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A Comparative Analysis of Bare Frame and Brick Infill Frame Structures Considering Soil Flexibility

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ABSTRACT

The benefit of soil-structure interaction (SSI) to structures subjected to seismic loads is often believed. This assumption may have been erroneous, as we learnt from the most recent earthquakes; SSI may affect the seismic response of various structural systems in different ways. Examining the effects of soil-structure interaction on multi-story buildings using different foundation systems is the goal of this effort. An examination of the seismic reaction of multi-story buildings with both rigid and flexible bases also took into account various soil types, including hard, medium, and soft. For our research, we have chosen a conventional G+6 storey building that is situated on several kinds of soils. In this case, we contrast the results that come about when soil-structure interaction is taken into account with those that happen when the structure is thought of as being fixed at its base.

Keywords: Soil structure, Base shear, Bare Frame, Brick Infill, Soft

INTRODUCTION

Built to resist a wide range of stresses and to support people within, structures are an essential part of today's infrastructure. The design and material qualities of these structures do not, however, determine their performance in isolation. The underlying soil's flexibility is a key but sometimes overlooked component affecting their behavior. Soil flexibility, a component of soil-structure interaction (SSI), is crucial in determining a structure's dynamic and static responses. When subjected to natural disasters like earthquakes or even just regular operational loads, a building's resilience depends on its foundation and the soil underneath it. The concept of soil-structure interaction is based on the fact that neither the foundation nor the soil underneath it can be completely incompressible. The outer weights of a structure are borne primarily by its foundation and, in the long run, by the soil itself. In response to these loads, the soil's kind and characteristics determine how the structure behaves. Soil deformation affects the structural reaction, which in turn affects the structure, creating a feedback loop. When buildings are constructed on loose or soft soils, the dependency between these factors becomes much more important since the soil's flexibility can increase displacements and vibrations, which could weaken the structure.

In order to build buildings that are both safe and efficient, it is essential to understand the soil's elasticity. In order to make calculations easier, structural designers have traditionally assumed fixed or rigid supports. Although this may be true in some cases, it fails to take into account how soil actually behaves when subjected to a load. The composition, moisture content, and density of soil are three of the many variables that affect the material's damping properties and the degree to which it is stiff. Soils with low stiffness and high deformability, such loose sands and soft clays, make structures built on them more likely to settle and tilt. On the other hand, even while thick sands and hard clays are more rigid, they could nonetheless behave nonlinearly when subjected to heavy loads. In dynamic events, like earthquakes, the impact of soil elasticity becomes most apparent. The structural reaction to seismic waves is directly affected by the soil's absorption and dissipation capabilities. Higher ground acceleration is caused by the quick transmission of seismic waves by inflexible soils like granite or tightly packed materials. But, towering structures' inherent frequencies can be amplified by flexible soils, which magnify lower-frequency waves. This can make their reaction much more apparent. Soil amplification is a real thing, and it shows how important it is to consider soil flexibility while making seismic plans. The local and global performance of a building are both impacted by the pliability of the soil. As an example, irregular stress distribution in structural components can result in cracking, deformation, and, in the worst-case scenario, failure, due to differential settlement, a prevalent problem in mobile soils. Similarly, the stability of the superstructure can be further affected by lateral loads, which can cause the foundation to rock or slide. Engineers may ensure long-term performance and safety by include soil flexibility into design calculations. This helps them to forecast and mitigate such concerns. Because of developments in both computer modeling and experimental methods, research into the soil-structure interaction has been picking up speed. One effective method for modeling the dynamic relationship between building foundations and structures is Finite Element Analysis (FEA). Engineers can assess the impact of soil pliability on several structural characteristics including natural frequencies, stress distribution, and stiffness by depicting the soil as a continuum or by employing discrete models like Winkler or Pasternak foundations. Validating theoretical models and directing design approaches, experimental methods like centrifuge modeling and shake table testing have also offered useful insights into SSI occurrences.

The importance of soil flexibility extends beyond conventional structures. Bridges, offshore platforms, and towers are specialized constructions that are especially vulnerable to soil-structure interactions. As an example, the combined impacts of axial, lateral, and torsional stresses create complicated interactions for bridge piers supported by pile foundations. Oil platforms and wind turbines are only two examples of offshore constructions that need to consider how the seafloor and superstructure react to environmental pressures including wind, waves, and currents. Soil flexibility should be considered in such instances to avoid underestimating design loads and possible failure. In light of the interplay between urbanization and climate change, the importance of soil flexibility is amplified. Tall structures and infrastructure have been erected on marginal areas with poor soil conditions as a result of rapid urban expansion. Soil flexibility is already a problem, and it's getting worse due to climate change and its related phenomena like higher sea levels and more frequent extreme weather events. Soil shrinkage and cracking can result from extended droughts, while flooding can reduce the soil's ability to support heavy loads. A comprehensive knowledge of soil-structure interaction is essential for designing robust buildings in these changing settings.

Soil adaptability is an important factor in sustainable and cost-effective design, along with other practical factors. It is possible to waste materials and incur more expenses by overdesigning foundations to account for soil uncertainty. Foundation designs may be optimized for safety, performance, and economic efficiency by precisely simulating soil-structure interaction. To reduce material consumption while maintaining stability, pile foundations can be constructed with different lengths and diameters to accommodate soil heterogeneity. Soil flexibility is an important factor to include in structural analysis, but there are a number of obstacles to overcome. It is challenging to simulate soil behavior effectively due to its intrinsic nonlinearity and substantial unpredictability. Complexity is further increased by factors such as anisotropy, heterogeneity, and time-dependent effects such as creep and consolidation. In addition, several factors, such as the kind of foundation, the load characteristics, and the environmental circumstances, affect the soil-structure interaction. These intricacies may elude simpler models, which are good for initial design but may call for more sophisticated analytical and numerical methods.

REVIEW OF LITERATURE

Rehal, Jasdeep Singh et al., (2021) Buildings in seismically active regions, such as India, often have frameworks made of reinforced concrete with walls filled with brickwork. In structural assessments, masonry infill walls are usually considered nonstructural and their mass is taken into account rather than their structural properties like stiffness and strength. Seismic zones make buildings there very susceptible to harm. In addition to the force of gravity, the structure must also be able to resist lateral loads, which may cause significant stress. To this day, reinforced concrete frames continue to dominate the global building industry. Brick infill walls or panels are often used to fill the vertical gap that is generated with the use of reinforced concrete beams and columns. Analyses will be conducted once diagonal struts are used to replace these infill walls in this research. Examining the outcomes of G+ 15 constructions with and without infill using computerized model analysis. We check the following (base shear, lateral floor displacement, story drift by buildings) so that we may compare the results.

Kiani, Kianoosh et al., (2020) Finding the basic period of vibration is one of the most important elements in structural analysis and design. How the structure's mass and stiffness are distributed determines the basic period. Consequently, the building regulations include a number of empirical formulae that are derived from testing measuring ambient vibration and the periods that actual structures experience during earthquakes. In most cases, the building type and height are the variables that determine these equations.

The analytical approaches' exclusion of non-structural factors explains why they differ from the code equation in determining the basic era of buildings. This is why it's important to think about how non-structural components, like infill panels, might affect these qualities. How Soil-Structure Interactions (SSI) affect the basic period is another important element. Soil pliability obviously lengthens the foundational stage of the building. Taking soil-structure interaction (SSI) into account, this study examines how moment-resisting frames' fundamental periods are impacted by infill panels.

For this reason, we compared 3, 6, 9, 12, 15, and 18 store 2-D frames with different infill opening percentages and infill panel layouts. We used Seismo Struct to model and analyze the frames that were under study. We compare the computed basic period values to those from the seismic code's recommended equation. Key criteria affecting the basic period of steel building frames, according to the findings analysis, several factors: the kind of soil, the amount of stores, the percentage of infill opening, and the stiffness of infill panels.

Elwardany, Hytham et al., (2019) In this study, we will examine how masonry infill panels, whether present or not, and soil-structure interaction (SSI) affect the reaction of nearby buildings to earthquake-induced pounding. With an emphasis on the dynamic behavior of individual frames, the research was further expanded to compare the behavior of structures engaged in pounding with that of structures that did not experience collisions. The assumption In order to examine the impact of SSI, the foundation level was equipped with linear springs and dashpots. The infill panels were symbolized by diagonal compression struts that were similar to the actual ones.

The underlying premise was that the steel frames would display a linear strain hardening of 1% and elastic-plastic behavior. To make it seem like the buildings were slamming on one other, the dynamic contact method was used. Two nearby multi-story buildings were subjected to nonlinear finite element analysis, with four possible configurations reflecting real-world scenarios. Seismic response in the situations analyzed typically showed those nearby buildings' responses may be drastically changed if soil flexibility and/or the infill panels' contributions are ignored. Buildings subjected to structural pounding during earthquake excitation may have their seismic behavior misrepresented as a consequence.

Jayalekshmi, B. et al (2014) The foundation is often assumed to be fixed in conventional structural assessments. Nevertheless, the lateral forces acting on the building and the earthquake loading are both affected by the soil below the foundation. So, it's not practical to evaluate the building as if it were fixed at the foundation. This study examines the variations for multi-story reinforced concrete framed structures, as a consequence of seismic regulations in both the European and Indian standard codes, as well as in the spectral acceleration coefficient, base shear, and storey shear. Raft foundations, with or without shear walls, sustain the structures of varied heights. The impact of soil pliability is further considered. According to the research, symmetrical structures with shear walls at each of the four corners had the lowest amount of base shear.

Jinya, Mohammad. (2014). Architects often design masonry walls as partitions or infills in reinforced concrete frame buildings; however, these walls are not meant to add to the building's vertical gravity load-bearing capability. By separating the inside of a structure from outside elements, infill walls shield occupants from potential dangers. On top of that, infills possess substantial stiffness and strength, which greatly influences the structural systems' seismic reaction. When earthquakes strike, brick infill walls often create two types of structural damage: weak stories and short columns. Used in business or residential buildings, You may find these holes on the outside.

This sample follows IS: 1905-1987 and makes use of bricks with compressive strengths of 5.0 and 12.5 N/mm 2 and masonry strengths of 0.50 and 1.06 N/mm 2. Central apertures are cut into the perimeter wall at various percentages of 15% and 25%, respectively. G+9 R.C.C framed building models were subjected to seismic coefficient method (SCM) and time-history (TH) studies in the ETABS program, in compliance with IS 1893:2002. This research takes into account the following parameters: axial force with and without soft story, story drift, base shear, and story displacement, all while evaluating the influence of infill walls with varied percentages of opening. In order to determine the strut width for the macro model, the The FEMA approach method is utilized in tandem with the equivalent diagonal strut (EDS) technology.

Bhattacharya, Koushik et al., (2004) The natural periods of the system are increased when the earth medium below the foundation is flexible, since this reduces the total rigidity of the structure frames. Changes in lateral natural periods may significantly impact seismic lateral response, as is well-established. As a result, this research aimed to determine how Building frames supported by grid or isolated foundations varied in their lateral natural periods due to soil-structure interaction. There are a lot of variables that might affect the results, including (a) soil type, (b) floor count, (c) bay count, (d) column to beam flexural stiffness ratio, and (e) ground excitation frequency.

In this type of study, four different building models are considered: (1) a (1) a framework with fixed supports; (2) a framework with supports that account for soil flexibility; (3) a framework with brick infill and fixed supports; and (4) a framework with brick infill and supports that account for soil flexibility. We examine two possible outcomes in each category: one without tie beams and one with them installed at plinth level. Based on variables such as shear modulus, soil Poisson ratio, and footing form and size, the soil-flexibility for different kinds of soil and foundations may be calculated using methods outlined in widely-accepted literature.

By physically simulating the system, we can examine how different building frames' lateral natural periods vary over time as a result of changes in a variety of parameters. Based on the results, any building frame may have the influence of soil-structure interaction evaluated quite accurately using the given variation curves for dynamic features and some basic linear interpolation.

MATERIALS AND METHODS

Figures 1, 2, and 3 depict the plan and elevation, respectively, for the current seismic research.

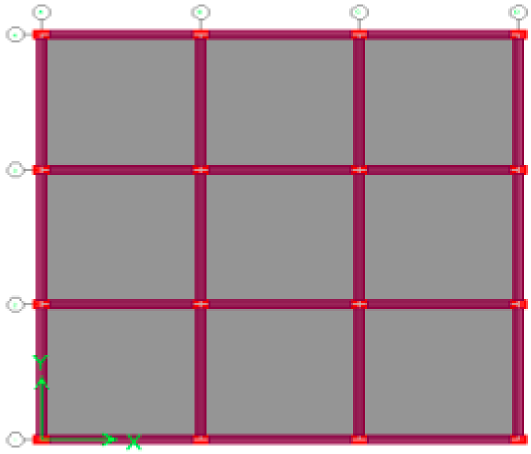

Figure 1: Plan of the building

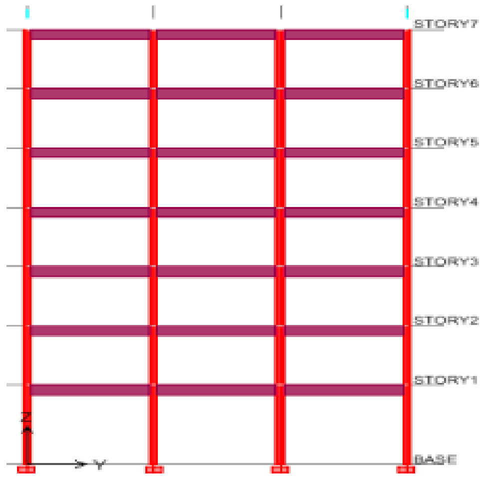

Figure 2: Elevation for Bare Frame

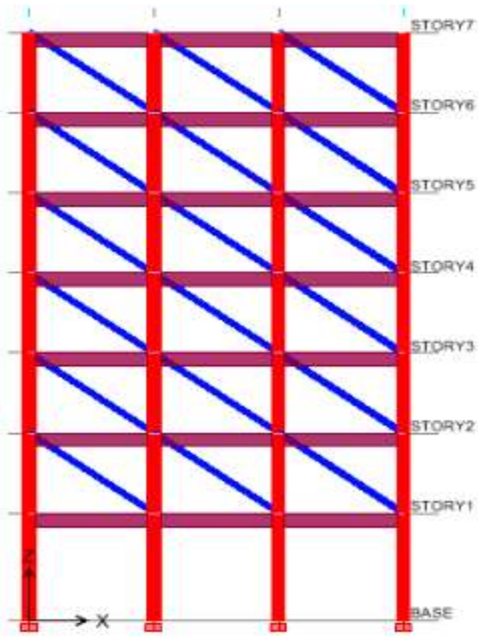

Figure 3: Elevation for Brick Infill Frame

The current investigation models the slab as a stiff diaphragm and the beams and columns as frame elements. In order to achieve in-plane stiffness, the slab is given membrane-type behavior. Assuming the beam-column joints are rigid, the floor's masses are consolidated at the center of rigidity. The models have all been developed and tested under the conditions of a gravity load, namely 1.5(DL+LL). We were successful in recreating this soil behavior by modeling it using a network of linear elastic springs. Two rotating springs on each side of the globally perpendicular axes and three translational springs along them are positioned underneath the foundation's center of gravity to mimic the impact of soil-flexibility. The method for simulating and computing the stiffness of analogous soil springs along the several axes of rotation has been defined by ATC-40. Multiplying the surface stiffness variables by the embedding stiffness factors takes bearing depth into consideration. Finally, the coefficients of translational and rotational stiffness are determined by dividing the total embedded stiffness by the area of contact and the moment of inertia, respectively, in the absence of coupling. The result is the distribution of stiffness intensities for each person. The ultimate stiffness with the appropriate units (kN/m for translational and kN/radiance for rotational, respectively) is obtained by multiplying the separately distributed stiffness intensity parameters with the corresponding areas. The soil parameters that were used to identify these similar springs are shown in Figure 4.

Type of Clay	S.B.C of soil kN/m2	Young's Modulus kN/m2	Poisson ratio	Shear Modulus kN/m2
Soft	120	15000	0.45	5172.41
Medium	160	50000	0.45	17241.37
Stiff	250	200000	0.45	68965.51

Figure 4: Soil Parameters for Performance Evaluation

RESULTS AND DISCUSSION

Base shear, storey drift, and lateral displacement results from various analysis are shown and compared for building models. Investigating the effects of nonlinear building behavior and soil-structure interaction is the primary goal of seismic studies. Furthermore, the nonlinear static pushover analysis is used to assess the performance of the building models during the design earthquake. Included in this evaluation are models with and without brick filling.

Base Shear

A building's base shear is affected by its mass, stiffness, height, and natural period. The equivalent static method uses the horizontal acceleration value from the code's natural period to inform design decisions. Its underlying premise is that the dynamics are controlled by the building's first mode of vibration and that higher modes do not have a significant impact. For both gravity and seismic design, Figures 5 and 6 show Using different kinds of soil, the base shear of models of buildings with and without brick infill may be calculated.

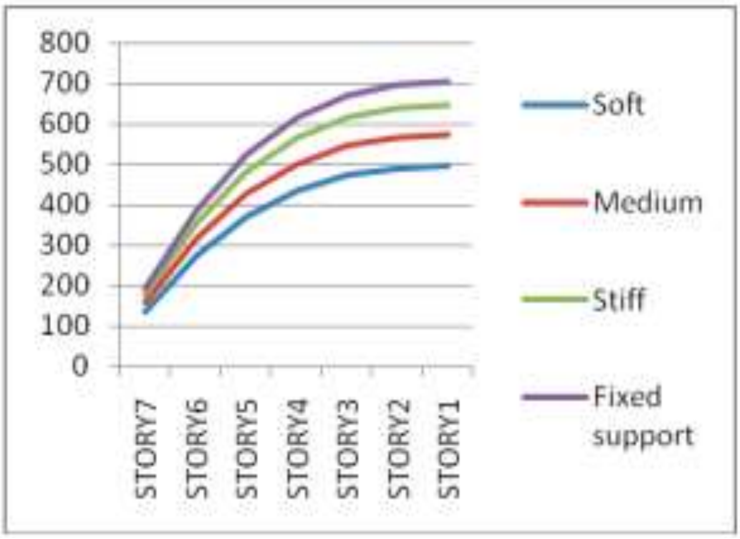

Figure 5: Base shear for Bare Framebuilding models on Different Soil Types

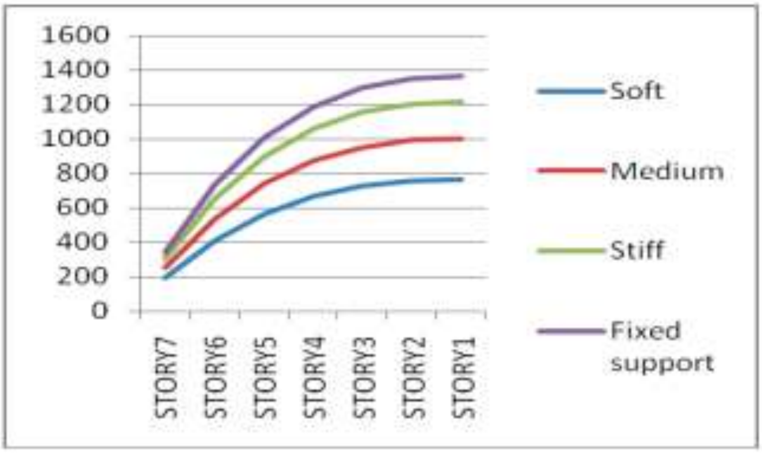

Figure 6: Base shear for brick infill Different soil types frame building models

Lateral displacements

Figures 7 and 8 display tabular data along the longitudinal axis representing lateral displacements for various soil types. The statistics clearly show that when the soil type goes from hard to soft, the displacement values go up.

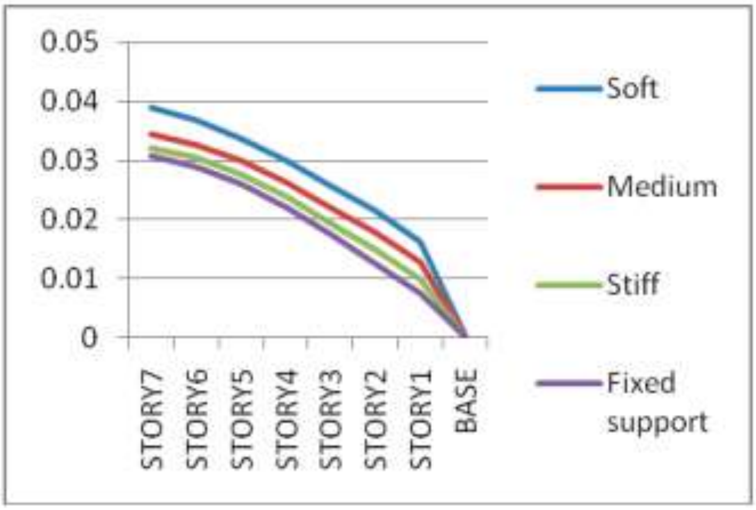

Figure 7: Bare Frame lateral displacement

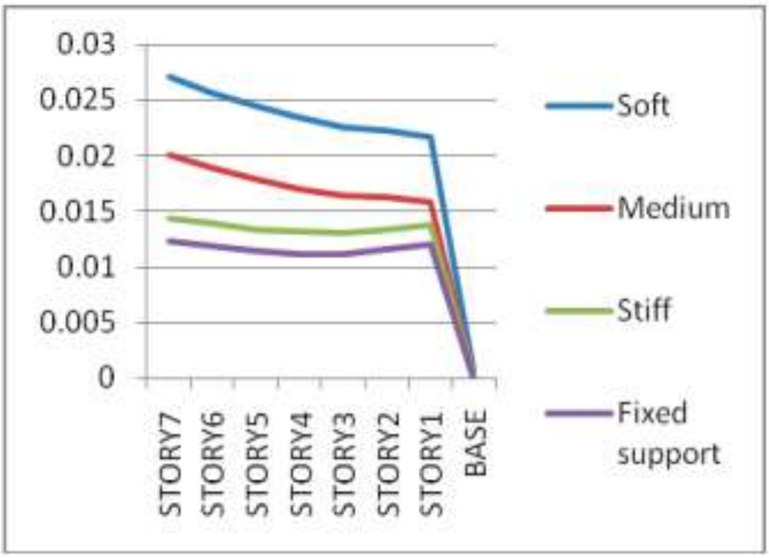

Figure 8: Lateral displacement for Brick infill Frame

Inter Storey Drift

In Figures 9 and 10, we can see the longitudinal variation of the interstory drift for the building models. The inter-story drift was seen to be greater on the first floor in the longitudinal direction in model 2, possibly because of the open ground story. The storey drift must not be more than 0.004 times the storey height, as stated in article 7.11.1 of IS 1893 (Part 1): 2002. The storey drifts on the higher floors of model 2 are within the acceptable range, but on the first floor, which is exposed to the ground, the stiffness and irregularity are too much.

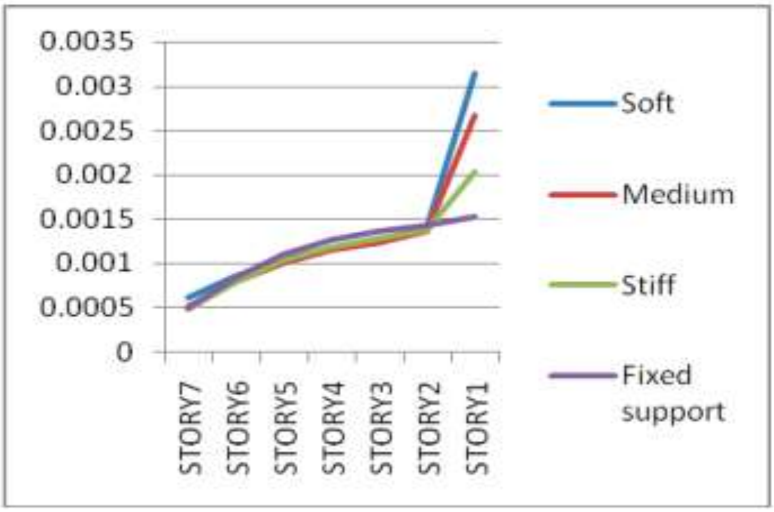

Figure 9: Storey drift for Bare frame

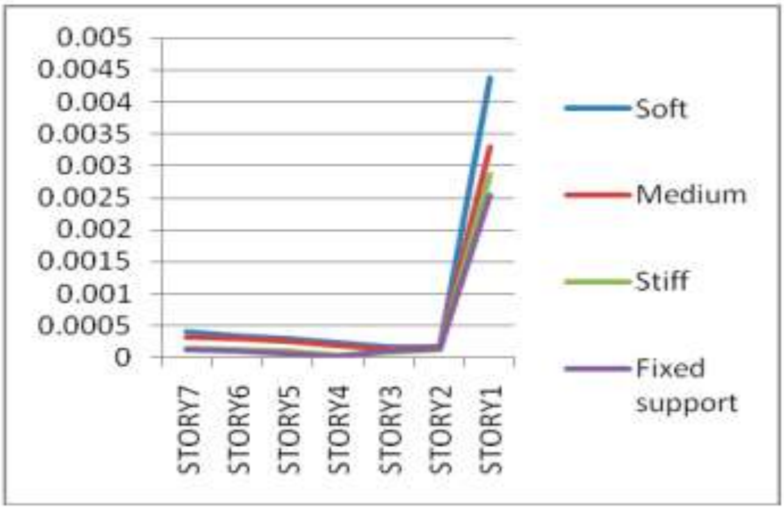

Figure 10: Drifts between storeys for brick infill frames

Performance Evaluation of Building Models

We use nonlinear static pushover analysis to evaluate all of the models based on their seismic performance. The most extreme combination of planned loads is used to assign default hinges for constructing models. There were eleven stages to the pushover study. Hinge formation in beams was noted to occur first with subsequent push to construction. The hinges started off in proceeded through the B-IO stage, IO-LS, and LS-CP. Table 2 displays the data for the performance measures used in model creation. The base shear is represented by V and the displacement by D in this context.

Table 1: Performance Evaluation of Building Models at Point V and

Soil Type	Bare Frame		Brick Infill Frame	
	V	D	V	D
Fixed base	1244.32	0.252	1634.39	0.077
Stiff soil	1241.25	0.258	1628.80	0.080
Medium Soil	1234.65	0.274	1603.71	0.093
Soft Soil	1178.07	0.288	1348.26	0.108

The results of the performance assessment of the Bare Frame and Brick Infill Frame models on different kinds of soil are shown in the table at Points V and D. All of the models exhibit a minor decrease in displacement values from a stable foundation to stiff earth, followed by an increase as the soil softens, and finally a maximum on very soft soil. In comparison to the Bare Frame, the Brick Infill Frame often experiences bigger displacements. At Point V, the displacement of the Bare Frame is somewhat lower in stiffer soils compared to the Brick Infill Frame, which exhibits a larger displacement in all soil types. The two models display a consistent upward trend in displacement with progressively softer soils at Point D, while the Brick Infill Frame once again shows the highest displacement values.

CONCLUSION

Consideration of soil flexibility in a comparative study of bare frame and brick infill frame constructions shows how soil-structure interaction significantly affects buildings' seismic performance. Soil type affects important building factors such lateral displacement, storey drift, and foundation shear; study shows that soft soils cause more displacements and drift. In addition, the degree to which both building styles are safe during seismic events varies; bare frame constructions, with their open ground floor, are particularly prone to plastic hinges developing on the first story. Although both bare frame and brick infill frame buildings are capable of withstanding earthquakes, there is clear room for improvement in terms of seismic resilience, especially for structures situated on unstable ground.

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