Soil Structure Interaction on Tall Industrial Chimney Under Seismic Loads

Amoghvarsh A Mamledesai[1], Basavaraj M Gudadappanavar[2]
[1, 2] Dept of Civil Engineering
[2]Asst.Professor, Dept of Civil Engineering,
[1, 2] SDMCET, Dharwad

Abstract- *The response of a structure during an earthquake depends not only on the structure itself but also on the characteristics of the ground motion and the subsoil conditions. The actual behaviour of the structure under seismic load may significantly differ from what the analysis provides considering the structure to be fixed at base.These interaction effects lead to dynamic responses that may differ considerably in amplitude and frequency content from that obtained, when a fixed support is assumed. The present study focuses on the quantification of the effect of soil flexibility on the most important design variables in the seismic response of chimney structures with raft footing. For the analysis RC Chimney models are considered and the soil beneath the structure is modelled using both linear elastic soil models to represent the behavior of the soil. The soil structure interface is modelled with tied surface to surface contact. The response spectrum analysis of the soil-structure model was carried out using the general FEM software SAP 2000 for ground motions.*

Keywords- Seismic load, Response spectrum analysis, FEM software, SAP 2000.

I. INTRODUCTION

The significance of soil structure interaction is to find out the difference in the response of the structure to when the soil is considered as fixed support and the actual behaviour of the soil under the foundations. There may be chances of underestimation of the design due to lack of negligence of stiffness of the soil. Therefore it is of very much important to consider the Soil-structure interaction while modelling a structure. It is important to consider the importance of the soil structure interaction; this can be done with 2 methods. One is the multi-step method and another is direct method. This depends on the modelling strategy of the soil nearby. In the direct method, the soil and structure are modelled explicitly. In multistep, the various steps are involved such as :

- The springs of static and viscous are considered at the base of the structure.
- The springs are distributed vertically along the soil profile.

In a Civil engineering, all the structures are related to the soil. There are directly or indirectly depends on the soil or ground. The Forces such as earthquake or wind acts on the structure, only the structure will not have displaced nor the soil will have displaced, they both are inter dependent. The term soil structure interactions refer to the motion of the soil which alters the structure response or the motion of the structure which alters the performance of the soil analysis and comparing the results obtained from these buildings.

Types of soil structure interaction.

The soil structure interaction can be categorized into 2 types.

1.1 Kinematic interaction.

The free field motion means the displacement of soil is due to earthquake ground motion. The soil displacement caused by the earthquake ground motion is called as the free-field motion. This type of motion should not have followed by the footing which is located in the soil. The inability of the foundation to sink under the soil due to free field motion is called as kinematic interactions.

1.2 Inertial interaction

The inertial interaction is caused due to some forces transferred to soil due to transmission of inertial forces from superstructure. The SSI is major when the ground shaking is at lower level. The soil modulus degrades the radiation damping in the near field, when more stringer earthquake will appear, on this occasion inertial damping will be prominent. The pile foundation will be greatly damaged, due to excessive displacement at ground surface.

II. OBJECTIVE OF THE STUDY

- To analyses the behavior of RC Chimney subjected to both static and dynamic analysis.

- To analyze the Chimney considering the effect of different soil zone and soil structure interaction.
- Comparison of RC chimney for fixed base model & soil structure interaction for various soil types.
- Discussing the significance of soil structure interaction under static and dynamic loads.

III. METHODOLOGY

The methodology adopted is as given below:

- SAP2000 is used to model and analyze the structure.
- Soil structure interaction is considered and assigned to various models.
- analyze the model for Seismic (Static and dynamic) as per Indian standard codes.
- Concrete mix of M30 grade and Fe500 steel is considered for the present study.

IV. DESIGN OF MODEL

The SAP2000 is a FEM based software used to analyze various structural components such as buildings, bridges, towers and many. It is a very useful for most of the engineers working in public works, industrial, transportation and other facilities. This is an RCC Chimney.The total height of the chimney is 300 m. Bottom radius is 9 m and Top radius is 5 m. Wall thickness is 250 mm.

4.1 MODELLNG:

I.RCC Chimney with fixed base –

- Hard Soil
- Medium Soil
- Soft Soil

II.RCC Chimney with Soil springs –

- Gravel Soil
- Siltysand Soil
- Clayey Soil

4.2 DEFINING MATERIAL PROPERTIES :

The grade of concrete is readily available by default in context with IS code. We can choose the required grade. The other properties are readily available along with concrete grade.

- Young’s Modulus (steel), Es = 2, 10,000 MPa
- Young’s. Modulus (concrete), EC = 27386 MPa
- Characteristic compressive strength of concrete, fck = 30 MPa
- Yield stress for reinforcing steel, fy = 500 MPa

4.3 DEFINING AREA SECTIONS:

The RCC wall is defined in this section. The shell elements are considered, since wall exhibits both out of plane and in plane bending.

4.4 DEFINING LOADS:

Since the structure is intended to throw out the gas, there will no major live load considered in the structure. The major load will be its self-weight.

- Dead load.
- Earthquake Load. (Static and Dynamic).

4.5 MASS SOURCE:

In the seismic analysis, the mass of the structure is considered, as some ratio of the load is acted as lateral force. All the dead load will be considered with a scale factor 1. This value is considered as the seismic weight. This shall be further multiplied with the horizontal seismic co-efficient, to get the base shear values.

Standard Model:

Figure 1: RCC Chimney – Modelled in SAP

Figure 2: Model 1

Figure 3: Model 2

Figure 4 : Model 3.

Figure 5 : Model 4.

Figure 6: Model 5.

Figure 7: Model 6.

4.6 CALCULATION OF LOADS: Loads considered for the analysis of the diagrid building are:

1. Self-Weight Of The Structure:Self-weight of the structure is assigned by the SAP software based on the material density given as input.
2. Dead Load And Live Load: The dead load is assumed to be 1 kN/m2 and Since the structure is intended to throw out the gas, there will no major live load considered in the structure. The major load will be its self-weight.
3. Seismic Load: Seismic load is calculated as per IS:1893-2002 Part1.

- Zone factor (Z) – II
- Seismic intensity – 0.10
- Silt type – type II
- Importance factor – I
- Reduction factor (R) – 5

4.7 LOAD COMBINATIONS:

The load combinations taken are as shown below:

- 1.5DL

- 1.2(DL+EX)
- 1.5(DL+EX)
- 1.5(DL-EX)
- 1.2(DL-EX)
- 0.9DL+1.5EX
- 0.9DL-1.5EX
- 1.2(DL+RSA)
- 1.5(DL+RSA)
- 0.9DL+1.5RSA

V. RESULTS AND COMPARISION

The response of different models will be tabulated from SAP software. The regular model and different structural systems were also studied for different load cases. The model has been validated and the following results are compared.

Comparison of different models:

- **Equivalent Static Analysis (ESA)**

I. Displacement –ESA

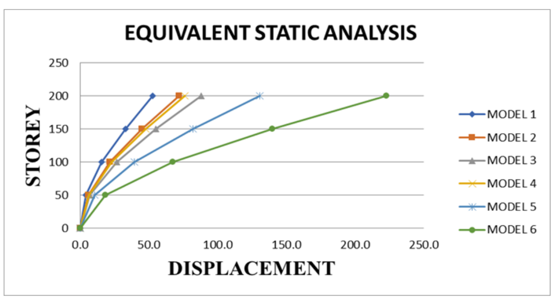

Figure 8: Comparison of Height v/s displacement

II. Time Period –ESA

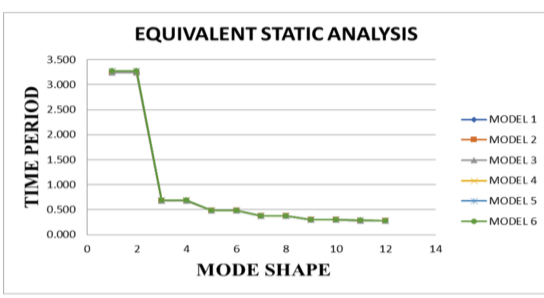

Figure 9:Time Period V/S Mode shape

III. Study of Base Shear –ESA

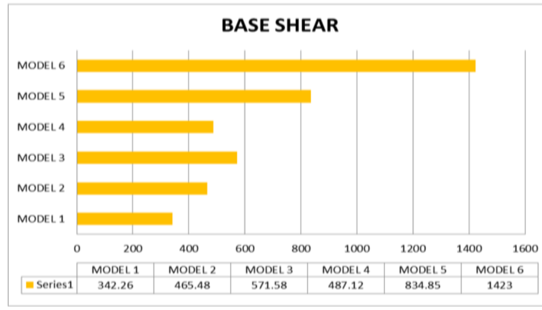

Figure 10:Base Shear

- **Response Spectrum Analysis (RSA)**

I. Displacement -RSA

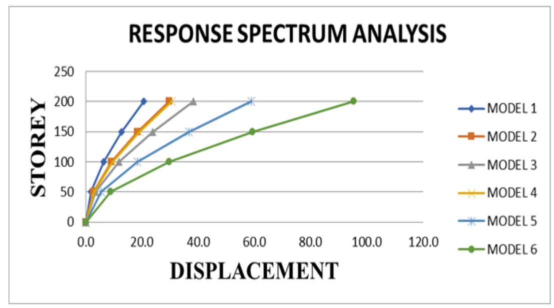

Figure 11: Comparison of Height v/s displacement

II. Time Period –RSA

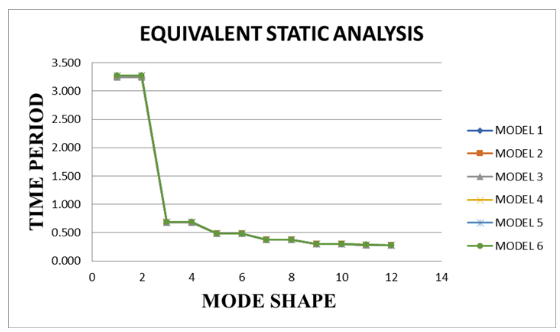

Figure 12: Time Period V/S Mode shape

- **Modal Analysis:**

➢ **Typical mode Shapes:**

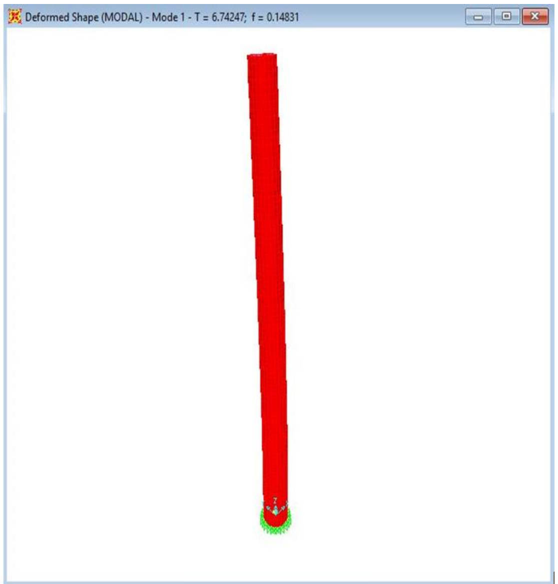

Figure 13: Typical Mode Shape 1

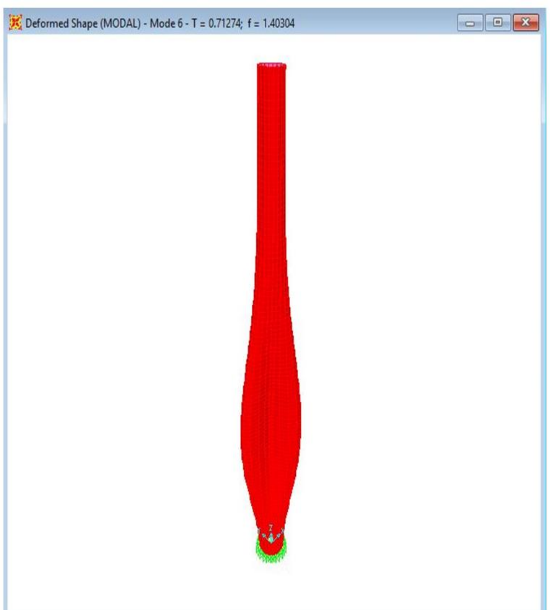

Figure 14: Typical Mode Shape 6

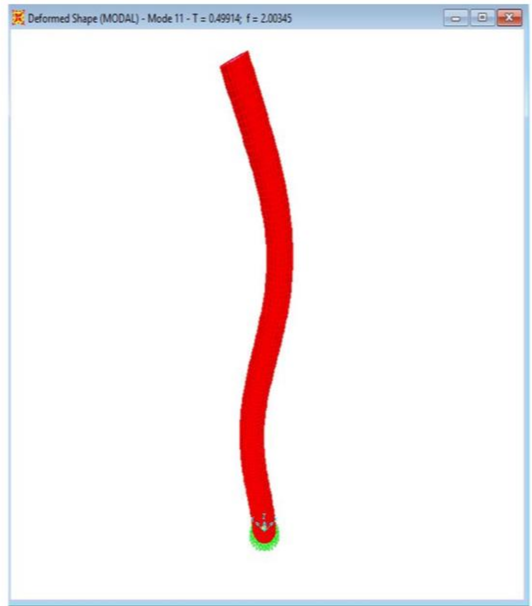

Figure 15: Typical Mode Shape 11

VI. CONCLUSION

Equivalent Static Analysis:

1. If the soil condition changes, the building displacement varies, as well. If the soil is hard lesser is the displacement and is vice versa for soft soil. It is found an increase in displacement by 26% and 40% for medium and soft soil when compared with hard soil.
2. If the soil condition changes, the building displacement varies, as well. If the soil is hard lesser is the displacement and is vice versa for soft soil. It is found an increase in displacement by 26% and 40% for medium and soft soil when compared with hard soil.
3. The time period for all the models are considerably same as the model dimension and mass will not change even for different soils.
4. The base shear is not constant in all the models. The it increases by 136% and 167% for model 2, 3 when compared with model1. However, it 142% higher for model 4, 179% times higher for model 5, 249% higher for model 6 compared with model 1,2 & 3 respectively.

Response Spectrum Analysis:

1. It is found an increase in displacement by 1.35 times and 1.66 times for medium and soft soil when compared with hard soil.

2. The displacement values for response spectrum analysis is less compared with Equivalent analysis. There is a difference of about maximum 60%.
3. The time period and base shear values will be same for Equivalent static and response spectrum analysis. This indicates, the values of base shear and time period will only dependent on the building mass, height and geometry of structure not on the analysis type.

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