Soil Structure Interaction Effect on the Dynamic Behavior of Irregular R.C. Frame with Isolated Footings

Anuradha¹ Dr. H.M.Somasekharaiha²
¹P.G. Student ²Professor
¹,²Department of Civil Engineering
¹,²R.Y.M.E.C, Bellary, Karnataka, India

Abstract— In the present study focuses on soil structure interaction analysis of 3D 2x4 bay 4 story RC frame plan and vertical irregular building resting on isolated footing supporting on soil medium with different zones and soil types subjected to normal loads and seismic loads. There are 3 linear-elastic and isotropic models of the soil beneath the structure such as fixed base, spring model and soil continuum. The dynamic analysis is carryout on RC frame irregular structure using time history analysis by the fem software sap2000. Based on the results, comparing with 3 models it conclude that the soil structure interaction investigate effect are lateral displacement, natural frequency, story drift and base shear increases and natural period is decreases.

Key words: Soil Structure Interaction, SAP2000, Natural Frequency, Natural Period, Dynamic Behavior of RC Frame with Irregular Building, Time History Analysis, Isolated Footing, Lateral Displacement

I. INTRODUCTION

In the last three decades, the effect of SSI on earthquake response of structures has attracted an intensive interest among researchers and engineers. Most of these researches focus on theoretical analysis, while less has been done on the experimental study. The interaction among the structure, foundation and soil medium below the foundation alter the actual behavior of the structure considerably as obtained by the consideration of the structure alone. Flexibility of soil medium below foundation decreases the overall stiffness of the building frames resulting in an increase in the natural period of the system.

The soil –structure interaction has attracted the attention of both structural and geotechnical engineers all over the world. Their major concern is the analysis and the design of a variety of structures, namely multi-storied buildings, towers, chimneys, industrial-structures, reactors and buried structures. The design of these structures undoubtedly represents one of the most difficult technical aspects of civil engineering practice, as it requires a synthesis of structural and geotechnical analysis.

In general design practice for dynamic behavior assumes the irregular building RC frames are fixed at their base. In reality the supporting soil medium displaced to some extent due to its natural deformation this leads decreases in the stiffness of the soil system and hence, Increase in the natural period of the system. Such partial fixity of the structure at the foundation level due to soil flexibility in turn alerts in the seismic response. The fixity of the soil at the base of the structure depends on load, soil type, size and type of foundation to be provided.

The isolated footing is used to support structure and it is designed by conventional method assuming that the foundation to be rigid. The isolated footing directly connects with the soil and reactions from the structure are carried through the supporting foundation. The super structure-soil is considered as a single unit for the analysis. The sap2000 is used to model the 3D fixed, spring and elastic soil continuum model (FEM model). The superstructure, foundation and the soil are considered as single unit and the problem is analyzed by the software (FEM). The structure and the foundation are placed on different soil conditions like soft, medium and hard. The properties like young’s modulus elasticity (E), poison’s ratio (μ) unit weight of soil (γ) and shear modulus of soil (G).

The study carry out for determining the response of a plan and vertical irregular RC building frame due to incorporation of the effect of soil structure interaction in terms of base reaction, story drift, natural period, natural frequency, and lateral displacements. The study includes the building with isolated footing on soft, medium and hard soil with different zones i.e., II, III, IV and V or Earthquake intensities as per IS 1893-2000.

A. Objectives

1) To study plan and vertical irregular buildings frame due to incorporation of the effect of soil structure interaction in terms of lateral displacements, natural frequency, natural period, story drift, and base reaction and to compare the results.

2) To study three irregularities in structures namely soil mass continuum, spring model and fixed base irregularities.

3) To study the behavior under the effect of dynamic loads using Time history analysis and to compare the results.

4) To study includes the building with isolated footing on soft, medium and hard soil with different zones i.e., II, III, IV and V and compare the results.

B. Scope of the study

1) The RC frame irregular buildings are considered.

2) The plan and vertical irregularity was studied.

3) Linear elastic analysis was done on the structures.

4) The modeled as fixed to the base.

5) The effect of soil structure interaction is ignored.

C. Methodology

1) Literatures of review existing by different researchers.

2) Selection of types of structures.

3) Modeling of the selected structures.

4) The dynamic analysis on selected building models and comparison of the analysis results.

D. The Methods of Dynamic Analysis

1) Equivalent static analysis.

2) Response spectrum analysis.

3) Time history analysis.
II. LITERATURE OF REVIEW

A. B.R.Jayalekshmi, Katta Venkataramana, R. Shivashankar, (2009) Studied the “Seismic Response of Space Frames with isolated footing on layered soil”. In this paper, Seismic response of multi storey RC space frame building with isolated footing resting on shallow layered soil. Different stiffness layer soil from very soft to stiff range is considered. The analysis of structure subjected to is code design using software ansys. Structure is presented the effect of layer soil on natural period and base shear. The effect of ssi increases the seismic base shear.

B. Vivek Garg and M.S.Hora, (2012) analyzed an “A review Interaction Behavior of Structure-Foundation- Soil System”. In this present study the building and soil is modeled by finite element method and by the conventional non-linear analysis, the columns in the building frames are assumed to be rest on the non-yielding support. The behavior of the structure due to static loading and seismic loading is analyzed by the finite element analysis. The present study is to evaluate the effect of SSI on the building frames. The differences in loading patterns, total and differential settlements in non-linear analysis are studied.

C. Mr. Magade S B, Prof. Patankar J P (2009) studied the “Effect of Soil Structure Interaction on Dynamic Behavior of the Buildings”. In this paper for the analysis purpose the building model is fixed at their base. Due to the relative movement of soil medium affect the building to deform for some extent. This decreases the overall stiffness of structural system and these increases the natural period. The response of the building is altered by the partial fixity of the foundation due to soil flexibility. The main objective of this paper is to study the effect of soil structure interaction on infill frame and bare frame with shear walls considered for different soil conditions using STAAD-PRO 2008 software package. The displacement, base shear, natural frequency is evaluated in analysis and these are compared with the different soil profiles.

D. Ayman Ismail (2014) studied the “Effect of Soil Flexibility on Seismic Performance of 3-D Frames”. In this paper the effect of soil stiffness on the seismic performance of seismic response rigid structural building frames resting on isolated footing. The flexibility of the soil cause the lateral natural period of the structural system decrease in lateral stiffness. The analysis of the effect of flexible foundation soil of 2D-3D frame-foundation and dynamic behavior from pushover analysis and static non-linear analysis using software sap2000. The effect of soil – structure interaction on lateral natural period as the same even a raft foundation is provided other than isolated footing.

E. D.K.Jain and M.S. hora (2014) studied an “Interaction Analysis of Space Frame – Shear Wall-Soil System to Investigate Foundation Forces under Seismic loading”. In this paper the soil structure analysis of G+5 RC shear wall multi storey framed buildings resting on isolated column footings. The model analysis is carried out by using the Ansys software. As for the Is code 1893-2000 the seismic lode combination are considered. The effect of SSI analysis carried out shear wall with and without on the footings for differential settlement of soil mass. The ssi effect significantly the forces and moments in the footings to the differential settlement. In the in most of column footings reduces bending moments.

F. H. Matinmanesh and M.Sales Asheghababi (2011) studied the “Seismic Analysis on Soil-Structure Interaction of Buildings over Sandy soil”. In this present paper 2D plane strain FEM element seismic SSI analysis considering 3 ground motion records in low, intermediate and high seismic motions for frequency, amplification, acceleration response and stress propagation content of the earthquakes with different subsoil, buildings height. The effect of SSI in both sandy soils amplifies seismic waves on the SSI.

III. PRESENT WORK

The present study carry out for determining the response of a plan and vertical irregular RC building frame due to incorporation of the effect of soil structure interaction in terms of base reaction, story drift, natural period, natural frequency, and lateral displacements. The study includes the building with isolated footing on soft, medium and hard soil with different zones i.e., II, III, IV and V or Earthquake intensities as per IS 1893-2000.

In the present work is to study the structural behavior of the building like displacement, bending moment on the mat foundation and on the 3D soil mass element by linear static method. And soil mass is modeled as 3D element with different soil property i.e. poison’s ratio (ν), modulus of elasticity (E) and shear modulus of soil (G).

The SAP 2000 is used to model the 3D soil element and time history analysis of the irregular RC frame buildings has been done by subjecting the whole system to earthquake ground motion. The 3D soil model and spring model are developed to study the soil structure interaction on the building.

Table 3.1 geometric parameters and dimensions RC frame building.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of storeys</td>
<td>4</td>
</tr>
<tr>
<td>Number of bays in x direction</td>
<td>2</td>
</tr>
<tr>
<td>Concrete</td>
<td>M25</td>
</tr>
<tr>
<td>Steel</td>
<td>HYSd500</td>
</tr>
<tr>
<td>Number of bays in y direction</td>
<td>4</td>
</tr>
<tr>
<td>Story height</td>
<td>3m</td>
</tr>
<tr>
<td>Slab thickness</td>
<td>175mm</td>
</tr>
<tr>
<td>Beam size</td>
<td>B-200x600mm</td>
</tr>
<tr>
<td>Column size</td>
<td>C1-200x375mm</td>
</tr>
<tr>
<td>C2-200x300mm</td>
<td></td>
</tr>
<tr>
<td>Footing size</td>
<td>F1-2.25x1.8x1.0m</td>
</tr>
<tr>
<td>F2-1.8x1.5x0.85m</td>
<td></td>
</tr>
<tr>
<td>F3-1.5x1.05x0.6m</td>
<td></td>
</tr>
<tr>
<td>Solid soil mass size</td>
<td>40x40x30m</td>
</tr>
<tr>
<td>Depth of foundation below ground level</td>
<td>1.5m</td>
</tr>
</tbody>
</table>
A. Design Consideration

1) Dead load
   The dead load is considered as per IS 875-1987 part I.
   Unit weight of concrete = 25 KN/m$^3$
   Unit weight of wall = 18.85 KN/m$^3$
   Floor finish = 1 KN/m$^2$
   Wall load on floor = 9.6 KN/m
   Wall load on floor = 4 KN/m
   Poison’s Ratio of Concrete (µ) = 0.2

2) Live load
   The live load is considered as per IS 875-1987 part II
   Live load = 2 KN/m$^2$

3) Earthquake load
   The earthquake loads are considered as per IS 1893-2002.
   Zone factors (Z) = 0.36
   Importance factor (I) = 1
   Response reduction factor (R) = 3
   Soil condition = II
   Natural period of vibration ‘Ta’ = 0.528 sec
   Average response acceleration coefficient (Sa/g) = 2.5
   Damping Ratio = 5%

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>(E) (N/MM$^2$)</th>
<th>(γ) (kN/m$^3$)</th>
<th>(G)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard Soil</td>
<td>65000</td>
<td>0.3</td>
<td>18</td>
</tr>
<tr>
<td>Medium Soil</td>
<td>35000</td>
<td>0.4</td>
<td>16</td>
</tr>
<tr>
<td>Soft Soil</td>
<td>15000</td>
<td>0.4</td>
<td>14</td>
</tr>
</tbody>
</table>

   Table 3.2 Soil types and properties.

B. Plan and Models for the RC Frame with Irregular Building

IV. RESULTS AND DISCUSSION

A study of three dimension 4 storey RC irregular RC frame building models with isolated footing and resting on soil medium and subjected to seismic load by using time history method is presented. The soil is idealized as an elastic continuum model and time history analysis is used for SSI analysis. The variation of Natural Frequency, natural period, lateral displacement, story drift, and base reaction for isolated and structural on different types of soil and zones are studied and comparison are made with those obtained from the analysis of the fixed base, spring model and soil continuum of the structure.

A. Base reaction

It is observed that base reaction is more in soil continuum and spring model compared to the fix base. In case of RC frame with irregular building, spring model story drift in zone 4 is more compared to the fixed base and soil continuum and fix base is more compared to the spring model and soil continuum in zone 5.
Fig. 4.1: comparison of base reaction of fixed base, spring model and soil continuum structures with zone 2 and soil type 2.

Fig. 4.2: comparison of base reaction of fixed base, spring model and soil continuum structures with zone 3 and soil type 2.

Fig. 4.3: comparison of base reaction of fixed base, spring model and soil continuum structures with zone 4 and soil type 2.

Fig. 4.4: comparison of base reaction of fixed base, spring model and soil continuum structures with zone 5 and soil type 2.

Fig. 4.5: comparison of base reaction of fixed base, spring model and soil continuum structures with zone 5 and soil type 1.

Fig. 4.6: comparison of base reaction of fixed base, spring model and soil continuum structures with zone 5 and soil type 2.

Fig. 4.7: comparison of base reaction of fixed base, spring model and soil continuum structures with zone 5 and soil type 3.

B. Time history results

The Time history results of peak acceleration, peak velocity and peak displacement is plotted in Fig. It is observed that peak displacement is more compared to the peak acceleration and peak velocity in all the three models.

Fig. 4.8: Comparison of peak acceleration, peak velocity and peak displacement vs. time for fixed base, spring model and soil continuum structures.

Fig. 4.9: Comparison of peak acceleration, peak velocity and peak displacement vs. time for fixed base, spring model and soil continuum structures.
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Fig. 4.10: Comparison of peak acceleration, peak velocity and peak displacement vs. time for fixed base, spring model and soil continuum structures.

Fig. 4.11: Comparison of peak acceleration, peak velocity and peak displacement vs. time for fixed base, spring model and soil continuum structures.

Fig. 4.12: Comparison of peak acceleration, peak velocity and peak displacement vs. time for fixed base, spring model and soil continuum structures.

Fig. 4.13: Comparison of peak acceleration, peak velocity and peak displacement vs. time for fixed base, spring model and soil continuum structures.

Fig. 4.14: Comparison of peak acceleration, peak velocity and peak displacement vs. time for fixed base, spring model and soil continuum structures.

V. CONCLUSION

In the present study the effect of soil structure interaction on dynamic analysis of the RC frame irregular building is resting on isolated footing with different zones and soil types.

1) In the study the different parameters such as soil structure interaction, soil types, zone types, natural frequency, natural period, base reaction, story drift and later displacement are considered and these parameters are important in the analysis of the RC frame with irregular structures.

2) As the number of story increases in the building, the lateral displacement, natural frequency base reaction and story drift also increases.

3) The natural period decreases with the increase in the number of stories in the building.

4) The value of the lateral displacement, story drift and base reaction (base shear) of RC frame with irregular building with soil continuum is more compared to the fixed base and spring model.

5) The value of the natural period of RC frame with irregular building with fixed base and spring model is less compared to the soil continuum.

6) The value of the natural frequency of RC frame with irregular building with fixed base and spring model is more compared to the soil continuum.

7) The finite element method is a useful method for studying the effect of soil structure interaction.

8) In this study, peak displacement, peak velocity and peak acceleration are obtained from the time history analysis of RC frame with irregular building at respective peak node. These values are found to be greater in the peak displacement compared to the other such as peak velocity and peak acceleration in all three models.

REFERENCES


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