International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

SSI and Infill Wall Stiffness Effects on Seismic Performance of Structures

*Prof. Hase U. C.[a],Prof.Abhale R. B.[b]**

"Amrutvahini Polytechnic, Sangamner422608,India"
"Amrutvahini Polytechnic, Sangamner422608,India"

A B S T R A C T :

Earthquakes cause damage to constructions at the surface by sending seismic waves through the soil layers and down into the bedrock. Walls may not aid in bearing gravity loads, but their contribution toward lateral load casing towers earthquake or wind is significantly greater due to added stiffness and strength. However, in reality, building frame analysis disregards the infill stiffness which leads to the low estimation of stiffness as well as natural frequency. Infill also participates towards energy absorption and thus enhances ability withstand seismic forces. So, there is a need to develop computationally accurate model for the soil-foundation structure interaction system regarding the design of govern seismic forces for improved efficiency in structural design. Very often, designers do not take into account flexibility of soil which ascribed to in found engineering thinking is benevolently simple. This suppression becomes problematic in dynamic analysis. This lack of consider soil data due to undergo complicated empirical testing alongside one of theory of substructure and superstructure block the large scope modelling do the infill stiffness. Believe it or not, ignoring the infill represents is problematic for strengthen the structure.

The seismic performance of structures is significantly influenced by both the characteristics of the supporting soil and the presence of infill walls. While the role of infill walls has often been simplified or neglected in structural analysis, their actual stiffness can modify the seismic response substantially. Similarly, Soil-Structure Interaction (SSI) alters the motion transfer from ground to superstructure, particularly in soft soils. This paper discusses the individual and combined effects of SSI and infill wall stiffness on the seismic response of buildings. A review of existing literature, analytical studies, and performance data from past earthquakes supports the argument that a comprehensive approach integrating both factors is essential for accurate seismic assessment and resilient design

Keywords: soil structure interaction, soil stiffness, infill wall, earthquake.

1. Introduction

Seismic design of buildings traditionally emphasizes the superstructure while often idealizing or simplifying the substructure and non-structural components. However, two often-overlooked factors—Soil-Structure Interaction (SSI) and infill wall stiffness—can significantly influence how a structure responds during an earthquake.

SSI refers to the mutual response between a structure and the supporting soil, where the flexibility and damping characteristics of the soil modify the dynamic behaviour of the structure. Infill walls, typically constructed from masonry or concrete blocks, are often treated as non-structural components. Yet their actual stiffness contributes to lateral load resistance, and their interaction with the frame can change the distribution of forces during seismic events.

The purpose of this paper is to explore how both SSI and infill wall stiffness affect seismic performance. Their interaction can either amplify or mitigate earthquake-induced forces, depending on structural configuration, soil type, and material properties.

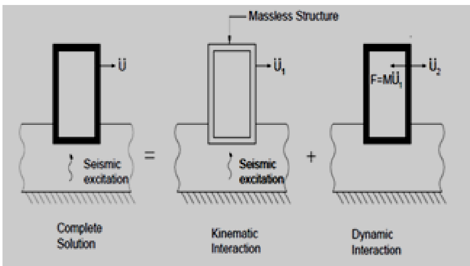


Fig 1. A schematic representation of issues involved in any SSI analysis

2. Soil-Structure Interaction (SSI) and Seismic Response:

SSI becomes more critical for structures on soft or loose soils, where the foundation does not remain rigid relative to ground motion. When subjected to seismic loading, the soil and structure deform together, leading to a modified base excitation and natural period of vibration.

2.1 Effects of SSI

SSI can lead to several key modifications in seismic response:

Period Lengthening: The added flexibility due to soil compliance increases the fundamental period of the structure, often leading to reduced seismic acceleration but potentially larger displacements.

Damping Alteration: Energy dissipation characteristics change due to radiation damping from the foundation and hysteretic damping from the soil.

Force Redistribution: Structural base shear and moment distributions are altered, which may affect critical design regions.

These effects are generally beneficial for stiff structures, as they reduce demand. However, for flexible or mid-rise buildings, especially on soft soil, the change may lead to resonance with long-period components of seismic waves, increasing risk.

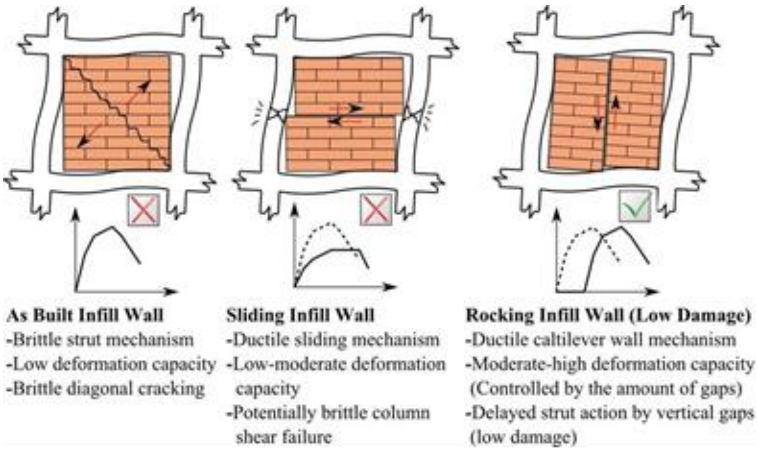


Fig.2 Effect of SSI infill wall

3. Infill Wall Stiffness and Structural Behavior

Infill walls contribute significantly to the in-plane stiffness of a building, especially in reinforced concrete frames. Their stiffness varies with material, arrangement, and openings (windows/doors), and their interaction with the surrounding frame leads to complex behaviors.

3.1 Benefits and Risks of Infill Walls

Infill walls can act as compression struts during lateral loading, increasing stiffness and strength. However, this contribution is often irregular and can result in undesirable effects such as:

Soft Story Formation: If infills are removed or unevenly distributed, upper stories may be stiff while the ground story is weak, creating a soft story prone to collapse.

Brittle Failure Modes: Unreinforced masonry infill can crack or fail suddenly under cyclic loads, posing safety risks.

Stiffness Irregularities: Variable stiffness across floors or bays can result in torsional responses and localized damage.

Despite these risks, infill walls enhance structural performance when their behavior is properly accounted for in design models.

4. Combined Effects of SSI and Infill Wall Stiffness

The interaction between SSI and infill wall stiffness can produce complex effects that are not simply additive. For instance, the lengthened period due to SSI can shift the structure out of resonance with certain seismic frequencies, but when infill walls increase stiffness, they may counteract this shift.

4.1 Coupled Behavior

Recent analytical and experimental studies have shown that:

Stiff infill walls reduce the impact of SSI by increasing the structure's lateral resistance.

When infill stiffness is considered, the fundamental period of the system may decrease, making SSI more or less influential depending on the frequency content of ground motion.

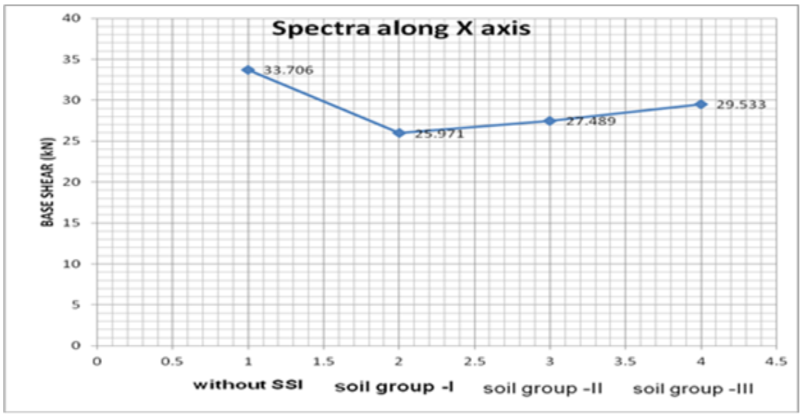
Damage concentration can shift due to combined effects, particularly in irregular buildings or those with asymmetric infill arrangements.

Understanding the coupled influence is essential for seismic retrofitting and performance-based design approaches.

5. Case Studies and Literature Insights

Case studies from past earthquakes (e.g., Bhuj 2001, Nepal 2015) reveal buildings with soft storeys due to missing infill walls experienced higher collapse rates, even when located on relatively stiff soils. Conversely, structures on soft soils with uniformly distributed infill walls had better overall seismic performance. Studies using finite element modelling have further demonstrated that ignoring SSI leads to underestimation of displacements and forces in the structural system. Similarly, excluding infill walls from analytical models may misrepresent actual dynamic characteristics, particularly stiffness and damping.

Direction of spectra applied	**Without SSI (kN)**		**With SSI (kN)**		
	anually	NSYS	roup-I	roup-II	roup-III
X direction	1.120	3.706	5.971	7.489	9.533
Y direction	9.330	1.193	6.638	8.322	9.203



6. Design Implications and Recommendations

Modern codes increasingly recognize the importance of including SSI and infill effects, but their implementation in routine design remains limited. To improve seismic resilience, the following recommendations are proposed:

Integrate SSI in Response Spectrum Analysis: Especially for structures on soft soils or with deep foundations.

Model Infill Walls Realistically: Using equivalent strut models that account for material properties and opening configurations.

Assess Irregularities: Both in plan and elevation, to avoid undesirable torsional or soft-storey effects.

Use Nonlinear Analysis Where Necessary: For performance-based design or critical infrastructure projects.

Encourage Research on Coupled Effects: To refine simplified models for everyday use by structural engineers.

5. Conclusion:

This research examines the influence of soil-structure interaction (SSI) and subsoil dynamic characteristics on seismic performance of a 4-storey reinforced concrete moment-resisting frame on various soils (Class I, II, and III). Results indicate that flexible-base models (with SSI) have reduced base shear than fixed-base models. Two SSI analysis techniques are discussed: the direct method, which simulates the continuum of the soil but is very computer-intensive, and the substructure method, which distinguishes soil and structure analyses for linear and nonlinear behavior.

The analysis indicates a 25% less base shear on loose soils than on stiff soils, reflecting higher seismic susceptibility of structures on softer soils. The Y-direction (shorter side) is more significant in seismic response as a higher percentage reduction in base shear. Hard soil models incorporating SSI result in similar outcomes to fixed-base models. ANSYS and hand calculations vary due to lumped mass modeling in hand calculations compared with more realistic discrete modeling in ANSYS.

6.REFERENCES

1. 1) Jonathan P. Stewart, Gregory Fenves and Raymond, "Seismic soil-structure interaction in buildings. I: Analytical methods" journal of geotechnical and geoenvironmental engineering, vol. 125, no. 1, january, 1999. Asce, issn 1090-0241/99/0001. Paper no. 16525

2. 2) S. Hamid Reza Tabatabaiefar , Behzad Fatahi and Bijan Samali, "Seismic behaviour of building frames considering dynamic soil-structure interaction" international journal of geomechanics. june 8, 2011.

3. 3) Konduru v. Rambabu, Mehter m. Allam, "Response of an open-plane frame to multiple support horizontal seismic excitations with soil–structure interaction", journal of sound and vibration 299 (2007) 388–396.

4. 4) Sekhar Chandra Duttaa, Koushik Bhattacharyaa, Rana Royb "Response of low-rise buildings under seismic ground excitation incorporating soil–structure interaction", soil dynamics and earthquake engineering 24 (2004) 893–914

5. 5) Mahir Ulker-kaustell, Raid Karoumia, Costin Pacoste, "Simplified analysis of the dynamic soil–structure interaction of a portal frame railway bridge",engineering structures 32 (2010) 3692–3698

6. 6) George lin, "Stability of frames with grade beam And soil interaction"journal of engineering mechanics, vol. 118, no. 1, january, 1992. ©asce, issn 0733-9399/92/0001-0125 paper no. 286.

7. 7) Alper Ucak and Panos Tsopelas, "Effect of soil–structure interaction on seismic isolated bridges" journal of structural engineering, vol. 134, no. 7, july 1, 2008. ©asce, issn

8. 8) Izuru Takewaki, "Closed-form sensitivity of earthquake input energy to soil-structure interaction system" journal of engineering mechanics, vol. 133, no. 4, april 1, 2007.

9. 9) Javier avilés1 and luis eduardo pérez-rocha "damage analysis of structures on elastic foundation" journal of structural engineering, vol. 133, no. 10, october 1, 2007. ©asce, issn 0733-9445/2007/10-1453–1461