Soil-Structure Interaction on Pile Raft Foundation in Multi-Storey RC Building with Vertical Irregularity

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Abstract. Tall buildings are normally supported on certain kind of piled foundation that is exposed to a mixture of vertical, horizontal and overturning forces. Combination of the pile-raft foundation may be a telling sort of foundation system for skyscraper as a result of the raft is in a position to provide an inexpensive rate of each unwieldiness and load resistance. Now in practice, all the foundation of high-rise building are design as a fixed base i.e. the relative behavior of soil and foundation are not to be considered. In this paper, soil structure interaction effect is considered in pile raft foundation of a multi-story building. The G+21 multi-story building is analysis in software ETABS 2016 and SSI is carried out in PLAXIS 3D. Here, vertically irregularities took in the modeling of G+21 story RC MRF building. The seismic analysis of the model is carried under the three different types of analysis methods i.e. Response Spectrum (RS), Equivalent Static Load (ESL), and Time History (TH) analysis suit to Bhuj time history record is used for analysis of the moment resistant frame (MRF) reinforced concrete (RC) building. The parameters being used for the comparative study of soil structure interaction (SSI) are base shear, story drift, and story displacement. Numerical results acquired using SSI model situations are matched to those equivalent to fixed-base situations. The present study shows that the effects of soft soil deposit might be adverse to the earth vibration reaction of the building and avoiding SSI in the evaluation might be prime to unsafe design.

Keywords: Seismic soil Structure Interaction, Pile Raft Foundation, Moment Resisting Framed Building, ETABS, PLAXIS 3D

1   Introduction

During the previous 50 years, critical improvement had been made in compassionate the idea of quakes and in what way they harm structures, and an enhancing the earth vibration display of the fabricated circumstance. However many residues were mysterious in respect to the conquest or slaking of quake deterioration globally, leaving space for withal research. During previous and modern earth vibration, it is understood that the SSI influences perform an energetic part in shaping the performance of the structure. The seismal SSI of multi-story strengthened RC structures turns out to be significant after the pulverization of the ongoing serious quake. For the building laid on the dirt, the movement of the base of the building will be not quite the same as the instance of a fixed base, as a result of the coupling of the dirt structure framework. The facts demonstrate that considering the dirt when figuring the seismic reaction of the structure does perplexity the investigation altogether. It likewise makes it fundamental to evaluation

surplus key components, which are requesting to control, for example, the properties of the dirt. For the building established on the dirt, the movement of the base of the building will be unique in relation to the instance of a fixed base in light of linking of the structure-soil framework [4],[5]. For building composition, it's routine to apply for utilizing a clear approach, like equivalent static load (ESL). This movement had many shortcomings, that is welcome, thanks to its plainness and a scarcity of other sensible moves. [1],[2]. The suchlike associate moves could also be thought to be force-based from the strategies prime stress is on the forces among the structure. The learning aims the SSI for elevated irregular buildings on raft footing; calculate the tactic of Indian seismic codal provisions for analysis techniques through the design of earthquake resistant structure; to debate the substitute way out for cases in which present allocation does not lead to the adequate outcome and to compute the consequences SSI on the structural replay so that designers could be aware of the likely impression of their judgment. TH analysis had been accomplished to calculate ESL and also the RS method; a Bhuj time history record had been used. Constant research with completely different ways of research method; style parameter of the beneath soil condition is distributed to search out on the unstable demands as well as the basic period, story displacement, story drift, story shear. The outcomes demonstration that SSI contains a noteworthy impact on unstable response demands.

2 Producer for seismic examination

Initial design method, equivalent static seismal forces are accustomed to verify the design inner force of structural elements victimization linear elastic studies of the structure and, in turn; decide the design strength for element demands.

2.1 Static Load Method

According to IS 1893 (part-1) (2016), the design base shear (V_b) on any chief path of a building shall be determined by [9]:

$$V_b = A_h.W \tag{1}$$

Where, A_h and W is the design horizontal acceleration constant value and seismal weight on the building respectively. The approximate basic translational natural period T_a of oscillation, in second, shall be calculable by the subsequent results: wherever h is the elevation of the structure.

$$T_a = 0.075 \ h^{0.75} \quad \text{(For RC MRF structure)} \tag{2}$$

Fig. 1 shows the design rushing coefficient (Sa/g) (corresponding to 5% damping)-equivalent static method.
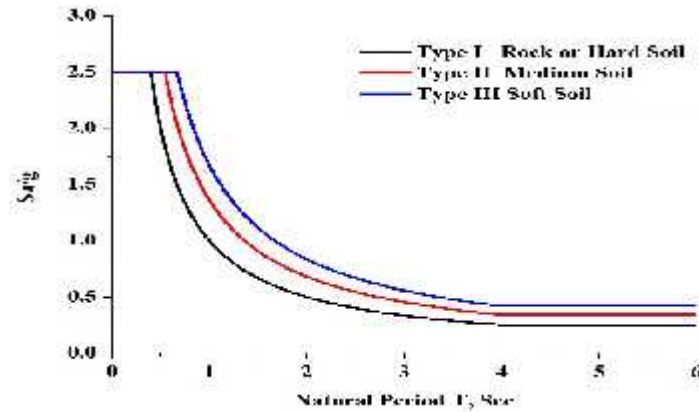
Fig. 1. Spectra for Equivalent Static Method

2.2   Linear-dynamic statistical analysis method

The linear dynamic analysis is relevant for all kinds of structures, whereas the horizontal force technique of examination has several restraints on its use because of the "fear" that it might offer traditional leads to bound circumstances; on the other hand, in spite of this drawback the tactic continues to be loosely used because of its simplicity of application [3]. Response spectrum analysis includes enough modes of shaking to capture sharing of a minimum of 85% of the erection's mass in every of two orthogonal ways [7].
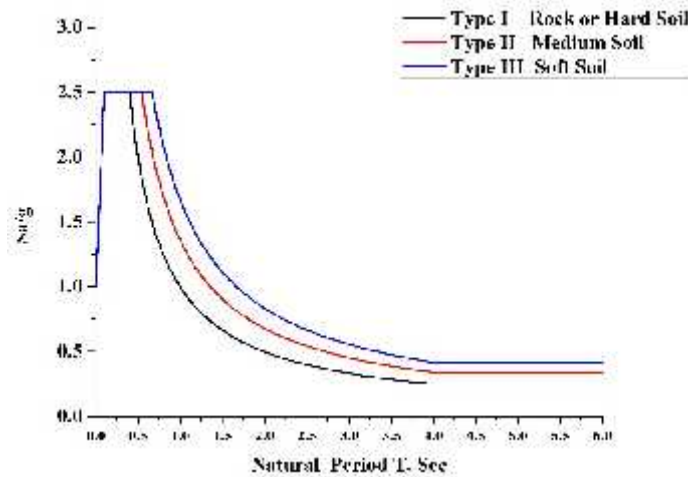

Fig. 2. IS 1893 (Part 1) (2016) Design response spectrum

Fig. 2 shows the spectra for RS curve for the present study, it should be noted that, IS 1893 (Part 1) (2016) incorporation of damping (5% damping) constant in the flexible response spectra equations. Therefore, no damping quantitative relation had been utilized in this analysis methodology.

2.3   Non-Linear Time History (TH) Method

The quake record within the kind of the rushing time history is involvement at bottom of structure [8]. Reaction of structure is calculated at every time for the intact spell of an earth movement. This technique varies from response spectrum analysis as a result of the impact of "time" is taken into account. Nonlinearities that usually arise during quake can be comprised in the time-history analysis. Complete mass partaking is crucial to get truthful earthquake forces. Generally, solely 80–95% involvement is gained in RS analysis. The results of the time history rest on principally on the specific of the used rushing time-history records and also the profiles of their corresponding elastic RS [6], the motive of victimization the nonlinear time history technique is to authenticate the result gained through different code specific scrutiny measures (ESL and RS methods) beside a time-history record.

3   Scientific modeling

3.1   Structural Description and Soil Material Properties

Since the previous 2 eras, the building surroundings in the Republic of India has a comprehensively exploited medium rise RC buildings partaking fifteen floors, the utmost elevation indorsed through native officials in maximum localities. These erections are designed through completely altered layout and systemic schemes having variable stiffness parameters that will have a good influence on their seismic performance. Vertical Irregularity in building as shown in Fig. 3, geometrical layout and nine equivalent divisions with a classic division width of 2m in x and y ways. The elevation of every floor is taken as 3m and consider the thickness of the slab as 150 mm and using M30 grade of concrete and Fe 500 Steel. Considering Floor finish 1 kN/m^2, imposed a load of 2 kN/m^2 and live load as 2 kN/m^2. The structural properties are shown in Table 1.

Table 1. Structural design parameters

Beam size	230 X 450 mm
Column size	
Up to 5 story	300 X 600 mm
6 to 10 Story	300 X 575 mm
11 to 15 story	300 X 525 mm
16 to 21 story	300 X 500 mm
Poisson's ratio	0.20

The soil properties used for sandy clay and dense sand were taken based on the geotechnical soil investigation report of Surat city. The values used are shown in Table 2. The thickness of raft is considered as 500 mm. The surface load on the raft was taken as 150 kN/m^2. The diameter, length, and a number of the pile were taken as 400 mm, 8 m, and 4 number respectively. The soil layer of sandy clay and dense sand are 3 m and 5 m respectively from the ground level.

Table 2. Properties of Soil used

Property	Sandy Clay	Dense Sand
E (KPa)	17500	34520
μ	0.35	0.3
Ø	6.20	12.7
c (KPa)	5.69	3.29
SPT value 'N'	22	14
(kN/m³)	18.5	18

Figure 3 shows the two different types of setback provides in the elevation of the building.

Vertical Irregularity in Model-1   Vertical Irregularity in Model-2
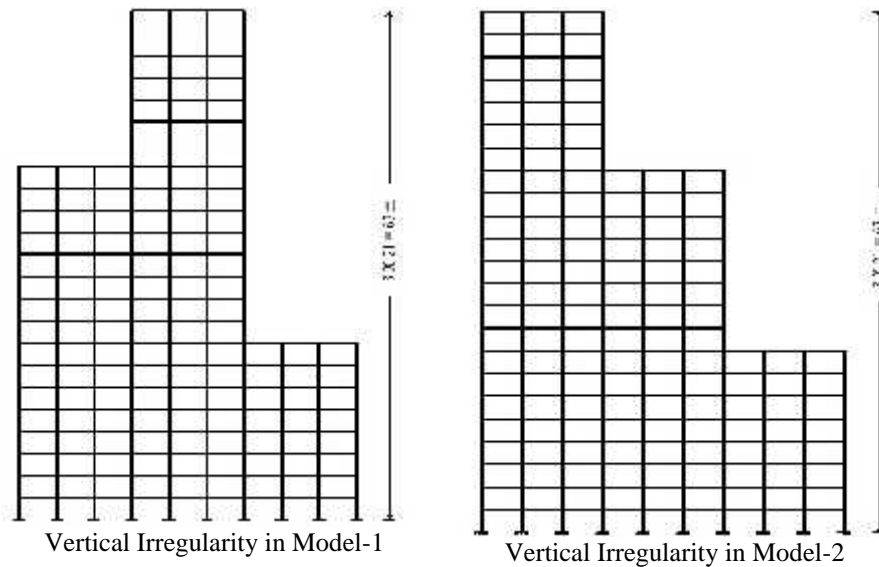
Fig. 3. Vertical Irregularity in structure for fixed base condition

4. Numeral outcomes and Views

Comparative work is disbursed to calculate design factor effects on the structural seismal demands in several methodologies of research and to live base shear, story drift and displacements for three ways of evaluation, the design factors embrace the SSI. Erection a model with two totally different systems had studied to gauge impact of SSI on resolution and analysis for base shear, drift, and movement. Time history record of Bhuj has been taken to analyzing the models.

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4.1 Drift Relation Reaction

Drift magnitude relation is that the most comparative movement of every floor separated by the peak of an equivalent level is a crucial variable had been gauged. Story drift magnitude relation response demand is explored for the studying highrise irregular erction of 21-floor victimization totally varying analysis are shown diagrammatically in Fig. 4.
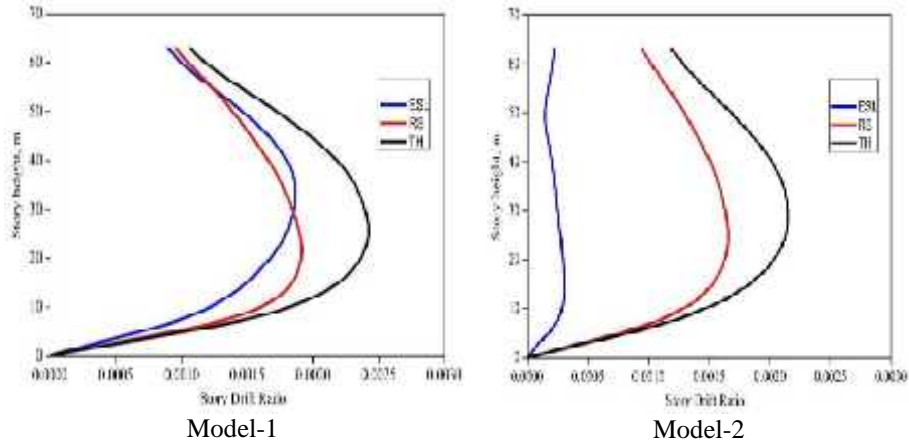

Model-1   Model-2

Fig. 4. Drift ratio for the 21-story building model

Fig. 4 represent the drift ratio bifurcation of the 21-floor model rises regularly and touches peak importance at the 10th-floor level. The peak profile in Model-1 and Model-2 using ESL are 0.0017 and 0.0003, RS are 0.0019 and 0.0016and using TH are 0.0024 and 0.0022 respectively. The drift values found by TH technique have significant values than RS and ESL strategies.

4.2 Story Displacement Response

For moment resisting RC building resting on relative sandy clay, SSI could considerably magnify the horizontal movements and inter-story drifts. This magnification of horizontal twists could amendment the enactment level of the structure. Hence, an ample vital study to judge the truthful accomplishment level of a building ought to contemplate the consequences of SSI within the model. during this case, a higher numeral structure soil model had been developing so that performance of soil and structure with uniform objectivity.
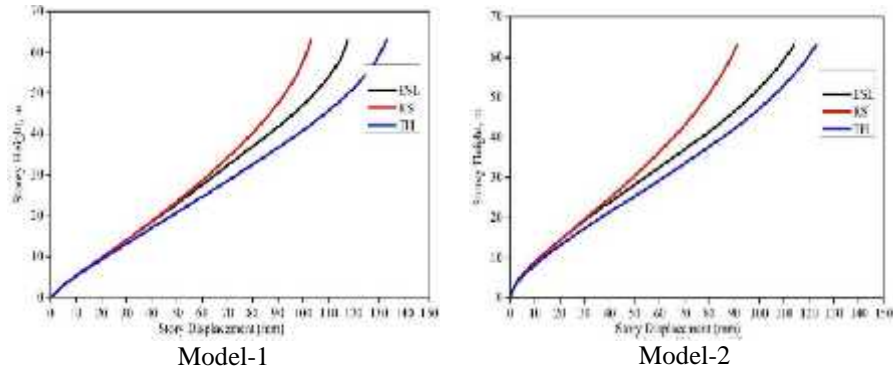
Model-1   Model-2

Fig. 5. Story displacement response for 21-story building model

In this work, the result of SSI on the story horizontal movement of a building are studied three totally different analysis strategies, the horizontal movement profile are bestowed in Fig. 5. It has been detected, the maximum story movement of model-1 (75.58 mm) building is more than model-2(64.09 mm).

4.3   Story Shear Reaction

This exploration is directed to higher perceive the seismal behavior of a usual MRF building incorporating structure soil impact. Fig. 6 Story shear response of 21- story building model. The seismal response of the frame in form of the story shear further as in-house forces above the peak of the erection parts are designated as response variables of engrossment as these are usually thought-about the foremost necessary reaction parameters in seismal design follow. In this work, the effects of SSI for the story shear response summary over height building had been calculating using the three varied analysis method are shown in Fig. 6. It has been found that base shear value for model-1 and model-2 for ESL method are 3520 kN, for RS method 3515 kN and 3513 kN and for TH method 3530 kN and 3535 kN respectively. The results of Story shear by TH analysis is above ESL and RS.
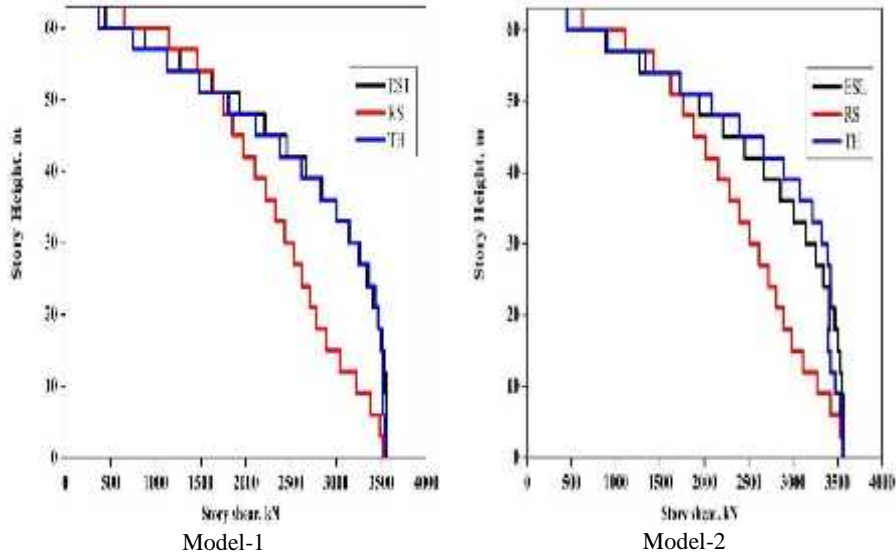
Model-1　　　　　　　　　Model-2

Fig. 6. Story shear response for 21-story building model

Conclusion

The study as an entire might prove helpful in stating design ways for seismal design of skeleton uniting the impact of soil-versatility. Story shear reaction premeditated from the ESL methodology is liberated from SSI outcomes and determined by solely on the skeleton weight. On the opposing, the story shear reaction evaluated by RS and TH strategies are extremely dependent upon the muse and beneath soil rigidity. The analysis establishes that the structure-soil interaction has an important outcome on the base shear, story drift ratio and story movement of the frame related to the usual hypothesis in which interface would be ignored. When the ground is rigid, the reaction of the frame won't be affected ominously by the soil data throughout the earth vibration, and therefore frame is examined underneath the mounted base circumstance. once the frame is laying on a versatile medium, the reaction of the frame is going to be totally altered from the mounted base form because of the interaction between the structure and soil. Hence, in view of structure-soil interaction belongings in the seismic design of lowrise MRF, mostly when laying on soft soil deposit, is crucial.

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