FINITE ELEMENT ANALYSIS OF FRAME WITH SOIL STRUCTURE INTERACTION

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Abstract

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" Present work is to study behavior of bare frame & in-filled frame having soil beneath. In these cases three types of soils are considered, soft, medium stiff and hard. Also in-filled panel is of brick masonry only. Various cases frames are studied. The following are the cases:

1] Analysis of bare frame with soil.2] Analysis of In-filled frame with Soil.3] Analysis of Bare frame without Soil.4] Analysis of In-filled frame without Soil Frame with different combinations mentioned above (with/without infill panel, with/without soil) is analyzed by using ANSYS 14.5. These results are comprised with SSI and without SSI.

Keywords: *Soil Structure Interaction, In-Filled Frame, Bare Frame.*

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1. INTRODUCTION

Generally 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 effect of infill wall of the structure is also not taken in to consideration. 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. There exits interaction between structure and soil mass below foundation. 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.

1.1 In-filled frame (Masonry Panel)

An infill (masonry) panel is the partition wall or the cladding element used in the reinforced concrete or steel frame structure. They are normally considered as architectural elements. Engineers often ignored their presence. Because of complexity of the problem, their interaction with the bounding frame is often neglected in the analysis of building structures. This assumption may lead to an important inaccuracy in predicting the response of the structure. This occurs especially when subjected to lateral loading. Even though they are considered nonstructural they interact with the bounding frame when the structure is subjected to strong earthquake loads or lateral loads. This interaction may beneficial for structural performance, but sometimes this leads to strong damage.

1.2 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.

2. 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]

Table-1.Properties of different materials for analysis

Material		Modulus of Elasticity (KN/mm^2)	Poisson's ratio
In-filled panel (brick masonry)		15.4	0.15
Concrete		25	0.2
Soil	Soft	10	0.25
	Medium	35	0.34
	hard	80	0.45
Steel		200	0.3

3. VALIDATION

Analysis of in-filled frames to resist lateral loads on buildings in terms of their failure modes, failure loads, and initial stiffness tested by previous author Riddington is verified. This verification is made by comparing the results of the analytical procedures of the previous authors with those of a finite element model for in-filled frames, which are verified using ANSYS14.5. [12]

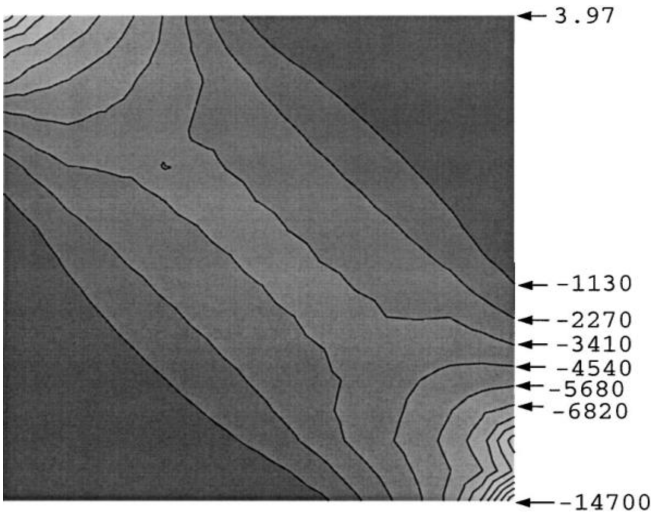

Fig.1 Riddington stiff frame: minimum principal stress (KN/m^2) plot at lateral load 460 KN

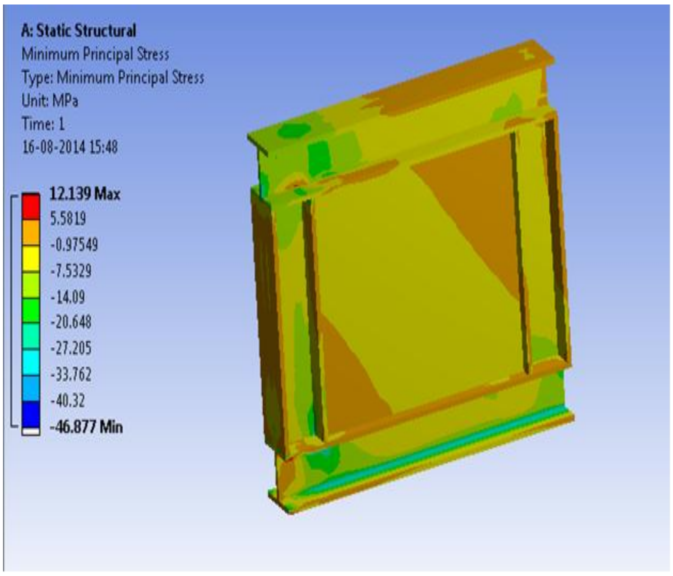

Fig.2.Riddington stiff frame: minimum principal stress (KN/m^2) plot at lateral load 460 KN by ANSYS 14.5

Table-2 Displacements for Riddington Frame & present FE Analysis in ANSYS 14.5

Load (KN)	Present FE Analysis	Riddington Frame
50	0.214646	0.235
100	0.429291	0.4705
150	0.643937	0.68
200	0.858582	0.8705
250	1.073228	1.129

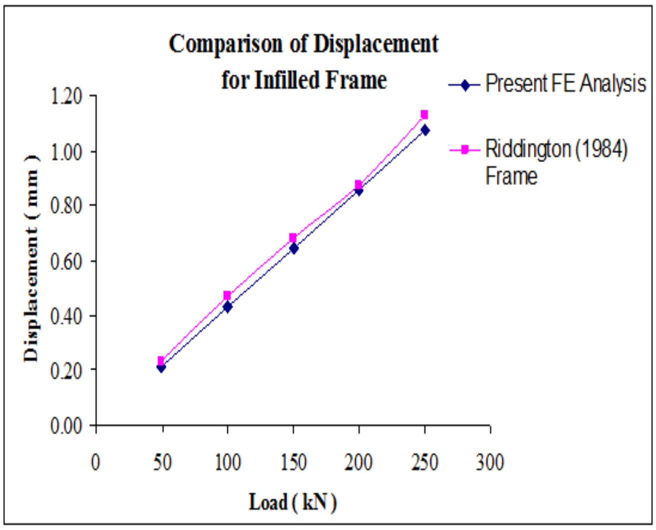

Fig 3 Graph showing Comparison of Displacement for in-filled frame

4. 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 and in-filled frame with soil is made and found that results are fairly comparable.

4.1 Case 1: Linear Analysis of Bare Frame with Soil

The model is modeled in ANSYS 14.5. Mathematical model is shown in Fig 4. Beam and columns are modeled as two dimensional frame elements having two degree of freedom per node while soil is modeled as four noded quadrilateral isoparametric elements. The lateral load is applied in x direction at the top of column of the structure. The Section Properties are, Size of Beam = 0.3 m x 0.45 m & Size of Column = 0.3m x 0.3 m

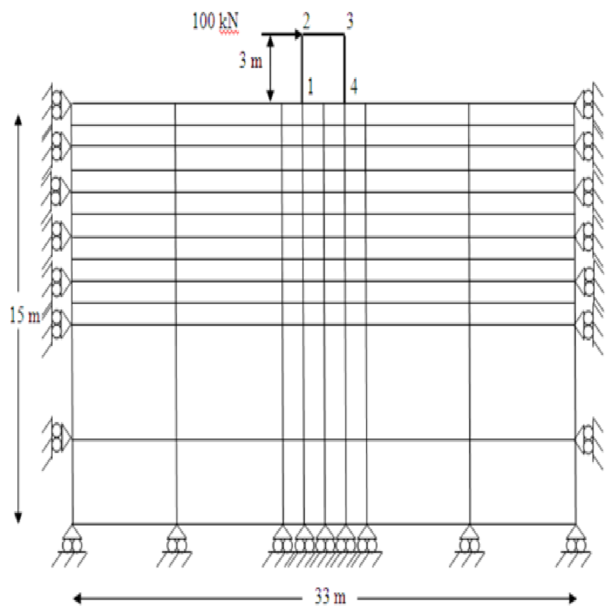

Fig 4 Finite Element Discritization of Bare Frame with soil

Table -3 Bare frame with Soil: Maximum Displacement

DISPLACEMENT			
Soil Type	**Soft Soil**	**Medium Stiff**	**Hard Soil**
Along X	27.27 mm	19.39 mm	16.84 mm
Along Y	4.3 mm	1.22 mm	0.32 mm
Rot @ Z	0.0035 rad	0.0045 rad	0.0042 rad

Table 4 Bare frame with soil: Maximum Bending Moments, Axial Force and Shear Force in beam and 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

4.2 Case 2: Linear Analysis of In-filled Frame with Soil

The two dimensional plane frames with soil including infill is analyzed by ANSYS 14.5. The thickness of infill is taken as 0.23 m. Rests of the structural characteristics are kept same as considered in case 1.

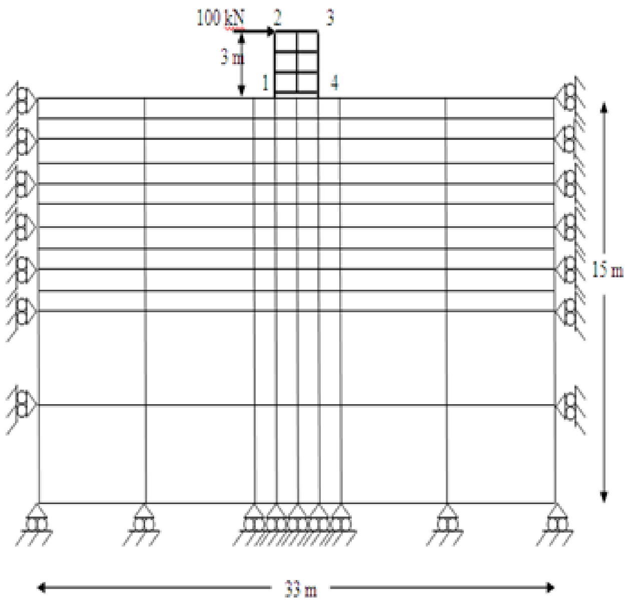

Fig 5 Finite Element Discretization of In-filled Frame With Effect of SSI

Table 5 In-filled frame with Soil: Maximum Displacement

DISPLACEMENT			
Type of Soil	**Soft Soil**	**Medium Stiff**	**Hard Soil**
Along X	14.14 mm	4.37 mm	2.14 mm
Along Y	5.20 mm	2.1 mm	0.59 mm
Rot @ Z	0.0031 rad	0.0010 rad	0.00055 rad

Table 6 In-filled frame with soil: Maximum Bending Moments, Axial Force and Shear Force in beam and column

Type of Soil	**Column**		**Beam**	
	Moment (KNm)	**Force (KN)**	**Moment (KNm)**	**Force (KN)**
Soft	2.04	60.4	2.01	60.4
Medium	2.042	60.5	2.042	60.5
Hard	2.04	60.6	2.04	60.6

5. LINEAR ANALYSIS OF BARE FRAME & IN-FILLED FRAME WITHOUT SOIL

In this case linear analysis of in-filled frame & bare frame without soil is carried out and results are compared. An in-filled frame is idealized using four noded isoparametric elements. The two dimensional plane frames with soil including infill is analyzed by ANSYS 14.5. The infill is modeled as four noded quadrilateral isoparametric elements. The thickness of infill is taken as 0.23 m.

Table 7 In-filled & Bare Frame without Soil: Maximum Displacement

DISPLACEMENT		
	Bare frame	**In-filled Frame**
Along X direction	0.85 mm	0.428 mm
Along Y direction	0.097 mm	0.068 mm
Rotation @ Z	0.00030 radians	0.00021 radians

Table 8 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

Table 9 In-filled Frame without Soil: Maximum Bending Moment and forces in Columns and Beams

Column		**Beam**	
Moment (KNm)	**Axial Force(KN)**	**Moment(KNm)**	**Shear Force(KN)**
4.565	87.41	4.46	87.25

6. ANALYSIS OF FRAME WITH SOIL AS A NON-LINEAR MATERIAL.

6.1 Analysis of Bare Frame with Soil as a Non-Linear Material

Analysis of bare frame with soil is done using soil as a nonlinear material. Finite elements discretization is done using Figure 4.

Table 10 Bare frame with Soil: Maximum Displacement

DISPLACEMENT			
Soil Type	**Soft Soil**	**Medium Stiff**	**Hard Soil**
Along X	27.34 mm	19.48 mm	16.94 mm
Along Y	4.34 mm	1.42 mm	0.38 mm
Rot @ Z	0.0037 rad	0.0046 rad	0.0045 rad

Table 11 Bare Frame with Soil as a Nonlinear Material: Maximum Bending Moments, Axial Force and Shear Force in Beam and Column

Type of Soil	Column		Beam	
	Moment (KN-m)	**Axial Force (KN)**	**Moment (KN-m)**	**Shear Force (KN-m)**
Soft	74.87	49.86	74.87	49.86
Medium	74.96	50.05	74.96	50.05
Hard	75.18	50.27	75.18	50.27

6.2 Analysis of In-filled Frame with soil as a nonlinear material.

Analysis of in-filled frame with soil is done using soil as a nonlinear material. Finite elements discretization is done using Figure 5.

Table 12 In-filled frame with Soil: Maximum Displacement

DISPLACEMENT			
Soil Type	**Soft Soil**	**Medium Stiff**	**Hard Soil**
Along X	14.24 mm	4.47 mm	2.19 mm
Along Y	5.26 mm	2.18 mm	0.63 mm
Rot @ Z	0.0033 rad	0.0011 rad	0.00058 rad

Table 13 Infilled frame with soil: Maximum Bending Moments, Axial Force and Shear Force in beam and column

Type of Soil	Column		Beam	
	Moment (KNm)	**Force (KN)**	**Moment (KNm)**	**Force (KN)**
Soft	2.09	60.47	2.081	60.6
Medium	2.045	60.56	2.049	60.56
Hard	2.044	60.63	2.043	60.74

7. CONCLUSION

1. Analysis of bare frame with Soil Structure Interaction shows more displacement than the analysis of bare frame without Soil Structure Interaction.
2. Also analysis of bare frame with Soil Structure Interaction shows less shear force as compared with analysis of bare frame without Soil Structure Interaction.
3. Analysis of bare frame with Soil Structure Interaction shows more bending moment as compared with analysis of bare frame without Soil Structure Interaction.
4. Analysis of In-filled frame with Soil Structure Interaction shows more displacement than the analysis of In-filled frame without Soil Structure Interaction.
5. Also analysis of In-filled frame with Soil Structure Interaction shows less shear force as compared with analysis of In-filled frame without Soil Structure Interaction.
6. Analysis of In-filled frame with Soil Structure Interaction shows more bending moment as compared with analysis of In-filled frame without Soil Structure Interaction.
7. In-filled frame have higher lateral stiffness lateral load resistance than the bare frame. It was also observed that behavior of masonry in-filled RC frame was excellent in terms of strength and stiffness.

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