Seismic and Wind Behaviour of RC Buildings with Different Foundation Systems Considering Soil-Structure Interaction

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***Abstract*—The analysis and design of reinforced concrete (RCC) multistorey buildings require proper consideration of factors influencing their structural behaviour under earthquake and wind loading. In conventional structural analysis, the foundation is generally assumed to be fixed at its base. However, in actual conditions, the flexibility of the foundation and supporting soil may influence the overall response of the structure. This phenomenon is known as Soil–Structure Interaction (SSI). The present review paper focuses on SSI in RCC buildings with different foundation systems and soil conditions. Research studies related to fixed-base and flexible-base structures, raft foundations, pile foundations and piled-raft foundations are reviewed. Analytical approaches including ETABS-based structural modelling, spring-based soil representation, response spectrum analysis, nonlinear analysis and three-dimensional numerical modelling are discussed. The review considers the influence of soil type, building height, foundation flexibility and superstructure stiffness on response parameters such as lateral displacement, storey drift, natural period and base shear. The reviewed studies indicate that soil–foundation flexibility can influence the dynamic characteristics and seismic response of buildings, while the extent of its influence depends on the properties of the soil, foundation and superstructure. The review identifies the need for further comparative studies considering different building heights and foundation soil configurations under consistent modelling and loading conditions.**

***Index Terms*—Soil–Structure Interaction, RCC Buildings, Fixed Base, Flexible Base, Raft Foundation, Pile Foundation, Piled-Raft Foundation, ETABS, Seismic Analysis, Storey Displacement.**

I. INTRODUCTION

Multistorey reinforced concrete (RCC) buildings are widely used in urban areas to meet the growing demand for residential, commercial and industrial infrastructure. As building heights and structural complexity increase, the response of these structures to lateral actions such as earthquakes and wind becomes an important consideration in structural design. The evaluation of a building's behaviour therefore requires attention not only to the superstructure but also to the foundation system and the ground supporting it.

Structural analysis is commonly carried out using computer-based software such as ETABS, STAAD.Pro and SAP2000. These tools are used to assess response parameters including lateral displacement, storey drift, base shear and natural period. In many conventional analytical models, the base of a building is assumed to be fixed. This idealisation treats the supports as perfectly restrained and does not explicitly account for deformation of the foundation or the supporting soil. In practice, however, soil is deformable and the foundation may undergo movement under loads transferred from the superstructure.

The interaction between the soil, foundation and superstructure is known as Soil–Structure Interaction (SSI). It represents the combined behaviour of these components under external actions. When foundation and soil flexibility are considered, the response of the structure may differ from that predicted by a fixed-base model. The extent of this difference depends on several factors, including soil stiffness, foundation type, building height, structural configuration and the characteristics of the applied loading.

Foundation systems transfer loads from the superstructure to the supporting ground. Depending on structural demand and geotechnical conditions, buildings may be supported on isolated or combined footings, raft foundations, pile foundations or piled-raft foundations. A raft foundation distributes loads over a broad contact area, while piles transfer loads to deeper soil strata. A piled-raft system combines the load-carrying contribution of the raft and piles. The interaction and load-sharing behaviour of these systems depend on the stiffness and arrangement of the supporting soil.

Ground conditions are also important in evaluating the response of structures. Hard, medium and soft soils differ in stiffness and deformation characteristics, and these differences can influence the foundation response and the dynamic behaviour of the building. In layered soil deposits, the properties and sequence of individual strata may further affect the interaction between the foundation and the ground. Accordingly, the soil profile and the method used to represent soil flexibility are important considerations in SSI analysis.

Numerous analytical and numerical approaches have been adopted to investigate SSI. These include spring-based idealizations, response spectrum analysis, nonlinear static and time-history procedures, and three-dimensional numerical modelling of the soil foundation structure system. Each approach represents the interaction at a different level of detail and involves modelling assumptions. Consequently, the interpretation of findings from different investigations requires consideration of the building configuration, foundation type, soil profile, loading and analytical method used.

This review paper discusses research on soil-structure interaction in RCC multistorey buildings, with particular emphasis on foundation flexibility, soil conditions and structural response. The reviewed studies are considered in relation to fixed base and flexible base assumptions, raft, pile and piled raft foundation systems, and different analytical techniques. The review also identifies areas where further comparative investigation may help clarify the influence of building height and foundation soil configuration on the response of multistorey buildings.

II. REVIEW OF LITERATURE

A review of the influence of soil–structure interaction by Jenifer Priyanka, Anand and Justin et al. (2012) on multistorey buildings supported by rigid and flexible foundations considered different soil conditions and compared the structural response when the foundation was assumed to be rigid and when the flexibility of the supporting soil was included. The authors examined parameters such as lateral deflection, storey drift, base shear and forces developed in structural members. The study explained that the foundation and supporting soil participate in the overall response of a building during earthquake excitation. It also highlighted that the effect of foundation flexibility becomes more important when the structure is supported on softer soil. The work emphasises the need to consider soil characteristics while evaluating the seismic behaviour of multistorey buildings.

Mathew et al. (2014) investigated the seismic response of a three dimensional reinforced-concrete building by considering soil-structure interaction. The study considered a multistorey RC structure and compared its response under fixed base and flexible base assumptions for different soil conditions. Nonlinear modelling and pushover analysis were adopted to examine the influence of soil flexibility on the deformation characteristics of the building. The authors discussed the role of soil stiffness in modifying the interaction between the foundation and the superstructure. Their observations indicated that the influence of SSI is dependent on the supporting soil and is more noticeable for softer ground conditions than for relatively stiff soil. The study provides useful background for understanding the effect of soil flexibility on the seismic response of RC buildings.

Another author Roopa, Naikar and Prakash et al. (2015) carried out an SSI analysis of a reinforced-concrete building with a raft foundation resting on clayey soil. The building was modelled using ETABS, while the foundation–soil interaction was represented through an appropriate spring-based idealisation. The raft foundation was considered as part of the structural system, allowing the influence of soil flexibility on the building response to be examined. The study considered the effect of the supporting clayey soil on dynamic characteristics and

response parameters such as natural period, storey displacement and storey drift. The authors discussed how the flexibility of the raft–soil system changes the behaviour of the superstructure compared with the conventional fixed-base assumption. This research is relevant to studies involving raft foundations and soil spring modelling.

Razvi et al. (2018) studied the effect of soil-structure interaction on a high-rise asymmetric reinforced concrete building using ETABS. The investigation compared fixed base and flexible-base structural models for different seismic zone conditions. To represent the flexibility of the supporting soil, the authors adopted a Winkler-type spring approach at the foundation level, with spring properties related to the soil characteristics. The structural response was examined in terms of storey displacement, storey drift and other seismic response parameters. The study discussed the differences between the conventional fixed base model and the model in which foundation flexibility was considered. It is particularly relevant to research using ETABS and a spring-based approach to investigate the influence of soil flexibility on an RC building.

A dynamic analysis presented by Kulkarni and Ghugal (2019) of an RCC building considered soil structure interaction with a piled-raft foundation. The study considered a multistorey building modelled in ETABS and examined its behaviour for different soil profiles, including homogeneous and stratified soil conditions. The influence of soil flexibility was represented through spring supports, and the structural response was evaluated with and without SSI. The authors considered the effect of soil conditions on the dynamic characteristics and lateral response of the building, including natural period, storey displacement and torsional behaviour. The study is important for understanding the response of buildings supported on piled-raft foundations and for recognising that the arrangement and stiffness of soil layers can influence the overall structural behaviour.

Mohasseb et al. (2020) investigated the effect of soil–pile–structure interaction on the seismic design of tall and massive buildings through case studies. The authors considered building systems supported on pile groups and examined the combined behaviour of the superstructure, piles and surrounding soil. A numerical modelling approach incorporating three-dimensional finite-element analysis and an enhanced cone model was used to study the interaction effects. The work discussed how the inclusion of soil and pile flexibility can modify the dynamic characteristics and lateral response of tall buildings. It also highlighted the importance of pile-group behaviour and the stiffness of the supporting soil when assessing seismic performance. Although the modelling procedure differs from a conventional ETABS spring model, the study provides useful understanding of pile–soil–structure interaction in tall buildings.

Further Kharade and Nagendra (2020) studied soil structure interaction in an RCC framed building using ETABS. The authors considered the combined response of the building, foundation and supporting soil, and represented foundation flexibility through soil springs. Fixed base and flexible base conditions were examined to understand the influence of SSI on the seismic response of the framed structure. The study discussed response parameters such as lateral displacement, storey drift, natural period and base shear. The authors highlighted that conventional structural analysis may not fully represent the behaviour of the soil foundation structure system when the flexibility of the supporting soil is ignored. The work is relevant because it demonstrates the use of ETABS and spring supports for investigating foundation flexibility.

Zagade, Patil and Galatage et al. (2021) carried out a linear dynamic analysis of a high-rise building using ETABS. The study considered a multistorey RC framed structure and adopted response spectrum analysis to investigate its behaviour under earthquake loading. Fixed and flexible support conditions were considered to understand the effect of foundation flexibility on the seismic response. The authors examined storey displacement and storey drift and discussed the change in structural response when the support condition was modified. The study provides a useful comparison between the conventional fixed-base assumption and a flexible support model.

A review by Chatterjee and Sengupta (2022) presented the effect of soil-structure interaction on the dynamic behaviour of structures. The paper discussed the basic mechanisms of SSI, including kinematic interaction and inertial interaction, and explained the limitations of assuming that a building is perfectly fixed at its base. Different modelling approaches, such as soil spring idealisation and numerical methods, were reviewed. The authors

described how the response of a structure depends on the combined properties of the soil, foundation and superstructure. The review also explained that SSI may influence different response parameters in different ways, depending on the characteristics of the structural and soil systems.

Hossain, Sakib and Hasan (2022) evaluated the seismic response of an RCC building considering soil–structure interaction. The study used ETABS to model the building and compared the response of fixed-base and flexible-base conditions. Soil flexibility was represented using a Winkler-type spring model, and response spectrum analysis was adopted to study the seismic behaviour. The authors examined parameters such as storey displacement, storey drift and natural period to understand the effect of foundation flexibility. The study discussed the importance of including the supporting soil in structural analysis rather than treating the base of the building as perfectly rigid.

Recently Abd-Elhamed, Mahmoud and Alotaibi (2023) studied the nonlinear seismic behaviour of reinforced concrete buildings having different heights and floor systems. The authors considered several building configurations and investigated their response using nonlinear time-history and nonlinear static pushover analyses. The study focused on the influence of building height and floor system arrangement on the structural response and the assessment of seismic performance. Although the paper does not directly compare fixed-base and flexible-base foundation conditions, it provides supporting information on the role of superstructure configuration in determining building response.

The assessment done by Dawoud et al. (2024) for seismic performance of a high rise reinforced concrete building supported on a piled-raft foundation while considering soil-structure interaction. The study examined the combined behaviour of the soil, foundation and superstructure using a three-dimensional numerical modelling approach. The authors considered earthquake loading and investigated the influence of pile embedment on the response of the building foundation system. The work discussed the effect of SSI on maximum displacement, inter storey drift and other seismic response characteristics. It highlights that the piles, raft and surrounding soil should be considered as an interacting system when evaluating the seismic behaviour of high-rise buildings.

Fathy et al. (2024) investigated the influence of superstructure stiffness on piled-raft foundations resting on layered soil. The study considered a multistorey building with different superstructure systems and examined the interaction between the building and its foundation. ETABS and PLAXIS 3D were used in a coupled modelling procedure to study the response of the superstructure foundation soil system. The authors focused mainly on the effect of superstructure stiffness on the internal response of the raft foundation, including its bending and shear behaviour. The study also considered the characteristics of the layered soil profile and the influence of the structural system on foundation response.

A comparative investigation presented by Sharma, Thakur and Arora (2026) of a fixed base and flexible base reinforced-concrete buildings considering soil structure interaction. The study used a spring-based representation of soil flexibility in SAP2000 and examined the influence of flexible support on the seismic response of the building. The authors considered dynamic characteristics and response parameters such as natural period, lateral displacement, storey drift and base shear.

III. SUMMARY

From the review of the available literature, it is observed that Soil-Structure Interaction is an important consideration in the behaviour of reinforced-concrete multistorey buildings. The conventional fixed-base assumption does not fully represent the actual condition in which a foundation is supported by deformable soil. The reviewed studies indicate that the flexibility of the supporting soil and foundation can influence the dynamic characteristics and seismic response of a structure, particularly its lateral displacement, storey drift and natural period.

The studies reviewed in this paper have considered different foundation systems, including raft, pile and piled-raft foundations, together with different soil conditions. The response of a building depends on the combined characteristics of the superstructure, foundation and supporting soil. Soil type, soil stiffness, foundation arrangement, building height

and modelling approach are important factors that need to be considered while evaluating SSI. The literature also shows that different analytical methods, such as spring-based modelling, response spectrum analysis, nonlinear analysis and three-dimensional numerical modelling, have been adopted to study this behaviour.

It is further observed that the available studies differ in their building configurations, soil profiles, foundation systems and analytical procedures. Some investigations focus on fixed base and flexible-base comparisons, while others examine a particular foundation system or the influence of superstructure stiffness. Therefore, the findings of different studies should be interpreted with consideration of their individual modelling assumptions and loading conditions. Direct comparison between studies may not always be appropriate when the structural and geotechnical parameters are not consistent.

Based on the reviewed literature, further comparative investigations are required to understand the behaviour of buildings with different heights and foundation–soil configurations under consistent modelling and loading conditions. Particular attention may be given to comparing fixed base, raft, pile and piled raft systems, including the influence of uniform and layered soil profiles. The review highlights the importance of considering the soil foundation structure system as a whole while assessing the seismic response of multistorey RCC buildings.

IV. CONCLUSION

- Soil-Structure Interaction influences the seismic response of multistorey RCC buildings, particularly lateral displacement, storey drift and natural period.
- The fixed-base assumption does not fully represent actual conditions, as it neglects the flexibility of the foundation and supporting soil.
- The structural response depends on the combined properties of the superstructure, foundation and supporting soil.
- Raft, pile and piled-raft foundations show different responses depending on their stiffness, configuration and soil conditions.
- Soil type, soil stiffness and the presence of uniform or layered soil profiles affect foundation behavior and structural response.
- Building height and structural stiffness influence the interaction between the superstructure, foundation and supporting soil.
- Spring-based modelling, response spectrum analysis, nonlinear analysis and three-dimensional numerical modelling are commonly used to study SSI effects.
- Differences in building configurations, soil profiles and analytical methods should be considered when comparing the findings of previous studies.
- Further comparative studies are required on fixed-base, raft, pile and piled raft systems for different building heights and soil profiles under consistent modelling and loading conditions.
- The superstructure, foundation and supporting soil should be considered as an integrated system while evaluating the seismic behavior of multistorey RCC buildings

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