International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 6 Volume No.6 October - November – 2022
DOI:10.46647/ijetms.2022.v06i06.017 ISSN: 2581-4621

Analysis of an Isolated Footing taking into account Soil Structure Interaction

Dhineshanand S[1], Ramkumar S[2]
[1]*Assistant Professor, Department of Civil Engineering,*
Kongunadu College of Engineering and Technology (Autonomous) – Trichy, Tamilnadu
[2]*Assistant Professor, Department of Civil Engineering,*
Kongunadu College of Engineering and Technology (Autonomous) – Trichy, Tamilnadu

ABSTRACT
In the proposed study an attempt is made to understand the effect of soil interaction on the performance of building frames resting on isolated footing. The purpose of this study is to describe and investigate different approaches of considering the linear interaction analysis (SSI- Soil-Structure Interaction) with regard to the response in the superstructure. The present study is focused on SSI analysis of symmetrical space frame of 3 bays in both x and y direction, 2 storey (3X3X2), 3 bays in direction, 4 storey (3X3X4) and 3 bays in both direction, 6 storey (3X3X6) resting on isolated footing with fixed base. Medium hard clay type of soil is used for this SSI study. The interaction approach is incorporated in the analysis using Conventional analysis (NIA model - Non interaction analysis) and Soil-structure interaction analysis (LIA model - linear interaction analysis). ANSYS is used for developing these models. The effect of SSI on various structural parameters i.e. natural time period, base shear, roof displacement, beam moment and column moment and axial force are studied and discussed. The comparison is made between the approaches of conventional and liner interaction modeling. The study reveals that the SSI significantly affects the response of the structure.
Keywords—Soil Structure Interaction, Framed Structures, Isolated Footing, ANSYS, Finite Element Method.

1. Introduction
Soil-structure interaction is a complex phenomenon which involves mechanism of interaction between various components of a building system. In common design practice interaction between soil, foundation and structure is neglected to simplify the structural analysis. A stress analyst generally ignores the influence of the settlements of supporting soil on the structural behavior of the super-structure. In addition to this, the effect of the stiffness of the structure is disregarded in evaluating the foundation settlements.

2. Methodology
Soil Structure Interaction is also carried out by considering elastic continuum with the help of Finite Element Method (FEM). The present study is focused on SSI analysis of symmetrical space frame of 3 bays in both x and y direction, 2 storey (3X3X2), 3 bays in both direction, 4 storey (3X3X4) and 3 bays in both direction, 6 storey (3X3X6) resting on isolated footing with fixed base and resting on homogeneous soil mass and subjected to gravity loading is analysed. The problem under consideration is symmetric about both axes in terms of geometry, material properties and loading. To investigate the interaction behavior, the interaction analyses are carried out for the following two cases. Conventional non interaction and linear interaction model are shown in the Fig.1 and Fig.2 respectively which is considered for the study.

Case 1: The conventional analysis (NIA- Non-Interaction Analysis) considering the columns fixed at their bases.
Case 2: The soil-structure interaction analysis (LIA - Linear Interaction Analysis) of space frame isolated footing-soil system considering the columns supported on individual column footings and resting on soil media.

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 6 Volume No.6 October - November – 2022
DOI:10.46647/ijetms.2022.v06i06.017 ISSN: 2581-4621

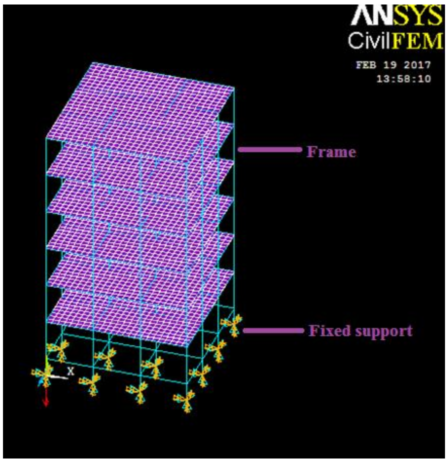

Fig 1. Conventional Analysis (NIA Model)

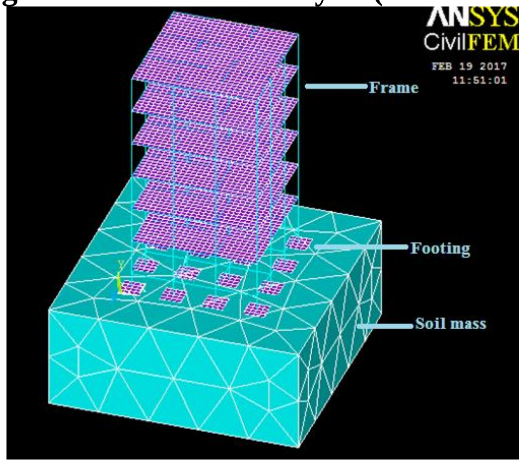

Fig 2. Soil - Structure Interaction Analysis (LIA Model)

The frame, foundation and supporting soil mass are considered to be linear elastic and to act as a single compatible structural unit for more realistic analysis. The geometric and material properties of proposed model are given in Table 1.

Table 1 - Geometric and Material Properties of Frame, Footing and Soil Mass

Component	**Description**	**Data**
Frame	Number of storey's	2, 4 and 6
	Number of bays in X and Y direction	3
	Storey height	3.5 m
	Column height below plinth beam	2 m
	Bay width in X and Y direction	4 m
	Size of beam	0.3 m x 0.4 m
	Size of column	0.4 m x 0.4 m

DOI:10.46647/ijetms.2022.v06i06.017 ISSN: 2581-4621

	Thickness of slabs	0.15 m
	Grade of steel and concrete	Fe500 and M25
Foundation	Isolated footing size	2 m x 2 m x 0.5 m
	Elastic modulus of concrete	2.5 x 10^7 kN/m^2
	Poisson's ratio of concrete	0.2
Soil (Medium Hard clay)	Extent soil mass	32 m x 32 m - 16 m depth
	Safe bearing capacity	200 kN/m^2
	Poisson's ratio of soil	0.3
	Density	2000 kg/m^3

Uniformly distributed loads are applied on floor beams and plinth beams which include self-weight and imposed load on building components shown in Table 2.

Table 2 - Loads on Structural Components

Structural Component	**Intensity of U.D.L** (kN/m)
Inner plinth beams	15
Outer plinth beams	19
Floor beams (1^{st} , 2^{nd} , 3^{rd} , 4^{th} and 5^{th} storey's) Outer slab beams Inner slab beams	32 46
Floor beams (6^{th} storey) Outer beams Inner beams	18 22

3. FEM Formulation

The FEM formulation of superstructure-foundation-soil is done in three dimensions using ANSYS software as follows.

3.1 Frame Element

The beams and columns are modeled as frame element. It is a uniaxial element with tension, compression and bending capabilities. The floor beams, plinth beams and the columns are discretized with two node beam bending element (BEAM4) with six degrees of freedom per node (Ux, Uy, Uz, Rx, Ry, and Rz). It is assumed that the joints between various members are perfectly rigid. The roof slab is discretized with four node plate bending element (SHELL63) having six degrees of freedom

DOI:10.46647/ijetms.2022.v06i06.017 ISSN: 2581-4621

at each node (Ux, Uy, Uz, Rx, Ry and Rz). The footing is discretized with eight node plate bending element (SHELL63) having six degrees of freedom at each node (Ux, Uy, Uz, Rx, Ry and Rz).

3.2 Solid Element

The soil is assumed to be linear, elastic and isotropic material. The slab and foundation are assumed to be elastic. The soil is discretized as eight-nodded (SOLID92) brick element. The element is defined by four nodes, thickness, and the material properties. Soil is modeled as a 3D element with different soil properties i.e. shear modulus of soil (G), poison's ratio (μ), unit weight of soil (γ) and modulus of elasticity (E). Using ANSYS the 3D modeling of the whole structure-foundation-soil system with soil is developed.

4. Parametric Study (Result & Discussion)

The analysis is studied by two approaches i.e. conventional analysis (NIA) and linear interaction analysis (LIA). Three R.C.C. framed structures 3x3x2, 3x3x4 and 3x3x6 with isolated footings is analyzed considering fixed base. The analysis of both the model is performed using ANSYS. Effects of SSI on different parameters are studied i.e. natural time period, roof displacement, base shear, beam bending moment, column bending moment and axial force. These are discussed one by one as followed.

4.1 Natural Time Period

Fig. 3 shows the values of natural time period of frame-footing-soil system due to various analyses. This difference is less for low rise building and goes on increasing with height of building linear interaction analysis approach (LIA model) incorporates the flexibility more precisely due to realistic idealization conventional analysis approach (LIA Model) hence the higher time period is observed for softer soil. There is about 10-12 % of increment in Natural Time Period from hard Soil in linear interaction analysis approach (LIA model) while it is almost negligible in conventional analysis (LIA model).

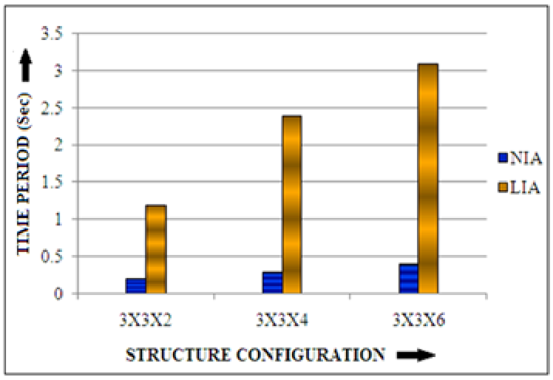

Fig. 3 - Natural Time Period of different structural frames for NIA and LIA model

4.2 Roof Displacement

Fig.4 shows the values of roof displacement in the floor of frame-footing-soil system due to various analyses.

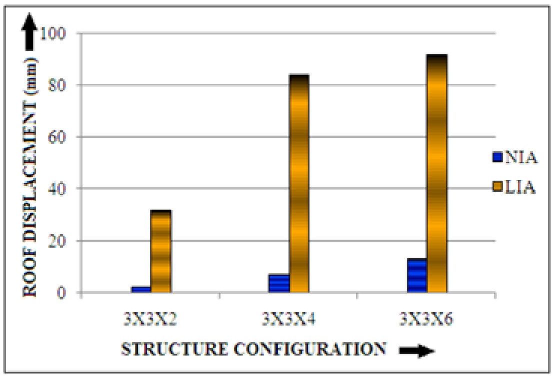

Fig. 4 - Different structural frames roof displacement for NIA and LIA model

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 6 Volume No.6 October - November – 2022
DOI:10.46647/ijetms.2022.v06i06.017 ISSN: 2581-4621

The comparison of roof displacement due to NIA and LIA reveals that the interaction of the roof displacement in floor members. Roof displacement in NIA model is about 3-4 times more than that in NIA model. However LIA model correctly reflects the flexibility as complete NIA model is used therefore roof displacement increases.

4.3 Base Shear

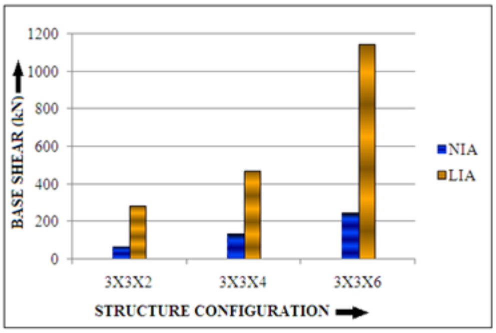

Fig. 5 - Different structural frames base shear for NIA and LIA model

Fig.5 shows the values of shear force in the beams of frame-footing-soil system due to various analyses. The comparison of shear force due to NIA and LIA reveals that the interaction effect causes redistribution of the shear forces in beam members. The inner end of the outer beams is relieved of the forces and corresponding increase is found in the outer end of the beams. This redistribution of shear forces is more significant in LIA in comparison to NIA.

4.4 Beam Moment

Fig. 6 shows the values of bending moment in the beams of frame-footing-soil system due to various analyses. The comparison of bending moment due to NIA and LIA reveals that the interaction effect causes redistribution of the moments in beam members. The inner ends of the outer beams are relieved of the moments and corresponding increase is found in the outer ends of the beams due to interaction effects. This redistribution of bending moments is more significant in NIA analysis in comparison to LIA analysis.

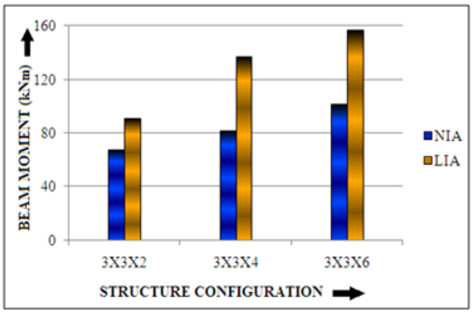

Fig. 6 - Different structural frames beam moment for NIA and LIA model

4.5 Column Moment

Fig. 7 shows the values of bending moment in the columns of frame-footing-soil system due to various analyses.

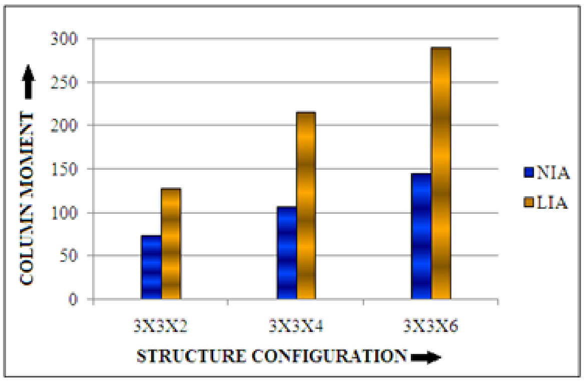

Fig. 7 - Different structural frames column moment for NIA and LIA model

DOI:10.46647/ijetms.2022.v06i06.017 ISSN: 2581-4621

The comparison of bending moments due to NIA and LIA reveals that the interaction effect causes redistribution of the moments in column members. The significantly higher values of bending moments are found due to LIA. A significant increase in the bending moment of outer columns at the column footing junction is found in LIA as well as reversal in the sign takes place because of the rotation of eccentrically loaded isolated footings.

4.6 Column axial force

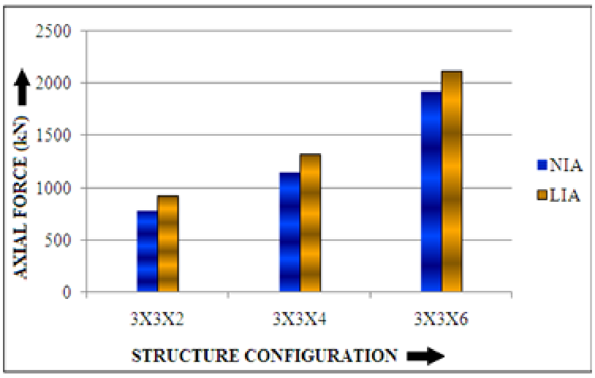

Fig. 8 - Different structural frames column axial force for NIA and LIA model

Fig.8 shows the values of axial force in the columns of frame-footing-soil system due to various analyses. The comparison of axial force due to NIA and LIA reveals that the interaction effect causes redistribution of the forces in column members. The inner columns are relieved of the forces and corresponding increase is found in the corner columns due to interaction effects. This redistribution of axial forces is more significant in case of LIA in comparison to NIA.

CONCLUSION

Natural time period is a primary parameter which regulates the seismic lateral response of the structural frames. The natural period of structure increases due to SSI effect. Roof displacement is also observed to be increasing due to incorporation of SSI. For medium hard soil the roof displacement is higher and in linear interaction analysis (LIA model) the increment is more than in conventional analysis (NIA model). The shear forces are relieved from the inner ends of the outer beams and corresponding increase is found in the outer ends of the beams due to interaction effects. Increase in soil flexibility causes increase in the base shear. For soft soil base shear increases with higher rate. Base Shear shows a remarkable increment with increase in soil softness and storey height. The interaction analyses provide higher bending moments in columns as compared to non-interaction analysis. The use of strap beam causes decrease in the bending moments in columns except at base of the inner columns. The interaction effect causes significant redistribution of the forces and moments in frame members. The interaction effect causes redistribution of the axial forces in column members. The inner columns are relieved of the axial forces and corresponding increase is found in the corner columns. This causes more uniform distribution of axial forces in the columns.

References

1. Agrawal R. and Hora M.S. (2010), ‘Effect of Differential Settlements on Nonlinear Interaction Behaviour of Plane Frame-Soil System’, ARPN -Journal of Engineering and Applied Sciences. Vol. 5, No.7, pp.75-87.

2. Al-Shamrani M.A. and Al-Mashary F.A. (2003), ‘A Simplified Computation of the Interactive Behavior between Soils and Framed Structures’,-Engineering Science. Vol. 16, No.1, pp.37-60.

3. Besides Lu and Hora (2003), **‘**studied the dynamic soil structure interaction of a twelve storey framed structure supported on raft pile foundations using ANSYS’,- Engineering Science. Vol. 13, No.3, pp.21-48.

Website: ijetms.in Issue: 6 Volume No.6 October - November – 2022
DOI:10.46647/ijetms.2022.v06i06.017 ISSN: 2581-4621

4. Deepa B. S. and Nandakumar C.G. (2012), 'Seismic Soil Structure Interaction Studies on Multistorey Frames', - International Journal of Applied Engineering Research and Development, Vol. 2, No. 1, pp.45-58.
5. Guzman T. (2010), 'Heavily Loaded Strap Footing-Design, Detailing and Behavior', - Structure Magazine. Vol. 6, No. 4, pp. 12-15.
6. Halkude S.A. and Kalyanshetti M.G. (2014), 'Soil Structure Interaction Effect on Seismic Response of R.C. Frames with Isolated Footing', - International Journal of Engineering Research & Technology (IJERT). Vol. 3, No. 1, pp.2767-2775.