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INFLUENCE OF SUBGRADE MODULUS AND THICKNESS ON THE BEHAVIOUR OF RAFT FOUNDATION

Ranjitha P[1], Sathyanarayanan Sridhar R[2]

[1] Post Graduate student, M.E. Computer Methods and applications in Structural Engineering, Coimbatore Institute Of Technology
[2] Associate professor, Department of Civil Engineering,
Coimbatore Institute of Technology, Coimbatore-14, Tamil Nadu, India

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Abstract - *Analysis of Raft foundation is complex and time consuming as it involves the value of subgrade modulus. The determination of subgrade modulus as illustrated in Indian Standards gives approximate values based on standard penetration test which is unrealistic and it does not explain the procedure for extension of values for larger size plates. The subgrade modulus values will vary over the entire area which makes the soil investigation by plate load test more complex and expensive. Raft is adapted when the soil is poor, and when the soil is poor and the depth of the raft is considerably more, the raft behaves more or less a rigid plate. The soil pressure acting against the slab can be calculated by dividing all the column loads by area of the raft and assuming to be uniformly distributed, instead of going for classical elastic methods like FEM and FDM which is tedious and as it involves the value of modulus of sub-grade reaction. This project involves the study on effect of rigidity of foundation and modulus of subgrade reaction of soil on contact pressure and force quantities.*

Key Words: Raft Foundation, Static Analysis, Soil Modulus, Flexural Rigidity.

1. INTRODUCTION

A “raft” or “mat” foundation is a large concrete slab used to interface columns in several lines with the base soil. In conventional method, the contact pressure is assumed to be uniformly distributed or linearly varying depending upon whether the footing supports symmetric or eccentric loading for both rigid footing and flexible footing. However, the actual pressure which is a result of soil structure interaction can be far from uniform. The contact pressure distribution for flexible footing can be uniform for both clay and sand. The contact pressure for rigid footing is maximum at the edges for footing in clay, but for footing on sand, it is minimum. Hence, the assumption of uniform pressure results in slightly unsafe design for rigid footing on clay as the max BM at centre is underestimated and conservative design for footing on sand as BM is overestimated.

The determination of modulus of subgrade reaction is given in Appendix B of Indian standard code for design and construction of raft foundation IS: 2950 (Part-1) 1981, which gives the value only for the plate of size 30 cm x 30 cm based on standard penetration test. The modulus of subgrade reaction is a function of size of the plate, there is no proper guidelines to extend the same value for larger size raft [18]. The objective of the project is to prove that for poor soil conditions conventional methods can be used which gives comparatively better results than classical methods.

2. RIGIDITY OF MAT FOUNDATIONS

Mat foundations are generally used with uniform thickness all over. Economy can be attained by reconfiguring the mat in different ways. One type of such reconfiguration is by thickening the mat below the columns. Case studies reveal that mat thickness away from the column faces can be reduced by about 40%. In the present work; the raft foundation has a uniform thickness. By varying this thickness and fixing all other factors; the effect of the raft rigidity on the analysis will be investigated.

3. ANALYSIS OF RAFT FOUNDATIONS

The methods available for analysis of rafts are rigid beam analysis (conventional method) and Non-rigid or Elastic method. Rigid beam analysis can be used when the settlements are small. This is the simplest approach.

Available textbooks, handbooks, various publications and papers give widely different approaches to design of raft foundations. A designer, when faced with a task of designing a raft foundation, finds himself in a precautious position where he has to balance the time available for design, the cost of design, the need of adequate safety and, above all, acceptance of the design by the client. Generally, it is not practical for any designer to go through the various approaches as available in engineering literature at a particular time, compare their merits and demerits and select the most suitable for his purpose. Resulting solution may not be as satisfactory as he feels.

The present work aims to estimate the accuracy of the conventional rigid method by comparing its analysis results to the more accurate finite element analysis.

4. PROBLEM FORMULATION

The example given in Foundation Design – Theory and Practice by N.S.V Kameshwara Rao, is taken for analysis[7].

The plate is considered to be resting on series of springs as in case of Winkler model. The analysis is carried out using STAAD.Pro software.

Plate of size 1.2m x 1.2m

Thickness of 120, 200, 300, 400mm

Boundary Conditions - Free edges

Central Point load = 100kN

Modulus of Elasticity = 3 x 104 N/mm2

Poisson’s ratio = 0.15

Subgrade Modulus - 100, 40, 10, 1 MN/m3

Mesh size – 150 x 150 mm

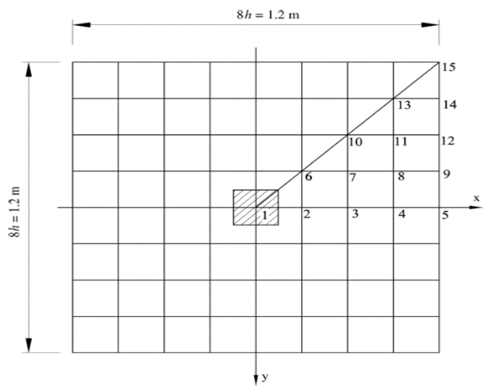

Fig-1: Isolated footing loaded at the center.

5. ANALYSIS AND RESULTS

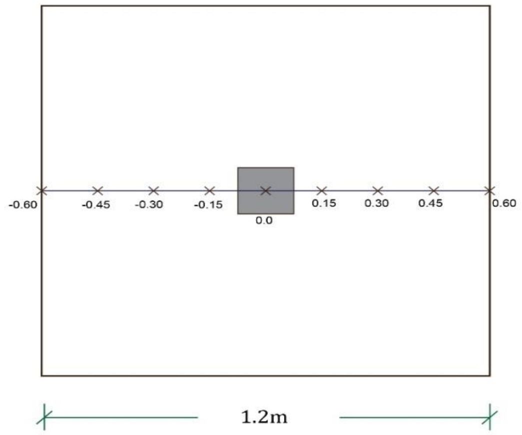

Fig-2: Line of study.

Analysis is carried out by meshing the plate in 8 x 8 divisions and supporting each node with spring of stiffness values equal to modulus of subgrade reaction. Conventional analysis is done by inverting the plate applying the pressure at top and supporting at the centre.

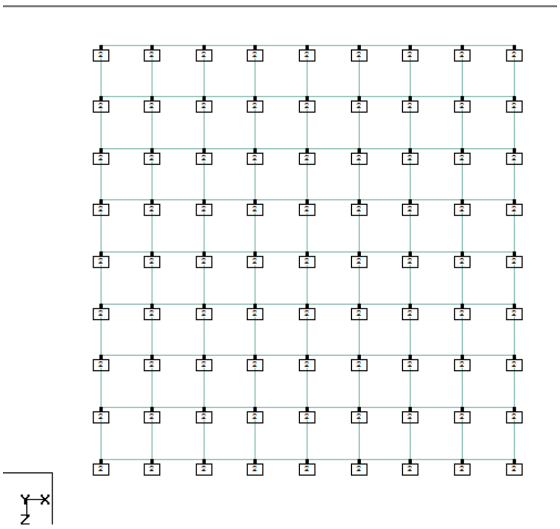

Fig-3: Analysis model.

Table -1: Contact Pressure –K=100MN/m^3

Thickness (mm)	120	200	300	400	Conv
-0.6	62.843	67.859	68.923	69.19	69.44
-0.45	70.677	69.706	69.498	69.45	69.44
-0.3	79.058	71.731	70.165	69.77	69.44
-0.15	87.017	73.736	70.882	70.14	69.44

0	93.658	76.084	72.09	70.95	69.44
0.15	87.017	73.736	70.882	70.14	69.44
0.3	79.058	71.731	70.165	69.77	69.44
0.45	70.677	69.706	69.498	69.45	69.44
0.6	62.843	67.859	68.923	69.19	69.44

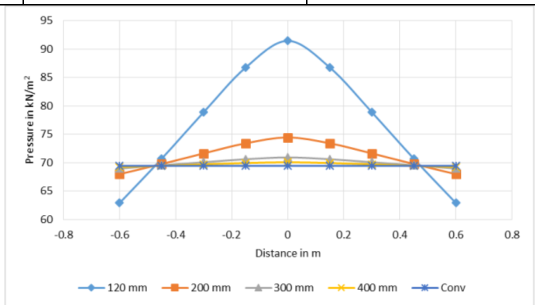

Fig-4: Variation of Contact Pressure K=100MN/m³

Table -2 : Contact Pressure – K=40 MN/m³

Thickness (mm)	120	200	300	400	Conv
-0.6	66.76	68.89	69.24	69.33	69.44
-0.45	70.00	69.56	69.47	69.47	69.44
-0.3	73.42	70.31	69.69	69.56	69.44
-0.15	76.71	71.07	69.91	69.64	69.44
0	78.58	71.47	70.04	69.69	69.44
0.15	76.71	71.07	69.91	69.64	69.44
0.3	73.42	70.31	69.69	69.56	69.44
0.45	70.00	69.56	69.47	69.47	69.44
0.6	66.76	68.89	69.24	69.33	69.44

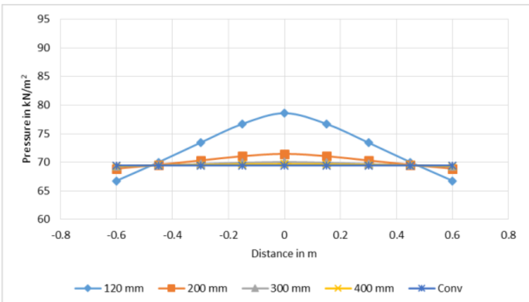

Fig-5: Variation of Contact Pressure K=40MN/m³

Table – 3: Contact Pressure – K=10 MN/m^3

Thickness (mm)	120	200	300	400	Conv
-0.6	68.71	69.33	69.42	69.42	69.44
-0.45	69.60	69.47	69.47	69.47	69.44
-0.3	70.49	69.69	69.51	69.47	69.44
-0.15	71.29	69.87	69.56	69.51	69.44
0	71.78	69.96	69.60	69.51	69.44
0.15	71.29	69.87	69.56	69.51	69.44
0.3	70.49	69.69	69.51	69.47	69.44
0.45	69.60	69.47	69.47	69.47	69.44
0.6	68.71	69.33	69.42	69.42	69.44

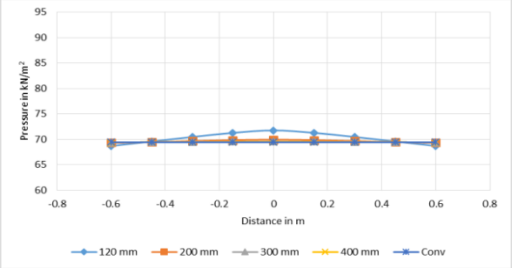

Fig-6: Variation of Contact Pressure K=10MN/m^3

Table-4: Contact Pressure – K=1 MN/m^3

Thickness (mm)	120	200	300	400	Conv
-0.6	69.33	69.42	69.42	69.42	69.44
-0.45	69.47	69.47	69.47	69.47	69.44
-0.3	69.56	69.47	69.47	69.47	69.44
-0.15	69.64	69.47	69.47	69.47	69.44
0	69.69	69.51	69.47	69.47	69.44
0.15	69.64	69.47	69.47	69.47	69.44
0.3	69.56	69.47	69.47	69.47	69.44
0.45	69.47	69.47	69.47	69.47	69.44
0.6	69.33	69.42	69.42	69.42	69.44

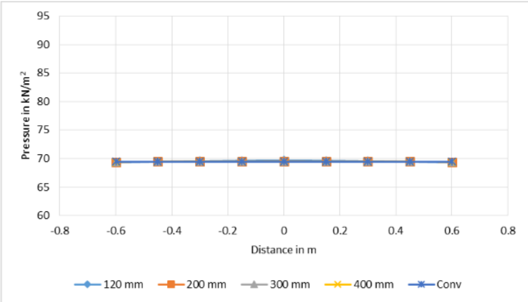

Fig-7: Variation of Contact Pressure K=10MN/m3

Table-5: Moment along X axis K=100MN/m^3

Thickness (mm)	120	200	300	400	Conv
0	25.18	25.83	25.96	26.00	26.02
0.15	6.12	6.68	6.80	6.83	6.85
0.3	1.79	2.14	2.22	2.24	2.25
0.45	0.15	0.03	0.00	-0.01	0.01
0.6	0.00	0.00	0.00	0.00	0.00

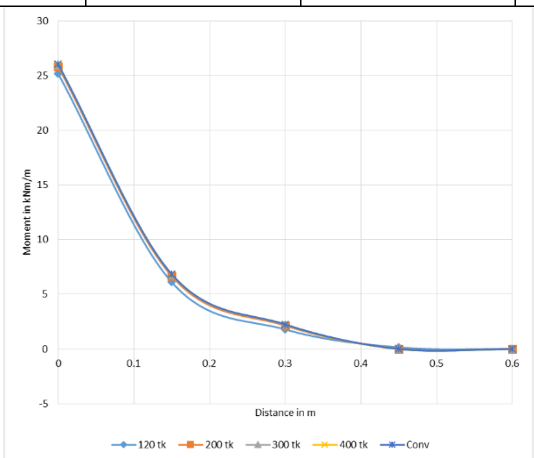

Fig-8: Moment along X axis K=100MN/m^3

Table-6: Moment along X axis K=40MN/m^3

Thickness (mm)	120	200	300	400	Conv
0	25.67	25.94	26.00	26.01	26.02
0.15	6.54	6.78	6.83	6.84	6.85
0.3	2.06	2.21	2.24	2.24	2.25
0.45	0.06	0.00	-0.01	-0.01	0.01
0.6	0.00	0.00	0.00	0.00	0.00

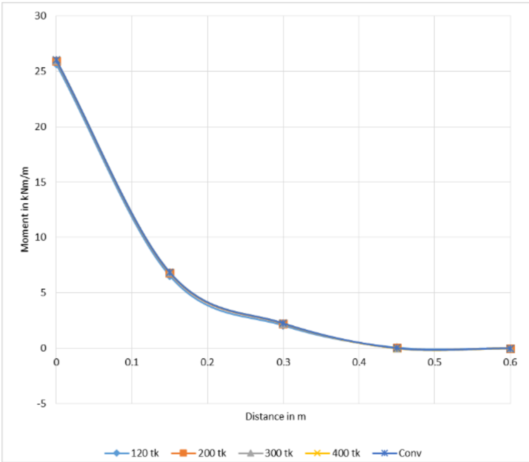

Fig-9: Moment along X axis – K=40MN/m^3

Table-7: Moment along X axis –K=10MN/m^3

Thickness (mm)	120	200	300	400	Conv
0	25.93	26.00	26.02	26.02	26.02
0.15	6.77	6.83	6.84	6.85	6.85
0.3	2.20	2.24	2.25	2.25	2.25
0.45	0.01	-0.01	-0.01	-0.01	0.01
0.6	0.00	0.00	0.00	0.00	0.00

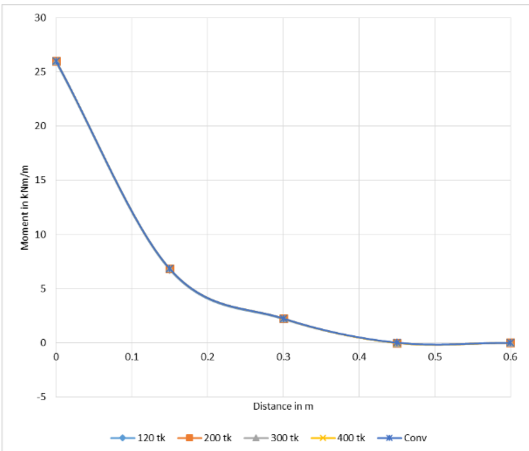

Fig-10: Moment along X axis –K=10MN/m^3

Table-8: Moment along X axis – K=1 MN/m³

Thickness (mm)	120	200	300	400	Conv
0	26.01	26.02	26.02	26.02	26.02
0.15	6.84	6.85	6.85	6.85	6.85
0.3	2.24	2.25	2.25	2.25	2.25
0.45	-0.01	-0.01	-0.01	-0.01	0.01
0.6	0.00	0.00	0.00	0.00	0.00

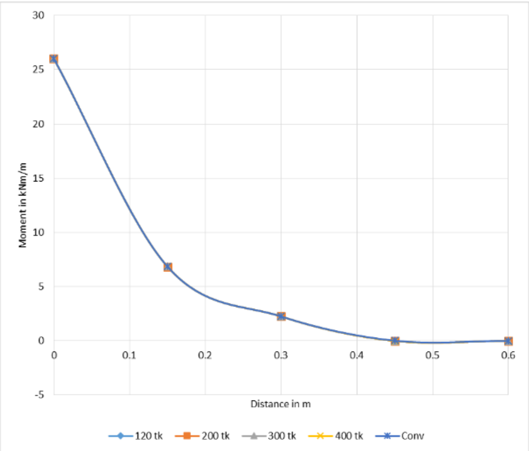

Fig-11: Moment along X axis – K=1 MN/m³

6. CONCLUSION

The effect of rigidity of foundation and modulus of subgrade reaction of soil on contact pressure and moment is studied. For extremely rigid footing, the contact pressure is uniform and for flexible footings, it is not uniform. As far as bending moment is concerned almost the same pattern is obtained for all cases. Since practically all the rafts are thick and are adopted only on weak soils, they are likely to be extremely rigid. Hence conventional method of analysis gives as good a result as that of rigorous analysis.

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