type of footing known as strap footing can also be provided. A strap footing (a sub category of combined footing) is essentially two or more isolated footing joined together by a beam (known as strap beam) at foundation level. Strap beam helps distribute load between two joined columns. In this study these two are compared by putting them 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. are used. For the purpose of this paper two column system with these two arrangements of footings are used and are analysed using Finite Element Method in CSi SAFE software.

2. OBJECTIVES OF WORK

A. To study the behaviour of isolated and strap 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 goth the cases.

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	3.5 m
3.	Basic properties: a) Material ● Grade of concrete used ● Rebar ● Soil bearing capacity	 M20 HYSD500 250 KN/m^2
4.	Depth of foundation	600 mm
5.	Live loads ● Column 1 (C2) ● Column 2 (C1)	 180KN 180KN
6.	Dead loads ● Column 1 (C1) ● Column 2 (C2)	 300KN 250KN
7.	Load combinations ● Service normal ● Strength (Ultimate)	 LL+DL (LL+DL) *1.5

4. MODELLING

MODEL 1: Isolated footings

MODEL 2: Strap Footing

Modelling done with the help of CSi SAFE software.

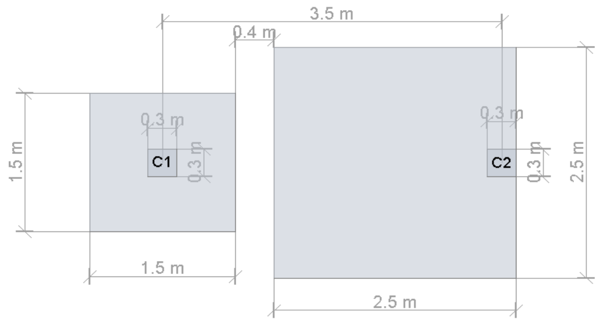


Figure 1: Plan view of model 1

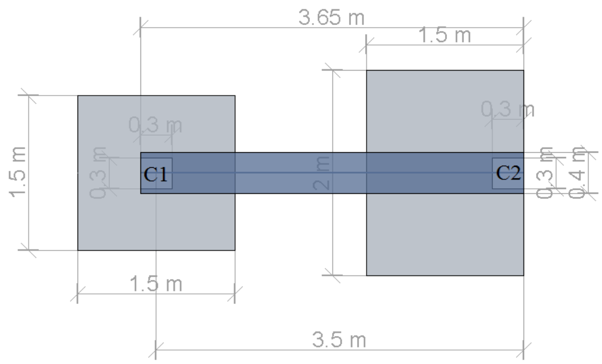


Figure 2: Plan view of model 2

5. ANALYSIS

5.1 Soil Reaction

Soil reaction is the reaction force per unit area (KN/m^2) needed to be provided by the soil, if not then the soil below will not be able to support the weight of the structure. Soil bearing capacity is the maximum thrust that can be provided by soil hence it must be greater than soil reaction.

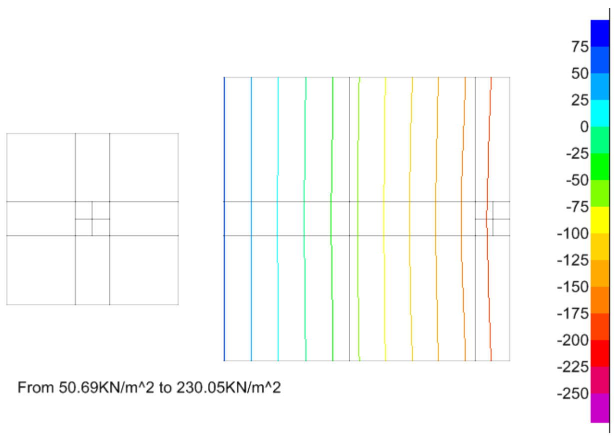


Figure 3: Soil Reaction for model 1

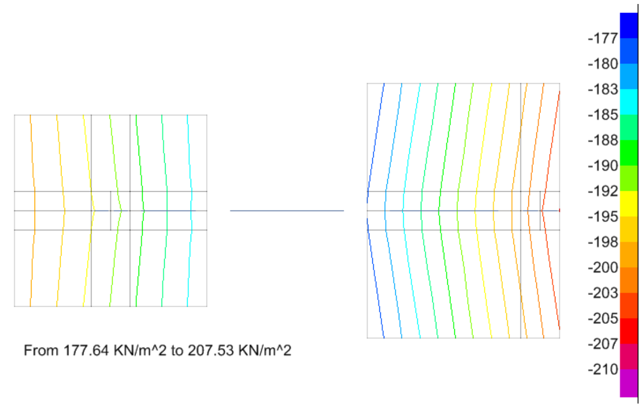


Figure 4: Soil Reaction for model 2

5.2 Settlement

Settlement is defined as the maximum downward displacement of foundation slab from its original position to new stable position due to compaction of soil below it. The maximum permissible value of settlement is 25mm, hence it should not be exceeded to keep the structure safe.

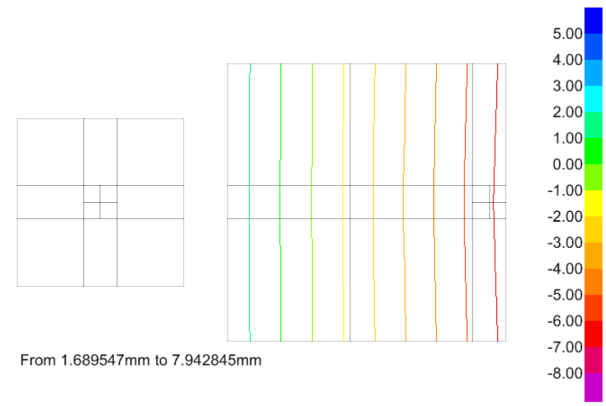


Figure 5: Settlement for model 1

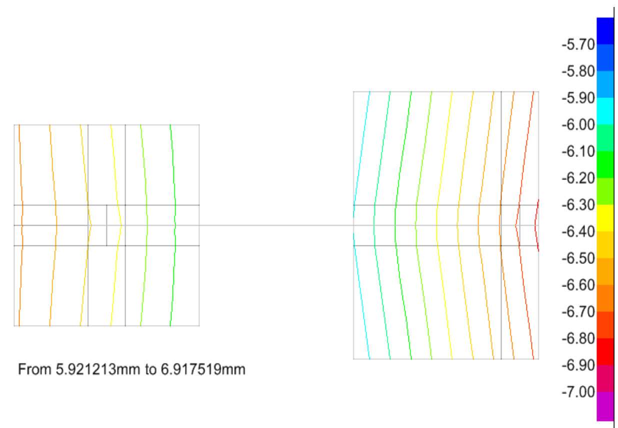


Figure 6: Settlement for model 2

5.3 Punching Shear

The maximum two-way shear acting on the foundation is known as punching shear. This can be represented through a ratio known as punching shear ratio, since it is a ratio its value should not exceed one for structure to be safe.

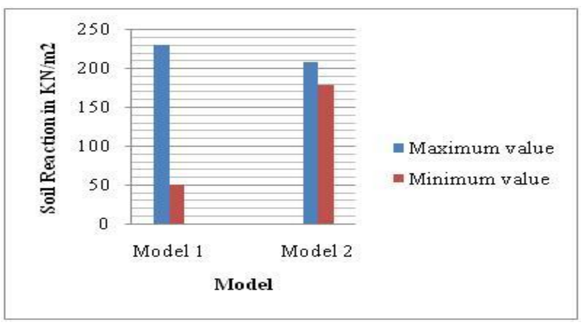
Figure 7: Punching Shear Ratio for model 1

Punching Shear Ratio not applicable for Strap footing.

6. RESULTS AND DISCUSSIONS

6.1 Soil Reaction

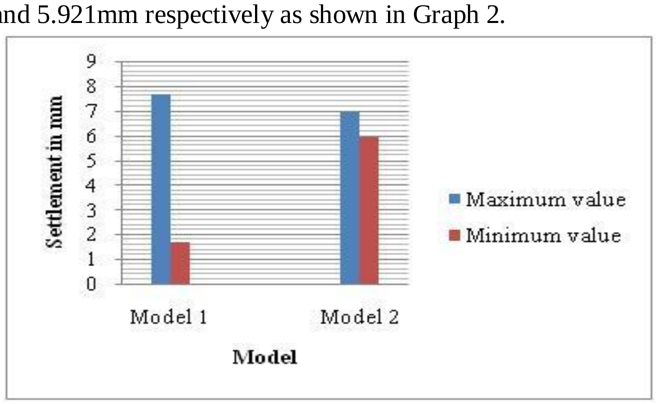
The maximum value of soil reaction for model 1 and model 2 are 230.05KN/m^2, and 207.53KN/m^2 respectively and the minimum value of soil reaction for model 1, and model 2 are 50.69KN/m^2, and 177.64KN/m^2 respectively as shown in Graph 1.



Graph 1. Model vs Soil Reaction

6.2 Settlement

The maximum value of settlement for model 1, and model 2 are 7.668mm, and 6.918mm respectively and the minimum value of soil reaction for model 1, and model 2 are 1.690mm, and 5.921mm respectively as shown in Graph 2.



Graph 2: Model vs Settlement

6.3 Punching Shear Ratio

The maximum and minimum value of punching shear ratio for model 1 are 0.6563 and 0.234 respectively while it is not applicable in case of strap beam.

7. CONCLUSIONS

A. The maximum value of soil reaction is given by model 1 which is 9.78% higher than model 2.

B. The minimum value of soil reaction is given by model 1 which is 71.46% lower than model 2.

C. The maximum value of settlement is given by model 1 which is 10.02% higher than model 2.

D. The minimum value of settlement is given by model 1 which is 67.56% lower than model 2.

E. Model 1 has large variation in both soil reaction and settlement as compared to model 2.

F. In model 2 both soil reaction and settlement are large below eccentric column C2, while small under concentric column C1.

G. Punching shear is of no concern in model 2, while it needs to be under permissible limit for model 1.

H. Area required (hence material required for construction) is less in model 2 as compared to model 1.

From above it can be concluded that although model 1 can be provided in this case but model 2 is more economical and has better distribution of load as compared to model 1, hence making it more preferable.

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[13] 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.

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