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RESEARCH ARTICLE

SEISMIC RESPONSE OF VERTICALLY IRREGULAR RC BUILDING UNDER SEISMIC FORCES CONSIDERING SOIL STRUCTURE INTERACTION BY RESPONSE SPECTRUM ANALYSIS- A CASE STUDY

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ABSTRACT

In recent years, India has been considered as one of the Earthquake prone countries in the world. Studies are carried out to examine the seismic behaviour of the structure when hit by an Earthquake. Only few of the researchers have researched regarding the effects of vertical irregularities in a Structural Building considering Soil Structure Interaction. In this paper, attempt has been made to study the effects of Vertical Irregularities in a RC Building with and without Soil Structure Interaction. The structure was modelled and Analysed by Response Spectrum Analysis using E-Tabs Software. The structure analysed has been already constructed in Earthquake prone area- Sikkim which falls under seismic zone- IV.

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INTRODUCTION

Swift release of stress in the forms of waves during the deformation and brittle rupture of rocks due to the gigantic tectonic plate is an earthquake. In earlier days, we have noticed that the RC structure get severely damaged when hit by high magnitude seismic waves. The breakdown of the structure starts at the point of weakness or faults and this faults spring up due to discontinuity in mass, stiffness, strength and geometry of the structure, these discontinuity are termed as Irregular Structures. When the structures are not well designed or constructed with required strength, the structure tends to shed the strength and collapse. Regular buildings are usually symmetric in nature about the axis and distribution of loads is uniform for both gravity loads and lateral loads whereas asymmetrical buildings are generally irregular and load path is not uniform for lateral loads and gravity loads. Vertical irregularities are the irregularities which is caused due to the Sudden change of mass, strength, stiffness and geometry which results in irregular critical load path transfer for loads with respect to height of the building. One of the major causes of vertical irregularities is critical load path. The structure must possess continuous load path for the load transfer. If load transfer is asymmetrical the structure gets severely damaged and even collapse. So, the structure to be built must be well designed and the design engineers must follow the design codes .i.e. I.S codes for safer tomorrow. The codes considered for the concrete is I.S 456:200. The code book considered for the Seismic analysis of the structure is I.S.1893 (part1): 2002. The factor of safety must be considered as per code books. The structure in which Soil Structure Interaction can be defined as the coupling of the structure and the soil during an Earthquake. It is one of the most flourishing areas of research for structural engineer. Soil Structure Interaction is influenced by two types of loading .i.e. Dynamic loading and static loading. Basically, engineers neglect Soil Structure Interaction while designing ordinary structure as they evaluate the structure under the assumption of fixed based dynamic response. When the structure is hit by the seismic waves, these waves tend to

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generate vibrations or motion on the structure. In order to resist the motion, the structure needs to overcome its own inertia force which in result deals with Soil Structure Interaction.

Literature review

Monish and Karuna (2015): They have investigated on "Effects of vertical Irregularities in RC Framed Buildings in Severe Seismic Zone." The main objective was to study the effects of vertical irregularities due to the sloping ground in high rise buildings under severe seismic zone considering parameters such as displacement, fundamental natural period and base shear.

Pavan Kumar *et al.* (2014): They investigated on "Earthquake Analysis of Multi-storied Residential Buildings- a Case Study." The main objective was to study the seismic analysis of structure for static and dynamic analysis in ordinary moment resisting frame and special moment resisting frame.

Pavan Kumar and Satesh Konni (2015): They have investigated on "Effects of vertical Irregularities of RC Frame Structure using non-linear static analysis." The main objective was to study the response of the irregular structure under dynamic loads. They considered the building to be irregular in elevation and same frames were to be analyzed using response spectrum.

Shreya Thusoo *et al.* (2015): They have investigated on "Response of Buildings with Soil Structure Interaction with Varying Soil Types". Their main objective was to determine or check for the extent of variations rooted to foundation stiffness.

Puneet Sharma *et al.* (2014): They investigated on "Soil Structure Interaction effect on an asymmetrical building with shear walls. The main objective was to analyse asymmetrical buildings with different location of shear walls using conventional approach .i.e. with fixed base and flexible base along with SSI.

Karthik and Vidyashree (2015): They have investigated on "Effect of steel bracing on vertically irregular building frames under seismic loads." The main objective is to check the variation of the structure when bracings are applied and assuming structure to be vertically irregular.

Scope of the study

After 2011 Sikkim earthquake (also known as the 2011Himalayan earthquake) there is a need for assessing the seismic sufficiency of existing buildings which were severely damaged or collapsed. Further, the structures to be constructed in severe seismic zones must be designed with adequate care and seismic analysis of the structure is must. Based on various review, case study deals with the behaviour of structural building under earthquake force considering soil structure interaction. Already constructed structure was considered. The building considered is of vertical irregularities and response spectrum analysis was carried out on the structure. Column was modeled as fixed on the base. Each and every detailing of the structural element provided by the department and detailing considered while modeling are same. The effects of soil structure interaction were taken into consideration.

Objective of the study

The primary intentions of the present study are as stated:

- To undergo a case study on vertical irregularity building using response spectrum analysis.
- To undergo a case study on vertical irregularity building using response spectrum analysis considering soil structure interaction.
- Comparing the parameters obtained from the analysis of a structure for response spectrum with and without soil structure interaction.

MATERIALS AND METHODS

Firstly, various journals were reviewed ad necessary information were gathered. Then, the selected model was modeled and analyzed considering soil structure interaction. The structural building considered is vertically irregular in nature and comprises of B-3 and G+4 with 3 metre of storey height. The soil bearing capacity considered was 180 kN/m^2. The main objective of the study was to check the response of the structure during Earthquake. The structure comprises of B-3 with the following areas i.e. 18.01x5.79(m) for Basement 3, 18.01x9.41 (m) for Basement 2 and 18.01x15.70 (m) for Basement 1. It also comprises of G+4 with the following areas .i.e. 18.01x15.70 (m) for the Ground Floor,18.01x16.92 (m) for the First Floor, Second Floor, Third Floor and the Fourth Floor respectively. The structure was modeled considering E-Tabs Software. The characteristic compressive strength of concrete considered was M30 and the characteristic strength of reinforcement considered was Fe 500. The frame properties were defined such as Beams of size 500x400 mm and 600x600 mm, Columns of varying sizes i.e.400X300mm, 500x450mm, 600x500mm, 300x400mm, 500x400mm respectively. The thickness of Slab considered was 150mm respectively. The Shell loads considered were Dead load of 1KN/m^2, Live Load of 3,4 and 5 kN/m^2 and Floor Finish of 1 kN/m^2. The Frame loads considered were Exterior wall load of 11.65 kN/m and Partition wall load of 5.08 kN/m respectively. After necessary data(s) were entered the modeled structure was analyzed and checked. For the same structure Response Spectrum Analysis was carried out considering Soil Structure Interaction in both X and Y Direction. The Base shear was calculated considering following parameters, Seismic Zone–IV, Average Response Acceleration Coefficient for rock or soil sites (S_a/g)-1.318 in X Direction and 1.327 in Y Direction, Response Reduction Factor(R)-5, Zone Factor (Z)- 0.24, Importance Factor(I)-1 respectively. The Base Shear in X Direction was 945.94 kN and 952.404 kN in Y Direction. The deflection was of 84mm as per I.S 1893(part1):2002.

RESULTS

After modeling and analysis were carried out, various parameters were considered and compared such as Base Shear, Displacement, Storey Drifts and Overturning Moment.

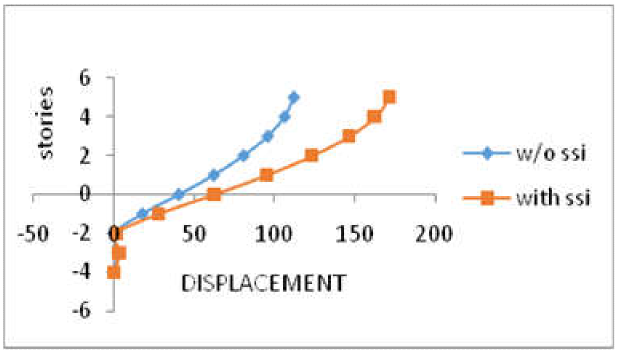

Fig.1. Comparison study of storey Displacement with and without Soil Structure Interaction in X Direction

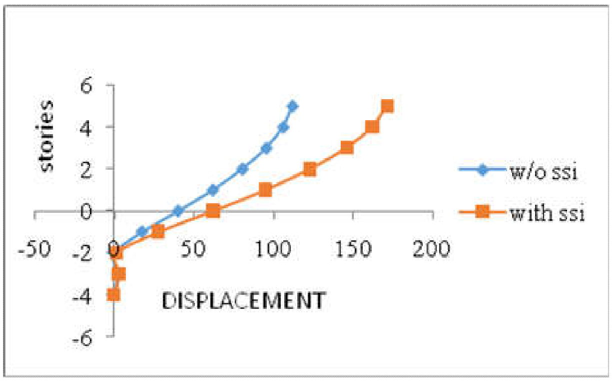

Fig.2. Comparison study of storey Displacement with and without Soil Structure Interaction in Y Direction

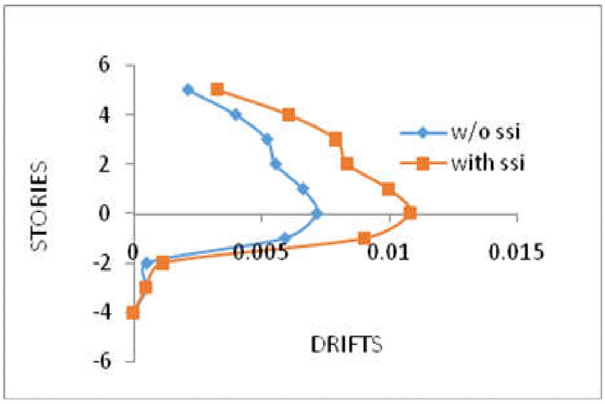

Fig.3. Comparison study of storey Drifts with and without Soil Structure Interaction in X Direction

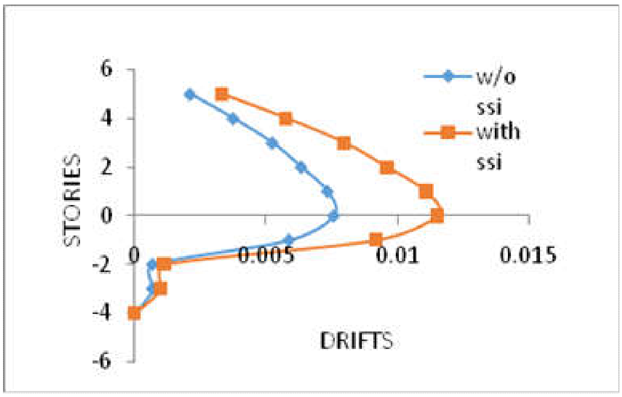

Fig.4. Comparison study of storey Drifts with and without Soil Structure Interaction in Y Direction

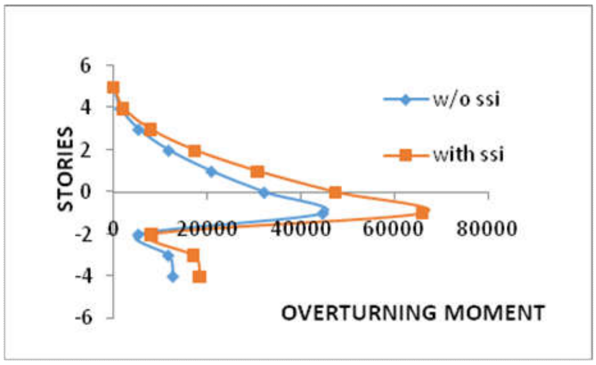

Fig.5. Comparison study of over Turning Moment with and without Soil Structure Interaction in X Direction

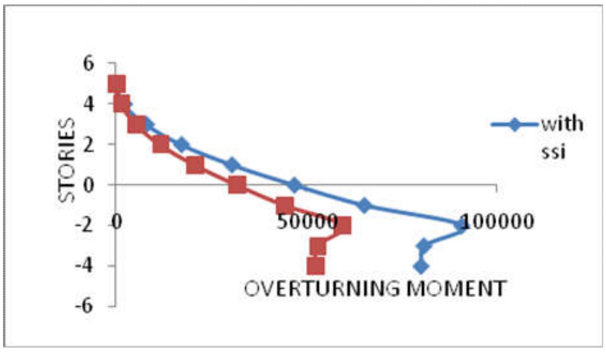

Fig.6. Comparison study of over Turning Moment with and without Soil Structure Interaction in Y Direction

DISCUSSION

In Figure 1, the comparative displacement at respective stories for Response Spectrum in X Direction with and without Soil Structure Interaction, here the displacement at top storey is 55.5mm larger with SSI than without SSI. So 53.52% more displacement is observed when the SSI is taken in to account comparative to without SSI. In Figure.2, the comparative displacement at respective stories for RS in Y Direction with and without SSI, here the displacement at top story is 59.357mm larger with SSI than without SSI. So 52.95% more displacement is observed when the SSI is taken in to account comparative to without SSI. In Figure.3, the comparative drift at respective stories for RS in X Direction with and without SSI, here the drift at ground level is 0.00367 larger with SSI than without SSI. So 51.2% more drift is observed when the SSI is taken in to account comparative to without SSI. Maximum drift is observed in ground level as the stiffness and fixity conditions changes between the stories. In Figure.4, the comparative drift at respective stories for RS in Y Direction with and without SSI, here the drift at ground level is 0.00391 larger with SSI than without SSI. So 51.65 % more drift is observed when the SSI is taken in to account comparative to without SSI. Maximum drift is observed in ground level as the stiffness and fixity conditions changes between the stories. InFigure.5, the comparative Overturning Moment at respective stories for RS in X Direction with and without SSI, here the Overturning Moment at basement 1 is 21286.3 kN-m larger with SSI than without SSI. So 47.66 % more Overturning Moment is observed when the SSI is taken in to account comparative to without SSI. In Figure.6, the comparative

Overturning Moment at respective stories for RS in Y Direction with and without SSI, here the Overturning Moment at basement 2 is 31341.7 kN-m larger with SSI than without SSI. So 52.6 % more Overturning Moment is observed when the SSI is taken in to account comparative to without SSI. Due to vertical irregularities and large lateral spacing between the foundations in Y direction, the overturning moment is more in basement 2 than in basement 1in Y axis.

Conclusion

From the above parameters considered the following conclusion were drawn:

1. As per discussion we have displacements which tends to exceed limit of IS:1893 (pat1):2002, so it is needed to improve the stiffness in structure by placing bracings or infill.
   a. Displacement is noticeable from ground storey.
   b. Ground storey it is very negligible; this response is due to presence of foundation at each of these levels.
2. Drift is maximum at ground level as the stiffness in structure changes from the below stories.
   a. Below ground storey it is very negligible; this response is due to displacement values.
3. Over turning moment is maximum at basement 2 decreases gradually as the story shear decreases when SSI is not considered.

a. But when SSI is considered over turning moment increases from basement 1 to 2 and later it decreases.

4. The storey response is considerably varying in Y direction than X direction. As the structure has vertical irregularity in footing level in Y direction. Thus it is advisable to analyze and design the model for response spectra in the direction of irregularity.
5. As per above conclusion it is advisable to check model with the SSI for max deflection and minimum base shear.

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Scope for further study

1. Considering the infill in analysis, for the deflection and story shear.
2. Considering the SSI when there is shear wall in the landslide direction.
3. Analysing the structure for time history data, for results near to accuracy.
4. Analysing the structure for static earthquake and wind force.

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