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Seismic Effect Study of Structures in Different Soils

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Abstract:- Every structure transfers its reactions to ground through the foundation. In the present situation every building is analysed as the base is fixed or hinged. Fixed condition is assumed if the structure rests on piles and hinged condition is assumed if the structure is supported by isolated footing. IS code 1893-2002 gives guidelines to earthquake resistant design of structures. An attempt has been made to validate the accuracy of the base condition assumptions and completeness of the guidelines in IS: 1893-2002. For this attempt, structures with different base conditions were analysed for seismic response. From the analysis it is seen that the use of fixed base models can not accommodate soil structure interaction. The software used for analysis was SAP2000, which is a Finite Element analysis package. An idealization for the foundation has been arrived.

Keywords:- seismic effect, zone factor, drift, response reduction factor, winkler foundation.

I INTRODUCTION

Earthquakes resulted in damage to structures that were not consistent with what was expected using purely elastic technique of analyses. Currently the seismic design codes use Response reduction factors R to define the design base shear from an elastic response spectrum. These reduction factors are to account phenomena such as over-strength, redundancy, damping, multi-mode effects, system ductility, radiation damping, and soil-structure interaction (SSI). Usually a structure's base is assumed to be experiencing the same motion as that of the free field ground motion which would be true if the base is rigid. In soils, generally this is not the case, and so the motion of the base field is different from that of the free field. The base motion could include a rocking component as well as horizontal translational and vertical components. Therefore the motion experienced at the base could be greater or weaker than that of the free field.
Soil-structure interaction is the phenomenon that involves the analysis of the relationship between the structure and the soil and how it affects the motion . As waves from an earthquake reach a structure, they produce motions in the structure itself. These motions depend on the structure's vibrational characteristics and the structural layout. For the structure to react to the motion, it needs to overcome its own inertia, which results in an interaction between the structure and the soil.

II RESEARCH SIGNIFICANCE

It is necessary to consider what is currently known about Soil Structure Interaction (SSI) effects and what can realistically be observed and analysed by current methods. The motivations for an SSI experiment can be itemized as:

1. To study the behaviour of Reinforced Concrete Building using Indian standard code of practice without SSI.
2. To study the effect of soil-structure interaction on response of Reinforced Concrete Buildings.
3. To study the effects of Soil structure interaction on various components of the building is studied.

The main aim is to study the behaviour on basement floor columns, since these columns together with the pilecaps are the most critical elements in securing the integrity of superstructures during earthquakes.

III METHODOLOGY FOR THE ANALYSIS

Modelling of Reinforced Concrete Buildings was done using SAP2000 which is a finite element software. The columns, beams and piles were modelled as line elements. Floor slabs and footing slabs were modelled using shell elements. Soil elements were modelled as solid elements with appropriate Young's modulus and Poisson's ratio. The structures with fixed base and hinged base were analysed by "equivalent static method" as specified in IS:1893 -2002 Part I. The structures those accounts SSI were analysed by "Response spectrum method". The spectrum used was as per IS:1893-2002 Part I. Appropriate zone factor and soil type were given for each model.The results between models considered SSI and those models without considered SSI are compared.

MODELLING OF STRUCTURE

Modelling of the structure is done using SAP2000. Building modelled has a length of 24m and breadth of 24m.The storey height was 4m and span of each beam was 4m.The building was analysed to Zone II, Zone III, Zone IV and Zone V as per IS:1893 :2002. The same building with 2 stories, 5stories and 10 stories were analysed. The soil type was another variable for the analysis. The beams and columns were modelled as line elements and slabs were modelled as shell elements. Loads were given as per IS: 875, IS: 1893 . Soil is modelled as linear spring elements for Winkler foundation. For an exact analysis soil was modelled as solid elements. Six type of base conditions modelled

For earthquake analysis equivalent static method as per IS: 1893-2002 is used. For response spectrum method spectrum as per IS: 1893-2002 is used.

Zone factor, Z = 0.10, 0.16, 0.24 & 0.36

Importance factor = 1. Response reduction factor is taken as = 5.

These models were analysed and a comparative study is done on natural time period of each models. Variations in bending moments on columns and beams and amount of storey drift are compared. Graphs are shown in the discussion part.

Model 1 For Model 1 the base condition given is fixed base. The fixity is given at a depth of 1.5m from the plinth beam level.

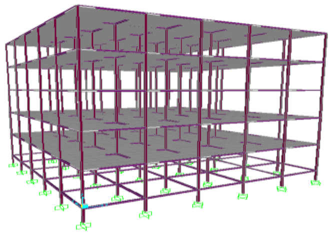

Fig.1. Model-1

Model 2 For Model 2 the base condition given is hinged base. The hinge is given at a depth of 1.5m from the plinth beam level.

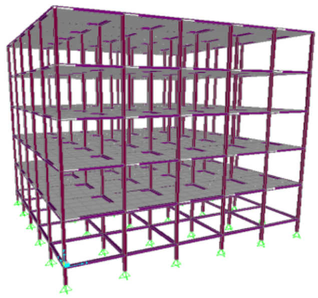

Fig.2. Model-2

Model 3 For Model 3 the base condition given is Winkler foundation. Winkler foundation is modelled as liner springs. The piles are modelled as line elements and the pile is connected to the springs to take care of the lateral and axial loads. This model is analysed using response spectrum analysis and the spectrum used was as per IS:1893-2002.

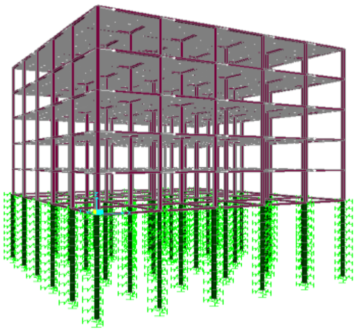

Fig.3. Model-3

Model 4 For Model 4 the pile is modelled as line element and fixity is given at a depth of ten times diameter of the pile.

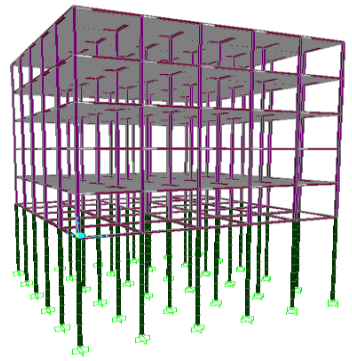

Fig.4. Model-4

Model 5 For Model 5 the piles are modelled as line elements and the pile is discritized to 40cm length. Soil is modelled as solid elements and the appropriate value of Young's modulus and Poisson's ratio were given. The pile nodes are connected to the solid element nodes. This model is analysed using response spectrum analysis. IS:1893-2002.

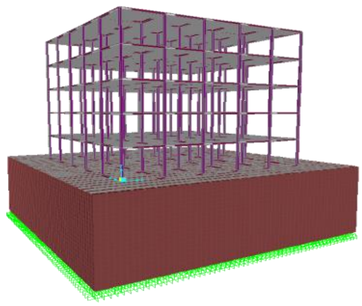

Fig.5. Model-5

Model 6 For Model 6 the base condition given is Winkler foundation. Winkler foundation is modelled as liner springs. The isolated footings are modelled as shell elements and the footing is connected to the springs to take care of the lateral and axial loads. This model is analysed using response spectrum analysis and the spectrum used was as per IS:1893-2002.

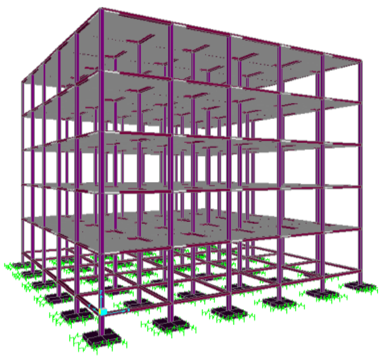

Fig.6. Model-6

SOIL TYPES CONSIDERED

The three soil types as specified in IS:1893-2002 were considered for analysis. The classification is
a) Type I – Hard soil ,b)Type II – Medium soil, c)Type III – Soft Soil

IV. RESULTS AND DISCUSSION

NATURAL TIME PERIOD COMPARISON

The building models are analysed using SAP2000.The natural time period of each building is obtained and is compared with the values according to IS:1893-2002 provision for calculation of natural period of structures without infill.

$T_a = 0.075 h^{0.75}$ Where

T_a = Natural time period of vibration in seconds.

h = Height of building, in m.

Here we can see that as the time period increases, as the height of building increases and without considering the base fixity the time period is calculated.

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Fig.7 Natural Time period variation for different models in comparison with IS:1893-2002

In the industry, pile foundations and isolated footings are idealized as fixed and hinged bases for the analysis. For seismic analysis the natural time period is calculated using the expression given in IS 1893-2002. Here we found out the exact time period for various structures with different base fixity with the help of the software SAP2000. Fig 7 shows the variation in time period for different models. It is observed that as the storey height increases the codal formula gives lesser value for time period. It is due to the fact that the equation given in IS:1893-2002 is an empirical formula and it does not considers the stiffness of columns but the storey height. The value of Time period for fixed and hinged foundations is less compared to the flexible foundations. Flexibly supported structures tend to have a longer natural time period T_a than rigidly supported structures. For the flexibly-supported structures, part of its vibrational energy dissipates into the soil through waves.

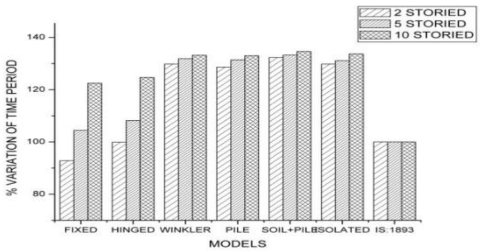

Fig.8. Percentage variation in time period compared to IS:1893-2002

Fig 8 is obtained by taking the ratio of the time periods of the models with the time period obtained from IS:1893. From the fig 8 it is observed that the variations of time period in the fixed base models are incremental as the height of building increases. Variations of time period in flexible base models are incremental but that is negligible only. From the observation it is concluded that the use of fixed base condition will result in errors in the bending moments and storey drifts. So the use of fixed base conditions should be avoided for analysis.

BENDING MOMENT COMPARISON FOR COLUMNS AND BEAMS.

The models are grouped into three categories according to the storey numbers.

1. Models with 2-stories
2. Models with 5-stories
3. Models with 10-stories

For comparison of the bending moments in columns a typical column in the basement floor is considered. The column in the basement floor is considered because these columns will be experiencing severe base shears. For comparison of beam moments one beam from first floor is selected. The bending moment values are tabulated and the graph is drawn for comparing. In the x-axis different models are numbered and in the y axis bending moment ratios are given. Bending moment ratio is ratio of bending moment in the fixed base model to the bending moment in other models. Bending moment ratios are taken, because the moment values in each column will be different but the ratio between the other models will not vary. the results are tabulated and plotted graphs are shown in following figures. Since SSI is important only in the case of seismic loading bending moment values are taken for the seismic case only.

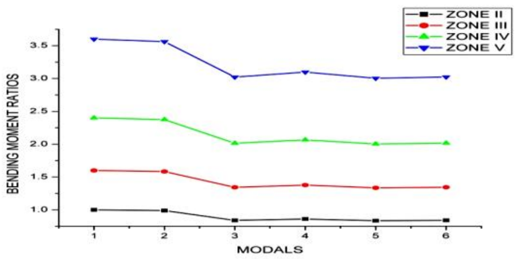

Fig.9. Bending moment variation in typical column for different models with soil type 2 and no: of stories 5.

From the Fig 9 it is seen that the bending moments in the fixed and hinged base models are high than those with flexible foundations. The variation is about 20%. These variations are constant irrespective of the seismic zones. The variation of bending moments across the zones is according to the zone factors. The variation of bending moment between the rigidly supported structures is negligible. It is observed that this correlation is due to the similarity in the natural time period.

From the natural period comparison we have seen that the natural period of the structures differs significantly according to their base rigidity. The natural time period "Ta" for flexibly founded structures was higher than the fixed base structures. From the fundamental principles it is clear that as the natural period increases stiffness reduces and hence the forces attracted will be less. In IS:1893-2002 the expression given for horizontal seismic coefficient is $A_h = \frac{ZIS_a}{2Rg}$

Where A_h = horizontal seismic coefficient.
Z = zone factor.
R = response reduction factor.
S_a/g = Average response acceleration coefficient.
I = Importance factor.

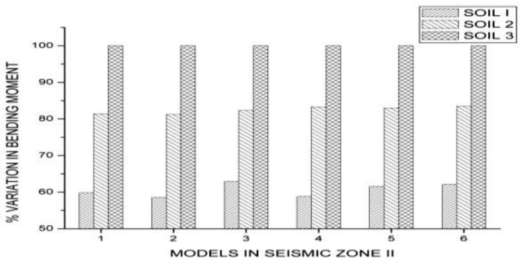

Fig.10. Percentage variation bending moment in typical beam in different models with Seismic Zone II

From Fig. 10 it is observed that the variation of bending moments in all the models except in Model 4 is according to the spectral acceleration coefficient. In Model 4 base is fixed at a depth of ten times diameter of the pile. As the height of building increases the diameter of pile increases and number of piles increases and it results in increase in stiffness. This increase in stiffness at the base level results in the higher bending moments. Hence we can say that Model-4 is not a consistent model. So it can not be recommended for high rise buildings.

STOREY DRIFT VARIATIONS

The absolute drift of each storey in each model is noted and the corresponding graphs are drawn.

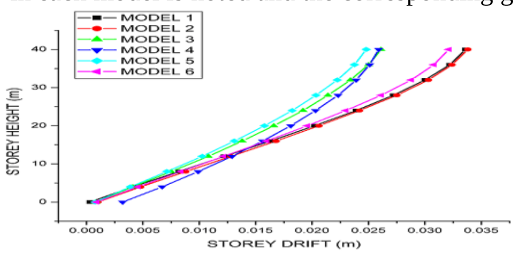

Fig.11. Variation of storey drift for 10 storied building.

Since the bending moments in the columns showing much difference between the fixed base model and the flexible base models, storey drift has the same amount of variation. As the number of stories increases the amount of the variation becomes large. In the case of high rise buildings the control of horizontal sway is the main problem. More horizontal stiffeners has to be implemented to control storey drift. With flexible foundations we can achieve economy due to exact analysis.

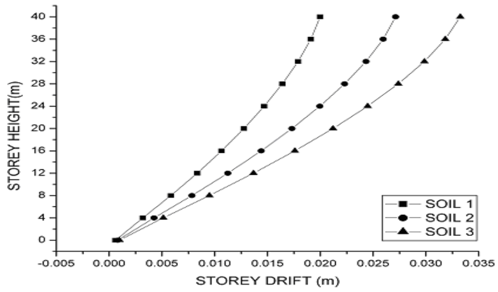

Fig.12. Variation of storey drift for 10 storied building (Model 6).

From Fig 12 it is seen that as soil type varies the drift increases for all the models. This increase is due to the effect of corresponding spectral acceleration coefficient.

For Model-1 and Model-2 the drift at the base levels are negligible, because the base is assumed as "translation restrained in any direction". But the bending moment in the columns are very high compared to other models and hence large drift is observed at higher levels.

It is observed that as the storey height increases Model-4 shows non consistent behavior of drift. This difference is due to the fact that the relative stiffness of the pile with respect to the total structure became negligible. So we can conclude that the Model-4 is not suitable for the analysis of high rise buildings.

If the storey height is very less the drift values are negligible and hence the comparison shows very less differences.

V. CONCLUSIONS

An attempt has been done to check the accuracy of the base fixity types assumed for the analysis. For the analysis six models with different base conditions were used. A comparison is done between the models. The results were represented in graphical form. From the results following conclusions are arrived.

1. While considering the SSI the design forces, moments and storey drift is less up to 20%. This variation is significant for high rise buildings in the higher earthquake Zones. This variation can save cost highly.
2. For structures with fixed and hinged base, the drift at the base will be zero and the stiffness should be carried to the higher floors, but here the storey drift is higher for the fixed and hinged base. So it can be concluded that the models which are not considering Soil Structure Interaction effects gives erratic results and the safety factors given to nullify the effects are very high hence lead to an uneconomical design.
3. Since the Model-4 shows higher values for bending moments and storey drifts compared to other flexible base models. As the soil type changes this variation is found significant. Hence we can not recommend the method of idealisation as Model-4.
4. Modelling the soil with solid elements (Model-5) needs high performance computers to perform the analysis. Even with high performance computers the time consumed for a single analysis will be very high. For easy accommodation of the Soil Structure Interaction effects we can model a structure with Winkler supports, where soil is modelled as linear springs. For the exact solution one should use solid soil models.

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