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# Seismic Study of Soil Structure Interaction Modelling Approaches

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***Abstract:* In this paper we study certain modelling techniques by which the concept of soil structure interaction can be simulated in engineering problems and become fruitful for modern construction methods. For practical examination, a baseline model is prepared and put in comparison with an isolated base model which conforms to a rigid bathtub model with spring arrangement. Soil flexibility is taken into consideration during modeling. These modelling techniques are analysed using response spectrum analysis to get the maximum response of seismic parameters like storey forces and spectral acceleration. The study showed that the isolated base model had a superior seismic response and may be used in a variety of engineering applications, such as the design of new infrastructure, such as structures for storing water or other types of sediment, geotechnical modelling**.
***Keywords: Baseline Model, Storey Forces, Spectral Acceleration, Soil Flexibility Rigid Bathtub Model***

## I. INTRODUCTION

The structural reaction to earthquake shaking depends on the interrelationship of three systems: the structural system, the substructure (foundation), and the characteristics of the soil beneath the structure. When a specific ground motion is applied, the system of soil and structure as a whole assesses the collective reaction of these systems. In other words, soil-structure interaction is the relationship between the mobility of the ground and structural movement. There is no independent deformation of the ground and buildings when a system of soft soil is disturbed by bed-rock movements. Soil movement influences structure reaction in systems with substantial soil-structure interaction. Inertial and kinematic interactions between soil and structures are the two processes involved. Fundamentals Natural periods for the majority of buildings and other structures lie in between the time periods of earthquake ground motion. The resonance of the structure's time period with the ground's motion may cause massive damage to the building. Structures can be less affected by earthquake ground motions if the natural period is shifted away from the main frequencies of earthquake shaking.

## II. LITERATURE REVIEW

This study involves a method that improves the life of expectancy of structures by connecting them to their foundation using responsive rubber bearings or sliding roller bearings that allow the structure to move freely. As a result, these bearings are able to tolerate large deformations. Use of seismic isolation bearings has increased greatly as a technique to separate structures from the ground during earthquake shaking in order to reduce damage to structures (Kelly and Konstantinidis 2011).

It is common to place seismic isolation devices at the bottom of buildings in order to safeguard the building's foundation (Skinner et.al 1993). When an earthquake strikes, the structure functions as a rigid body with restricted deformations due to the intentional deformations that occur inside the isolation system (Kelly 1997).

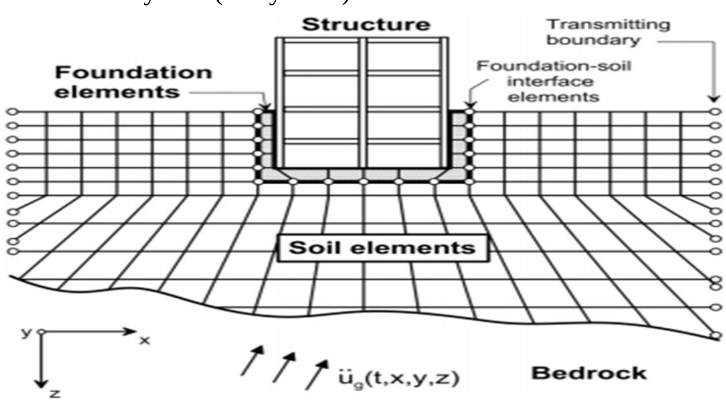


Figure 1: Dimensions of soil structure interaction

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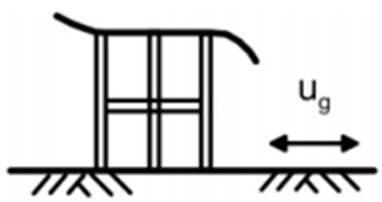
In seismic response analysis, soil-structure interaction is a critical factor in consideration. We need to know if a structure's initial control point will respond to an earthquake when it is erect, since seismologists describe seismic excitation in terms of specific control points on the ground at the original site. To determine if SSI has occurred, an expert in seismic motion applies seismic motion to the structure's foundation in a method known as fixed base analysis.

## III. MODELING APPROACHES

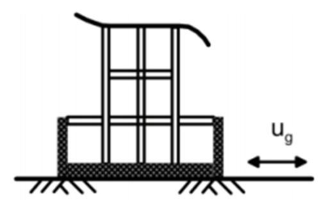
Example applications were developed using the following general approach:

*A.* Eligible instrumented structures that have experienced (and recorded) ground movements caused by earthquakes are chosen.
*B.* Creation of baseline models for complete substructure-based study of seismic response
*C.* Correction of baseline models by changing structural parameters such that they roughly match documented responses of the buildings.
*D.* Differential idealization of the soil foundation interface to examine the influence of different modelling techniques on the expected reaction of structures.

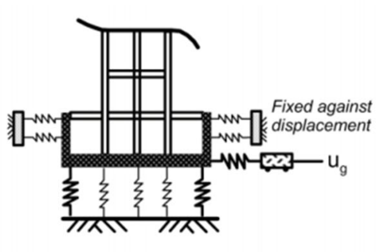
As you can see in the figure, the example applications investigated a variety of modelling approaches in the industry, which are based on standard engineering practices. They include the Baseline Model (MB) and various simplified idealizations of the soil-foundation interface (Models 1, 2, 3, and 4).



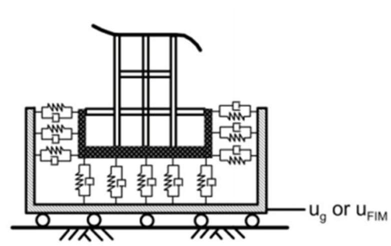

Fixed at ground surface




Subteranean model, included fixed at base




Fixed End Springs

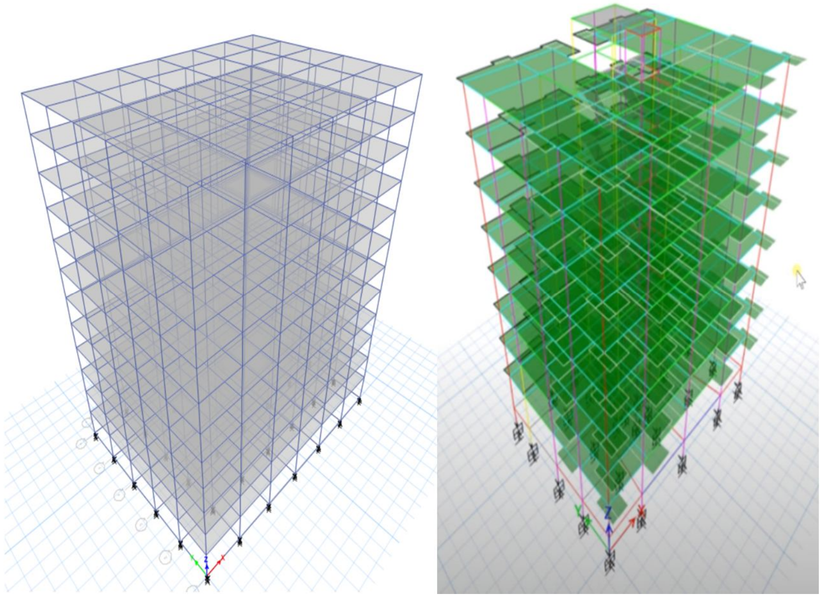



Rigid Bathtub Model

Figure2: Modeling approaches

In Model 1, when modelling the above-ground component of a building, it's important to note that the base is anchored to the ground surface. The model's base is then subjected to free-field ground motion ($u_g$), which is applied to the model's foundation. In Model 2, modelling of both above-ground and underground sections of the building was carried out. The embedded portion's foundation soil is ignored (i.e. no horizontal foundation springs are employed), and free-field ground motion ($u_g$) is applied at its base. In Model 3, both the above-ground and below-ground parts of the building are modeled. Horizontal and vertical soil springs are included, and the far end of each spring is secured against translation. However, in reality, it is employed in nonlinear static (pushover) analytical applications. In Model 4, both the above-ground and subterranean components of the building are represented. Horizontal and vertical soil springs are included. When it comes to seismic demand, there is a big difference between Model 4 and the base model.
To avoid kinematic stress on basement walls, depth-variable displacement histories are not taken into account. The use of free-field movements instead of foundation input motions also completely ignores kinematic interaction by substituting the recorded motions with free-field motion.

## IV. MODELLING OF BASELINE AND BASE ISOLATED ON ETABS



Fixed Baseline (Model 1) Isolated Base (Model 4)

Figure 3: Models in ETABS

Using Etab software, a 10 storey reinforced concrete building is modeled and then evaluated for reaction spectrum. In this study, a linear soil model combined with base-isolated bearings is considered. To absorb seismic energy when the structure sways back and forth, base isolation is used. This helps to reduce overall displacements of the structur Springs used in isolated models in software have an initial condition of zero force which represent origin situation and with time as earthquake shaking will impose alternating cycles of increased and decreased pressures relative to the initial state, structure-to-soil contact can be represented by a spring that develops tension, provided that the level of deformation does not lead to failure, inelastic strains are allowed to raise the strength of material.

| | |
|---|---|
| TYPE OF MODEL | Base line model : Model with fixed base<br>Model with lead rubber bearings |
| STRUCTURE DETAILING | Plan view: Rectangular (22.5m X32m)<br>Type: Reinforced concrete structure with special moment resisting frames<br>Storey Height: 10 story with each being 3.1 m<br>Ground storey height: 3.5 m |
| TYPES OF LOAD | Dead load =1.5 KN/m2<br>Live load= 2.5KN/m2<br>Floor finish=1KN/m2 |
| RESPONSE SPECTRUM FACTORS | Zone Factor= 0.36 for Zone 5<br>Response Reduction Factor=5<br>Importance Factor=1<br>Damping= 5 |
| LEAD RUBBER BEARING FACTORS | Rubber stiffness= 65434.87 KN/m<br>Stiffness in vertical direction= 28776543 KN/m<br>Stiffness in horizontal direction= 17543.8 KN/m(Linear)<br>27034 KN/m(Non Linear) |
| MATERIALS | Concrete = M25<br>Steel= FE415<br>Density of brick infill=19.2 KN/m3 |
| SECTION DIMENSIONS | BEAM= 300mm x600mm<br>Column=350mmx350mm<br>Slab thickness=125mm |

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## V. RESULTS AND DISCUSSION

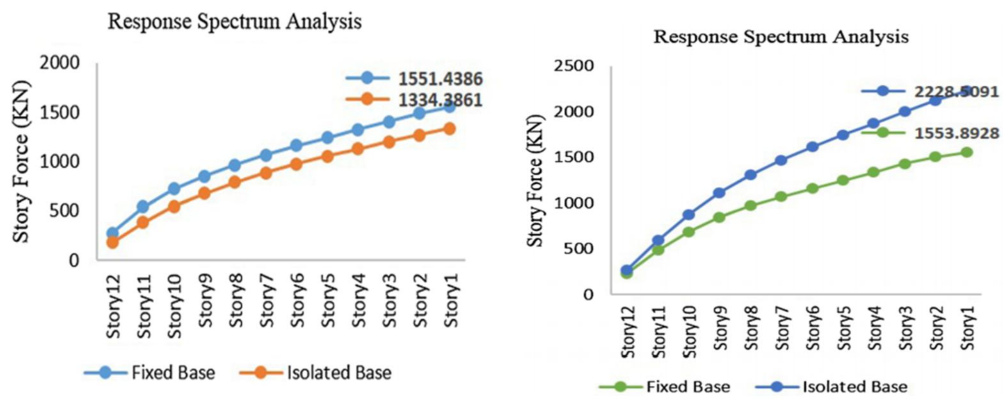
### A. *Storey Forces*

Table 1: Storey Forces In Hard Soil

| NO OF STOREY | HARD SOIL | | |
|---|---|---|---|
| | BASELINE MODEL | ISOLATED BASE | %DIFF |
| 10 | 728.90 | 547.65 | -30.71 |
| 9 | 867.76 | 665.72 | -24.3 |
| 8 | 989.65 | 786.65 | -22.56 |
| 7 | 1002.34 | 856.35 | -19.87 |
| 6 | 1123.54 | 934.21 | -19.01 |
| 5 | 1233.79 | 1042.24 | -17.67 |
| 4 | 1318.70 | 1133.65 | -17.21 |
| 3 | 1413.28 | 1191.79 | -17.01 |
| 2 | 1487.78 | 1276.58 | -17.31 |
| 1 | 1551.43 | 1334.38 | -16.34 |

Table 2: Storey Force In Soft Soil

| NO OF STOREY | SOFT SOIL | | |
|---|---|---|---|
| | BASELINE MODEL | ISOLATED BASE | %DIFF |
| 10 | 689.90 | 867.19 | 20.67 |
| 9 | 834.45 | 1123.65 | 22.76 |
| 8 | 978.79 | 1301.81 | 25.13 |
| 7 | 1023.45 | 1431.21 | 27.89 |
| 6 | 1156.76 | 1602.23 | 28.12 |
| 5 | 1232.43 | 1765.43 | 28.23 |
| 4 | 1331.90 | 1865.34 | 28.54 |
| 3 | 1423.76 | 2013.12 | 28.49 |
| 2 | 1509.87 | 2003.23 | 28.99 |
| 1 | 1553.89 | 2228.50 | 30.34 |




HARD SOIL SOFT SOIL

Figure 4 : Storey Forces For Standard Fixed Baseline Model And Isolated Base Model

*B. Spectral Acceleration At Roof*

A point in time when the ground accelerates to its maximum is known as peak ground acceleration (PGA).Theoretically PGA is calculated using attenuation function that describes the correlation between intensity, magnitude and epicentral distance. Generally speaking, earthquakes strike in all directions. Most of the time, there is no separation between horizontal and vertical components. On the whole, horizontal PGAs tend to be more significant than vertical ones. Engineers use peak horizontal acceleration (PHA) as a common ground acceleration measurement.

Both the models' highest spectral acceleration values are presented in Figures 4 and 5. According to the data, spectral acceleration maximum responses are 1537.62 mm/s2, 1029.68 mm/s2 for hard soil, and 2014.98 mm/s2, 1621.45 mm/s2, respectively, for soft soil, under fixed and isolated base.

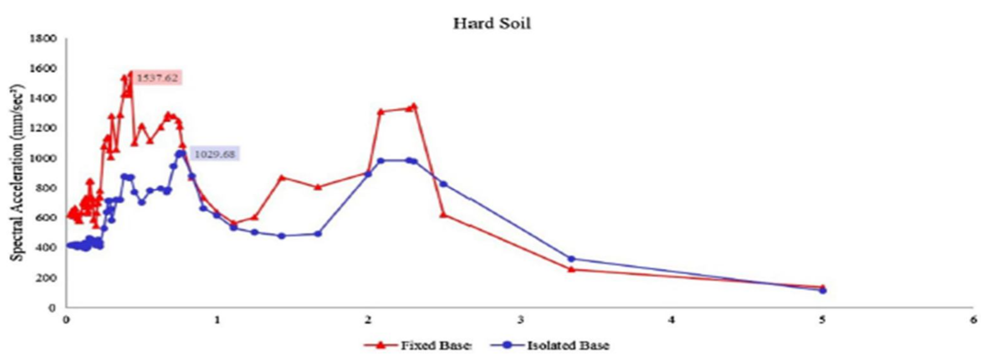



Figure 5:Spectral Acceleration Of Hard Soil

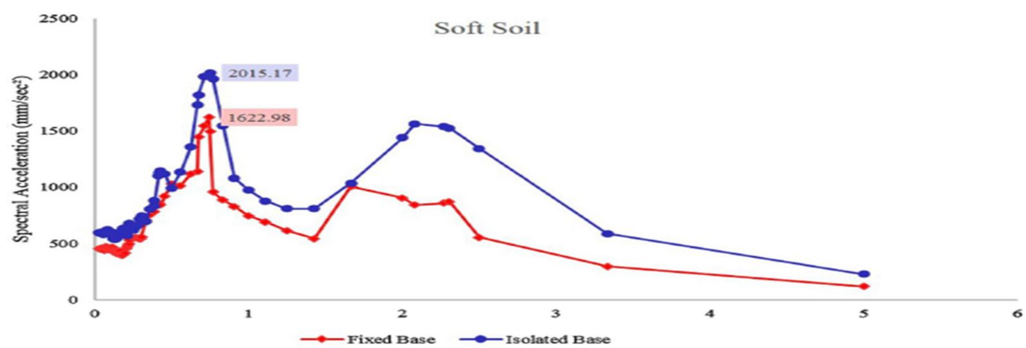



Figure 6: Spectral Acceleration Of Soft Soil

## VI. CONCLUSION

This research is carried out to better understand the modelling approaches of soil structure interaction under earthquake ground motions. First, a soil model and a base-isolated structure must be calibrated and connected. It is then determined through ETABs how the system will behave in the event of extreme seismic vibrations. System responses and parameters are examined by researchers to see if there are any correlations or patterns. Storey forces and acceleration caused by earthquake vibrations are monitored and compared to the deformation of the isolation system and superstructure in order to estimate how the base isolation system will respond.

*A.* In comparison to the fixed baseline model, the storey force value at the first floor of the model with an isolated base decreased by 15.93%.This shows that the feasibility of isolated base models is more consistent than the standard baseline model. Practically, we can go with isolated base models from various soil structure models. As soil stiffness decreases, so does the value of storey shear, which is evident in the analysis as soft soil has high storey forces as compared to hard soil.

| | Standard base line model | Isolated base model |
|---|---|---|
| Storey forces (Maximum) | 1549.43 kN | 1333.98 N |

*B.* On an average in contrast to standard base line models, isolated base models provide a greater stiffness towards spectral acceleration.

| | Standard base line model | Isolated base model |
|---|---|---|
| Spectral acceleration($mm/s^2$) | 1763.44 | 1633.24 |

*C.* It's possible to include SSI effects inertially into the structural model using "bathtub" configurations, given current software capabilities. SSI's seismic reaction is accurately represented by this model.

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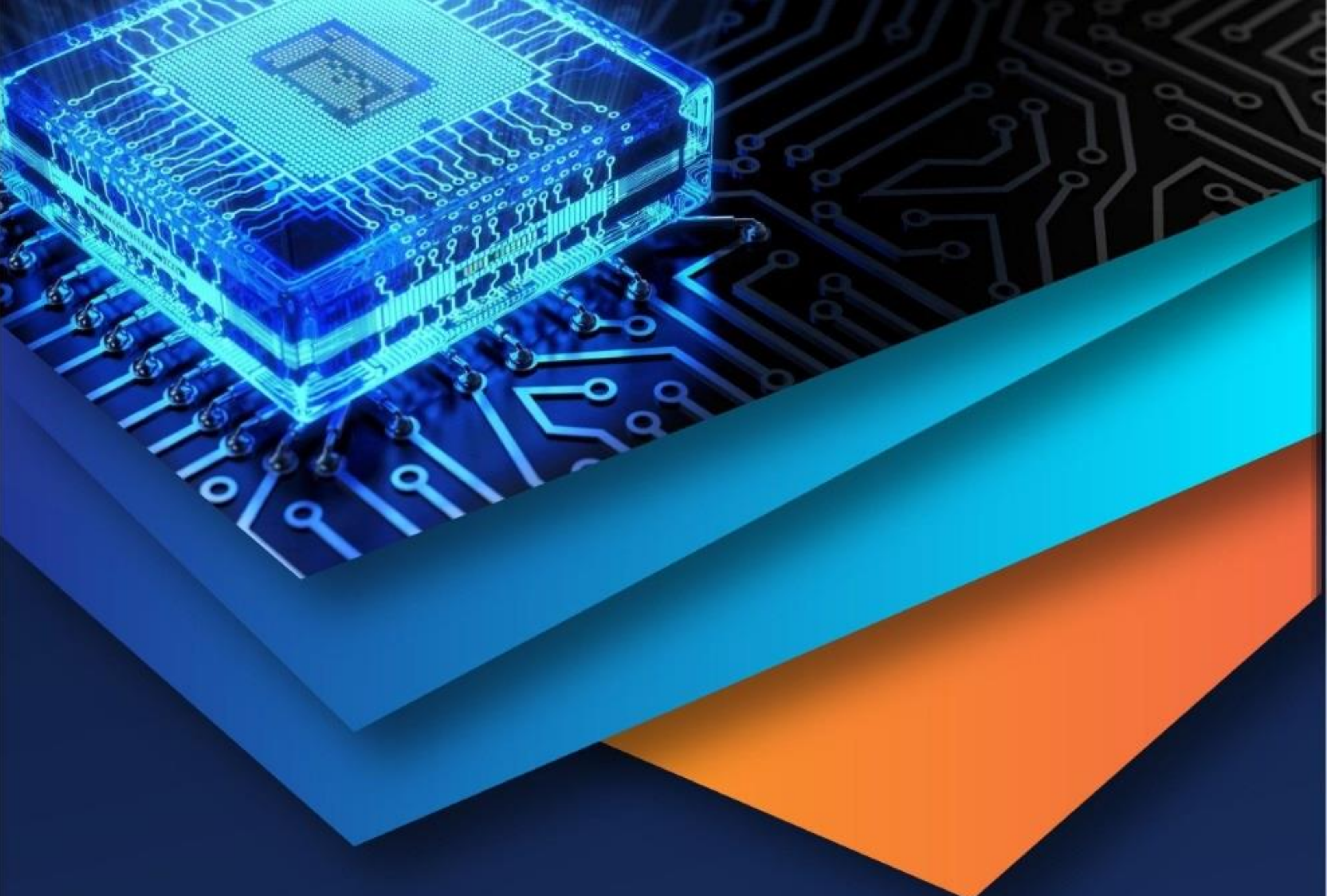


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