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Finite Element Analysis of frame with square meshing & radial meshing in Soil Structure Interaction

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ABSTRACT: *Mostly structure is analyzed and designed assuming fixed support at the foundation level and hence effect of compressibility of soil under the foundation is ignored. The structure analyzed and designed in this way does not give the actual or realistic behavior. In actual condition the structure is generally supported on compressible soil mass. Present work is to study behavior of bare frame having soil beneath. In these cases three types of soils are considered, soft, medium stiff and hard. For the analysis of a building frame, the columns at the foundation level are considered as fixed. But in real condition it is not the case. While considering soil in the analysis of building frame 100% fixity may not be ensured. Because of the settlement and rotation of foundation, shear force and bending moment in superstructure get altered. This effect is called as "Soil Structure Interaction". The soil domain is discredited by using square meshing and radial meshing. These cases are analyzed by using ANSYS 14.5 comprised between Square and Radial meshing for different extent of soil domain and presented to have results and conclusion.*

Key Words: *Bending moment, Radial Meshing, Shear force, Soil Structure Interaction, Square meshing*

I. INTRODUCTION

The flexibility of foundation, the compressibility of soil mass and other factors play an important role in the redistribution of moments and shear forces in the superstructure because of differential settlement of soil mass. However, the structure always interacts with the soil to some extent during lateral loading, imposing soil deformations that cause the motions of the structure - soil interface to differ from those that would have been observed in the free field. The allowable movement of foundation and structure depends on soil structure interaction. In Actuality, however, the structure always interacts with the soil to some extent during lateral loading, imposing soil deformations that cause the motions of the structure - soil interface to differ from those that would have been observed in the free field. By taking the effect of soil under the structure, it is evident that time period of the structure gets increased. As regards to the soil structure interaction behaviour, the differential settlements rather than the total settlements are responsible for redistribution/alteration of forces/moments of superstructures. The allowable movement of foundation and structure depends on soil structure interaction, desired serviceability such as visible, harmful cracking distortion.

1.1 Soil Structure Interaction

However, the structure always interacts with the soil to some extent during lateral loading, imposing soil deformations that cause the motions of the structure - soil interface to differ from those that would have been observed in the free field. The allowable movement of foundation and structure depends on soil structure interaction.

II. Properties Of Material

Properties for masonry material and components should be based on the available construction documents. The following material properties shall be obtained for the as-build structure. [1] Soil beneath foundation can be any type of soil; it may be soft soil, may be rock or may be black cotton soil. So depending upon its type the engineering and mechanical properties of soils are decided using different types of tests. [2] In this study, finite element based software ANSYS 14.5 was used to generate and analyze building frame models for the assessment of the relative effectiveness of the various lateral load resisting systems. Modeling is done by Finite element method.

TABLE-1.Properties of different materials for analysis

Material		Modulus of Elasticity (KN/mm^2)	Poisson's ratio
Concrete		25	0.2
Soil	**Soft**	10	0.25
	Medium	35	0.34
	hard	80	0.45

2.1Section Properties

Size of Beam = 0.3 m x 0.45 m
Size of Column = 0.3m x 0.3 m
Thickness of Soil = 4.0 m
Depth of soil = 6 m
Width of soil = 15m

III. Procedure For Analysis Using Ansys

The analysis procedure can be summarized into the following steps:

- Modeling of frame, infill and the interface using the above mentioned elements.
- Assigning corresponding properties to the elements.
- Applying the load and assigning the constraints.
- Solving the problem.
- After solving the problem, the nodal forces in the link elements are checked only compression only link elements are retained and the problem is solved again.
- The above step is repeated until the forces in the link elements are compressive.

IV. Linear Analysis Of Frame With Soil

Three types of soil are used in the analysis namely, soft, medium stiff and hard. A validation for linear analysis of bare frame with soil with soil is made and found that results are fairly comparable.

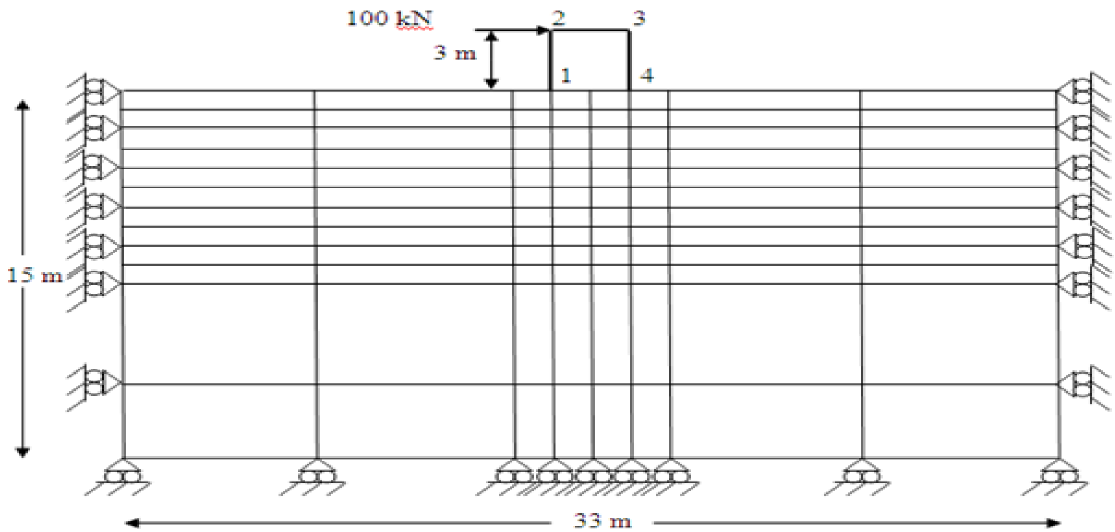

Fig 1. Finite Element Discritization of Bare Frame with soil

TABLE 2. Bare frame with Soil: Maximum Displacement

DISPLACEMENT			
Soil Type	**Soft Soil**	**Medium Stiff**	**Hard Soil**
Along X	27.20 mm	19.39 mm	16.84 mm
Along Y	4.28 mm	1.20 mm	0.31 mm
Rot @ Z	0.0036 rad	0.0043 rad	0.0040 rad

TABLE 3. Bare frame with soil: Maximum Bending Moments, Axial Force and Shear Force in beam & column

Type of Soil	Column		Beam	
	Moment (KNm)	**Force (KN)**	**Moment (KNm)**	**Force (KN)**
Soft	75.3	49.98	75.05	49.98
Medium	75.4	50.14	74.8	49.8
Hard	75.5	49.72	74.7	49.72

V. Linear Analysis Of Bare Frame Without Soil

In this case linear analysis of bare frame without soil is carried out and results are compared.

TABLE 4. Bare Frame without Soil: Maximum Displacement

	Bare frame
Along X direction	0.85 mm
Along Y direction	0.097 mm
Rotation @ Z	0.00030 radians

TABLE 5. Bare Frame without Soil: Maximum Bending Moment and forces in Columns and Beams

Column		Beam	
Moment (KNm)	**Axial Force(KN)**	**Moment (KNm)**	**Shear Force(KN)**
6.485	94.41	5.46	97.25

VI. Analysis Considering Different Extents Of Soil Domain

6.1 Square Meshing

The soil domain is discretized by using more number of four noded quadrilateral isoparametric elements as shown in Fig 1. The section properties and the material properties of the floor beam, columns and the foundation beam are in table 1. The soil domain is discretized by using four noded isoparametric elements up to 6 m depth below the foundation beam element. As given in the Fig 1. different meshes M1, M2, M3, M4, M5 and M6 shown, are analysed. Here the size of soil element is kept constant. The main aim of this study is to find out the effect in horizontal displacement by modeling soil domain in constant square element. The maximum horizontal displacements are obtained by ANSYS 14.5 for with Soil Structure Interaction.

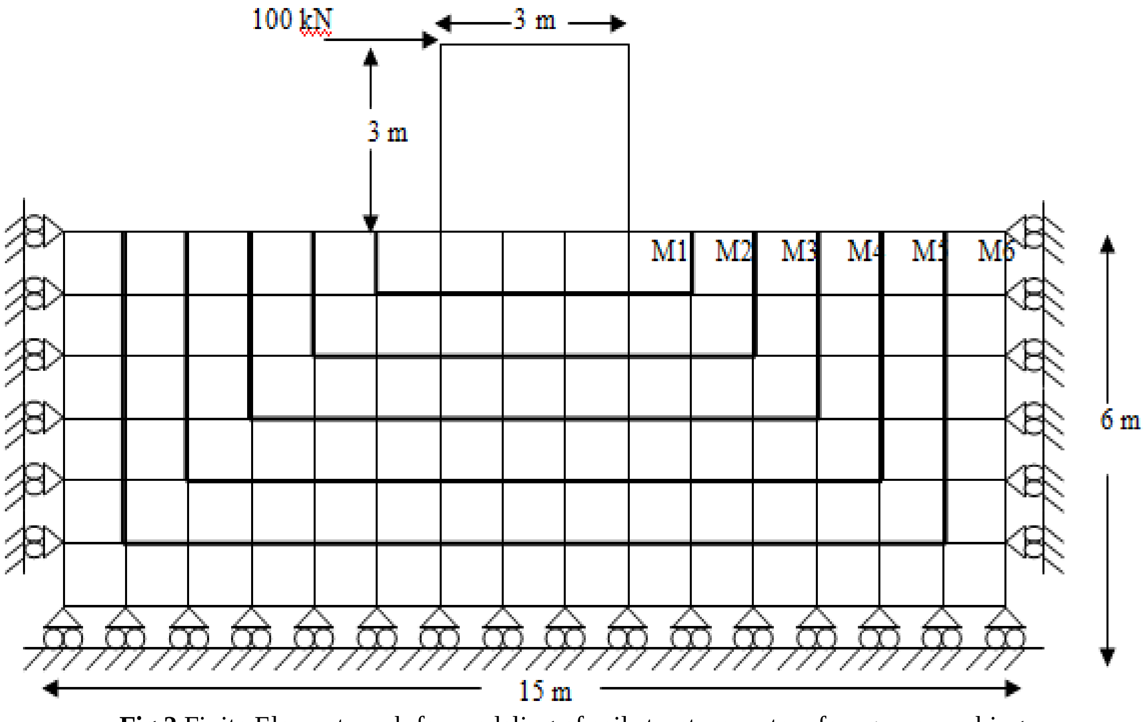

Fig.2 Finite Element mesh for modeling of soil structure system for square meshing

6.2 Radial Meshing

The analysis in this case is same as of square meshing; the only difference is that the size of element is different as shown in Fig 2. In radial meshing the discretization is done in such a way that the size of element is small near to the frame while goes on increasing while going at large depth. The section properties and the material properties of the floor beam, columns and the foundation beam are kept same as in the section 4.2. The soil domain is discretized by using four noded isoparametric elements up to 6 m depth below the foundation beam element.

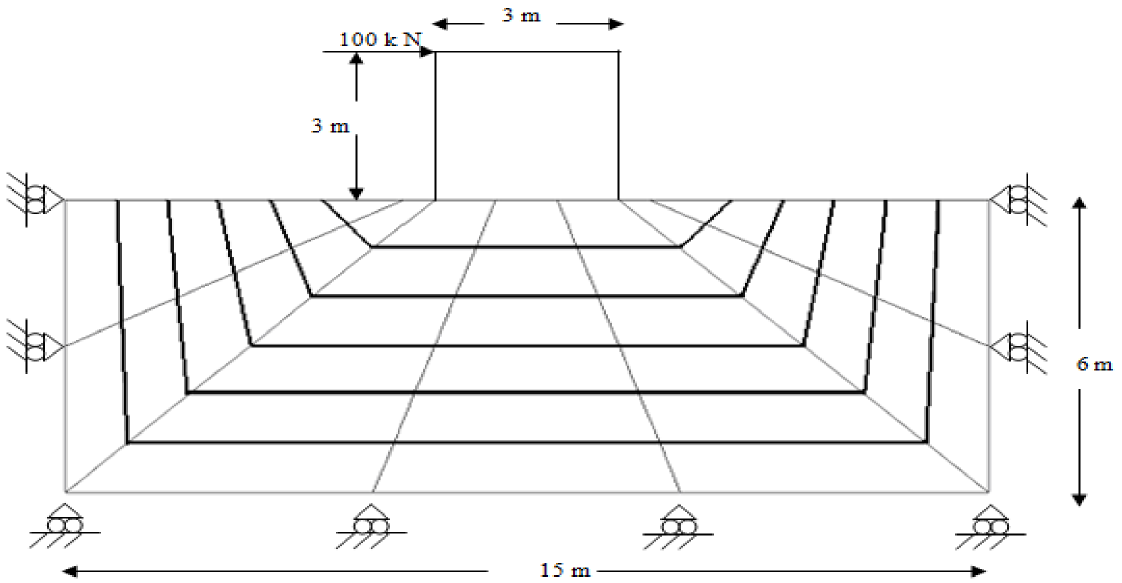

Fig 3. Finite Element mesh for modeling of soil structure system for radial meshing

TABLE 6. Displacement for square and radial meshing for varying depth of soil domain

Maximum Horizontal Displacement		
Depth (m)	**Square Meshing**	**Radial Meshing**
1	0.037741	0.034621
2	0.024588	0.022962
3	0.025951	0.024389
4	0.027173	0.025288
5	0.027906	0.025915
6	0.028466	0.029357

TABLE 7. Displacement for square and radial meshing for constant depth of soil domain

Maximum Horizontal Displacement			
No. of element	**Square Meshing**	**Number of Elements**	**Radial Meshing**
45	0.0280	47	0.0258
53	0.0284	55	0.0262
61	0.0286	63	0.0268
69	0.0288	71	0.0272
77	0.0290	79	0.0274
85	0.0292	87	0.0276

TABLE 8. Displacement and number of elements for different types of Soil for square meshing

Number of Elements	Soft Soil	Medium Stiff Soil	Hard Soil
45	0.0280	0.0188	0.0166
53	0.0284	0.0189	0.0167
61	0.0287	0.0190	0.016805
69	0.0290	0.0190	0.016827
77	0.0290	0.0191	0.016842
85	0.0291	0.0191	0.016851
93	0.0291	0.0191	0.016858

TABLE 9. Displacement and number of elements for different types of Soil for radial meshing

Number of elements	Soft Soil	Medium Stiff Soil	Hard Soil
47	0.0257	0.0171	0.0149
55	0.0263	0.0174	0.0150
63	0.0267	0.0176	0.0151
71	0.0271	0.0177	0.0152
79	0.0275	0.0179	0.0153
87	0.0277	0.0180	0.0154

VII. Compsrision & Discussion

7.1Comparison between Square and Radial meshing for different extent of soil domain

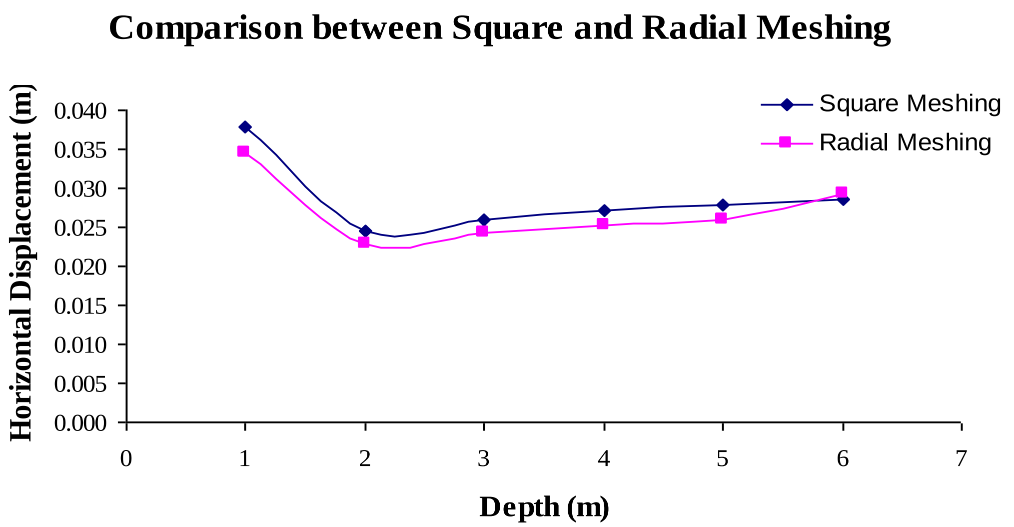

Fig 4. Graph showing comparison between square and radial meshing for different extent of soil

Above graph shows the depth (m) on X axis and horizontal displacement (m) on Y axis in this graph radial meshing shows less horizontal displacement up to 5m depth while increasing the depth greater than 5m the displacement goes on increasing than the square meshing. That is it suggest the radial meshing is more suitable for limited depth and square meshing is suitable for greater depth.

7.2 Comparison between Square and Radial meshing for constant depth of soil

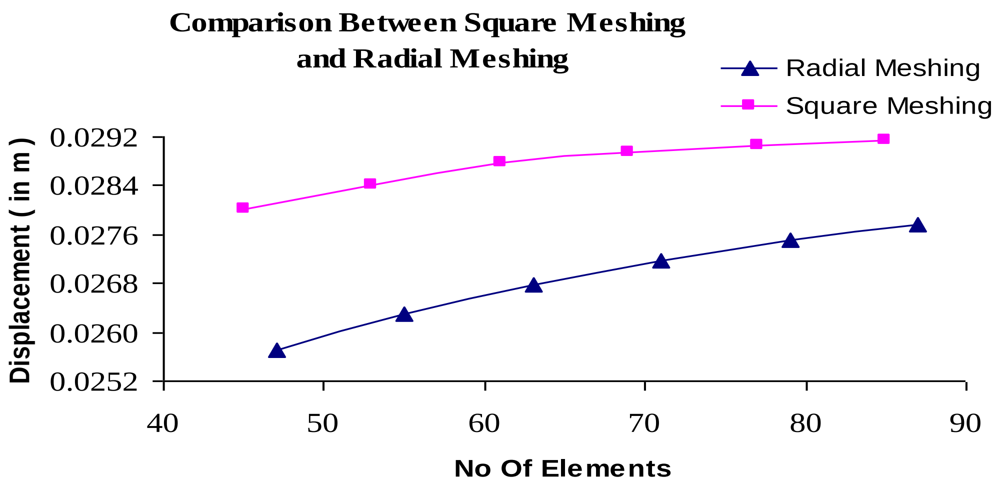

Fig 5.Graph showing Square and Radial meshing for constant depth of soil

In this graph no. of elements on X axis and displacement (m) is on Y axis, in case of radial meshing the above graph shows displacement is increases while increasing the no. of element but in case square meshing initially displacement increases at higher rate but in later this rate will goes on decreases while increasing no. of elements.

7.3 Comparison between Displacement against Number of Elements for various types of meshing and for different soil

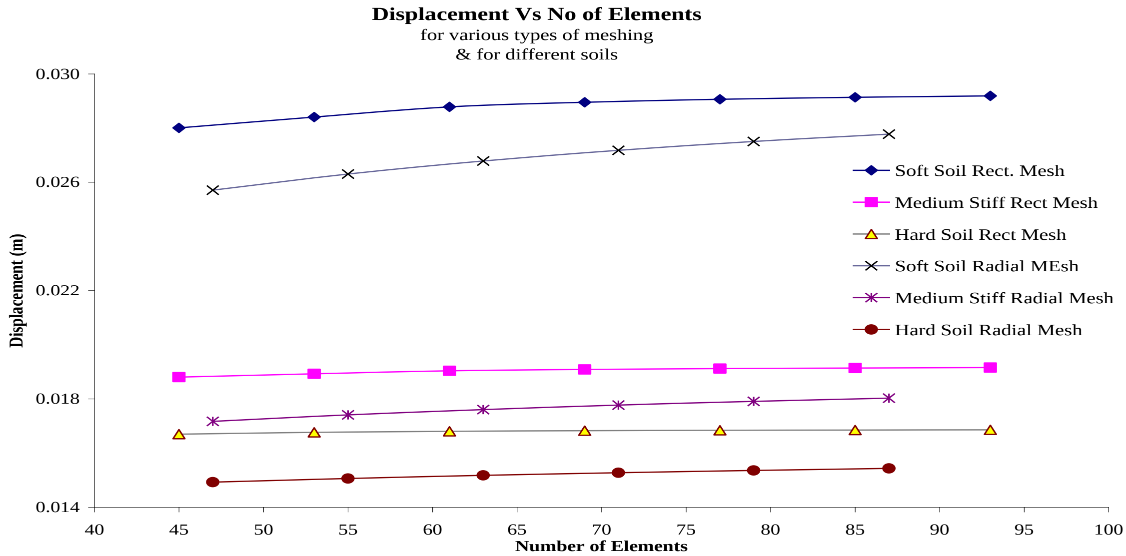

Fig.6. Graph showing Displacement against Number of Elements for various types of meshing and for different soil

The above graph shows the soft soil having more displacement than the medium stiff and hard soil, and the hard soil having less displacement so it concludes the displacement is depends on soil type and its properties.

VIII. Conclusions

- Analysis of bare frame with Soil Structure Interaction shows more displacement & bending moment than the analysis of bare frame without Soil Structure Interaction.
- Also analysis of bare frame with Soil Structure Interaction shows less shear force as compared with analysis of bare frame without Soil Structure Interaction.
- The radial meshing is more suitable for limited depth and square meshing is suitable for greater depth.
- The soft soil having more displacement than the medium stiff and hard soil and the hard soil having less displacement so it concludes the displacement is depends on soil type and its properties.
- Three types of soils are considered for the analysis of frame with soil namely soft, medium stiff and hard.
- It is found that for each type of soil again forces and bending moments get change in beams and columns.
- Analysis Frame with soil structure interaction done very precisely, Very accurate result prediction can be done by using ANSYS Software instead of calculation made by numerical methods.

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