Grenze International Journal of Engineering and Technology, June Issue

Review Paper on Optimal Design Considering Soil Structure Interaction using Staad Pro

Mehul Loya[1] and Dhiraj Agrawal[2]
[1]PG student, Department of Civil Engineering, Yeshwantrao Chavan College of Engineering, Nagpur, India.
Email: mehul3433@gmail.com
[2]Assistant Professor, Department of Civil Engineering, Yeshwantrao Chavan College of Engineering, Nagpur, India

***Abstract*— The interaction of a civil engineering structure and the soil below it, is known as Soil–Structure Interaction (SSI). It majorly affects the structure behavior during analysis and design. In the general practice of design methods, we often assume that the foundation is rigid or fixed, which makes the analysis simplified by ignoring the variability of different soil conditions. This can lead to inaccurate analysis of structural performance. So, as per the study, considering SSI in structural analysis is necessary for making a safer, more accurate, and cost-effective structural design. This project provides a comparison of design of structures that account for SSI for different soil types using STAAD.Pro as the main platform for analysis and design tools. As the previous studies are majorly based on complex mathematical models or advanced simulation tools such as Abaqus, which are not used in the regular work, this work focuses on making SSI modeling accessible to practicing engineers through STAAD.Pro. The study shows the necessity of integrating SSI into routine design workflows and encourages its broader adoption in commonly used software, promoting a more sustainable and resilient approach to structural engineering.**

***Keyword*— Soil Structure interaction (SSI), Civil Engineering, STAAD Pro, Abaqus, Structural analysis and design, SSI adoption on a routine basis.**

I. INTRODUCTION

In the field of civil engineering, the design and analysis of structures are basically performed with the assumption of a fixed or rigid base[4], [5]. However, this consideration overlooks the interaction between the structure and the supporting soil. SSI has a great effect on the structure behavior under different loads, especially in earthquake-prone regions or for zones of poor soil conditions[2], [3], [4], [5] & [6]. Neglecting SSI results in an incorrect prediction of structural behavior, which may give up safety and result in higher construction costs[2], [3], [4], [5] & [6]. This project tries to fill that gap by studying the various structural configuration by modelling different soil conditions in STAAD.Pro. This research includes creating multiple models of the very same structure, each with a different base stiffness that represents various soil types, such as clay, medium dense sand, and hard rock. These models will be analyzed under identical loading conditions to check the outcome of soil stiffness on the key structural components. The primary target of this study is to give a comparative design which takes the SSI role in structural performance and illustrates that changes in soil property can considerably affect the design results[4], [5].

Grenze ID: 01.GIJET.12.2.63_22

Using STAAD. Pro for the analysis and design, the research encourages a practical and user-friendly approach for SSI modeling, hence these models need to be incorporated into routine engineering practice. This study works for the development of performance-based design strategies that are incorporating real conditions. It offers engineers a base for incorporating soil variability into design decisions, leading to safer, more resilient, and economically optimized infrastructure.

II. Literature Review

A. As per Ravi Kant, Wesam Al Agha, Waleed Alozzo Almorad, M.S. Thakur, Nambiappan Umamaheswari[1]

Using ABAQUS finite element software, this study examines how SSI affects the seismic performance of high-rise reinforced concrete (RC) buildings. Buildings with 20, 25, and 30 stories are modelled with raft foundations and dual frame-shear wall systems for the project work. The study compares the outcomes of fixed-base models and models incorporating SSI with soft and hard soil conditions. The seismic input is based on the El-Centro earthquake time-history record. Lateral displacement, base shear, story drift, and natural time period are important factors which were examined in this study. The findings demonstrate that SSI is important, particularly in soft soil. Increases in displacement, drift, and base shear along with a longer time period are inevitable as you add more stories. On hard soil, though—particularly with a large raft foundation—the building behaves almost identically to a fixed-base model. The bottom line is that, when it comes to high-rises on soft ground, we do have to include SSI effects in order to come up with a truly accurate design. Another thing that is emphasized by the study is the importance of optimizing sizes and configuration.

B. As per Amar R Chougule, S S Dyavanal[2]

The research paper was based on the aspect of how SSI affects the seismic performance of multiple-story buildings with regards to foundation types. This indicates a major concern that numerous low-rise buildings on shallow foundations ignore SSI during design, and this can lead to unsafe structures during earthquakes. They modelled a G+6 story building in ETABS software, testing both bare frames and ones with brick infills, with applied seismic loads across rigid or fixed base, stiff medium, and soft soils using Winkler springs to simulate soil flexibility. Soft soil spikes up the building's time period and decreases the base shear. The lateral displacements and story drifts increase significantly for softer ground. Pushover analysis indicated plastic hinges tend to develop in the first story primarily, especially when lying on soft soils, and the building falls into the category of life safety to collapse prevention range. The study concludes at the end that SSI has a significant effect on seismic behaviour and needs to be considered in design when it comes to important buildings in order to enhance safety and durability.

C. As per Dhritiman Mondal [3]

This study is based on the dynamic effects of SSI in the seismic response of a ten-story structure. It calls out the basic problem: traditional design methods assume a fixed, rigid base as a conventional condition, which might often be on the cautionary side and under- or over-estimate the actual condition, more so in places with soft clayey soils. Employing finite element tools such as ANSYS, STAAD.Pro, ETABS, and SAP2000, modeling with various soil conditions like medium, soft, and hard soil conditions, & performed modal and response spectrum analysis, they further compared key metrics like storey displacements, column bending moments, and natural periods. All these points out the findings of the research that SSI shapes dynamic response dramatically. Softer soil extends the natural periods, increases base shear, and lateral displacements. Lastly, the study ends with the conclusion that SSI should always be integrated in design to make an accurate analysis and safeguard structures-particularly high rises and important structures.

D. As per Kamala Kumari G, Dr. S. R. K. Reddy [4]

In this study, the authors extensively analyzed the effects of SSI on the behaviour of the twelve-story building situated at Amaravati, Andhra Pradesh, Seismic Zone III. It is not only an ordinary structure but has two “soft stories” allocated for parking with ten stories of residential and commercial structure above it. The authors cite that the usual design practice to consider the building to be rigidly “fixed” to the ground, though an ideal simplification, in reality result it may be in gross errors, particularly when the soil is quite soft and flexible. In this research to detail the errors caused due to this simplification, they analysed the structure considering the building to be modelled on the “mass spring dashpot system” with five different types of soil, from soft clay to hard rock. By applying standard formulas (Whitman & Richart) to arrive at the pile, mat, and isolated footing springs, they increased the number of DOF from the usual twelve to fourteen to consider the soil behaviour. It is seen that the seismic force and displacement showed large values considering soft soils, but stiffer soils or harder foundations such as pile foundations and mats worked wonders to keep the structure intact or firm. The main message is quite crystal clear— we should never neglect how the soil supporting the structure behaves, since it might be hazardous to the structure's existence. The authors finally conclude that the consideration of SSI is greatly important while designing earthquake-resistant high-rise structures, particularly when the structures rest on soft ground.

E. As per Prof. Dilip J. Chaudhari, Nikhil N. Chopade [5]

In this paper, the role of SSI during the seismic response of the six-story RC structure in the seismic zone V is analyzed. The authors have presented the comparison of four structural conditions, which include the traditional fixed base structure (without soil consideration) and the flexible base structure on hard, medium, and soft soils. Via the SAP2000 tool, the authors have done nonlinear dynamic analyses using seven earthquake records. In doing this, the authors aim was to check how the building behaves in terms of inter-story drift & shear, and its time period.

The findings highlight that soil flexibility is a major importance. As the soil gets softer, the building's time period increases, and inter-story drifts increase—especially in the lower floors. Interestingly, however, the actual shear forces on the stories dropped. When designing for "Life Safety" performance, the study found that softer soils led to lower reinforcement requirements in beams and columns, because of reduced seismic force demands. The conclusion of this paper was incorporating SSI is critical for accurate design especially on medium to soft soils to ensure we aren't over-designing or misjudging a building's safety.

F. As per Jitendra Shrivastava, Prof. Gaurav Shrivastava [6]

This study focuses on a comparison of a G+5 reinforced concrete building with 7 without consideration of SSI by using advance tool i.e. ABAQUS to run the structural simulations. The researchers aim was to analyse whether the soil below the structure matters in the structural behaviour. To find out this, they compared a standard "fixed-base" model against a model that takes Soil-Structure Interaction (SSI) in consideration, by taking a raft foundation on medium clay soil.

Following the response spectrum method from IS 1893:2016, they incorporated real-world soil properties—like density, Poisson's ratio, and elasticity—into the analysis. The results show that the soil conditions play a huge role in how the building reacts. The study concludes that ignoring these the SSI, majorly on soft clay, leads to underestimating the seismic impact which could result in unsafe designs. So, they suggested, for a more accurate earthquake-resistant structure, you have to account for the soil instead of just assuming the foundation as rigid.

III. General Criteria of Building

- The number of storeys is considered as G+15 Storey.
- Height of each storey is considered as 3m.
- Building considered to be located in Mumbai, India.

IV. Structural Analysis

A. Design Parameter Consideration:

Scope

This research covers the literature review & analysis of Residential Building Using Staadpro with & without considering SSI.

Codes and Standard

IS 456-2000[7].
IS 875 (Part 1) [8].
IS 875 (Part 2) [9].
IS 875 (Part 3) [10]
IS 1893- Part 1:2016 [11].

Units of measurement

All units used in the analysis and design are SI system unless otherwise specified.
Soil Data [11]: The Table shows the value of Modulus of Subgrade (Ks) used for analysis for accommodating the soil conditions in KN/m3 tabulated in table I.

TABLE I. SOIL DATA

Soil Type	Modulus of Subgrade (Ks) in KN/m3
Medium Dense Sand	35000
Clayey Soil	25000

Material
Grade of Material - Reinforced Concrete
Concrete grade – M25
Grade of Steel- Fe500
Unit weight of material [8]
R.C.C. - 25 KN/m^3
P.C.C. - 24 KN/m^3
Elastic Modulus [7]
Modulus of elasticity for M25 Grade concrete 5000xSQRT (Fck) = 25000000 KN/m^2
Modulus of elasticity for Steel (Fy) = 200000000 KN/m^2
Clear Cover: The values of clear cover values considered in analysis are tabulated in table II

TABLE II. CLEAR COVER

Component	Clear Cover in mm
Column	40
Wall	30
Beam	25
Slab	25

B. Load Consideration

Dead load – Wall Load
Exterior 200 mm thk. brick wall 3m Ht.
0.2*20*3 = 12.0 KN/m
Exterior 150 mm thk. brick wall 3m Ht.
0.15*20*3 = 9.0 KN/m
Exterior 200 mm thk. brick wall 1.2m Ht.
0.2*20*1.2 = 4.8 KN/m
Exterior 150 mm thk. brick wall 1.2m Ht.
0.15*20*1.2 = 3.6 KN/m   Floor Load
Slab load of 150mm Thk
0.15*25 + 1 = 4.75 KN/m^2
Live load
Live load on slab in Flat area = 2 KN/m^2
Live load on slab in Common area = 3 KN/m^2
Live load on Roof slab = 1.5 KN/m^2

C. Load Cases Consideration[7],[11]:

UNFACTOR LOAD COMB
101 DL+ LL
102 DL+ EQX+
103 DL+ EQX-
104 DL+ EQZ+
105 DL+ EQZ-
106 DL+ WLX+
107 DL+ WLX-
108 DL+ WLZ+
109 DL+ WLZ-
110 DL+ LL+ WLX+
111 DL+ LL+ WLX-
112 DL+ LL+ WLZ+
113 DL+ LL+ WLZ-
114 DL+ LL+ EQX+

115 DL+ LL+ EQX-
116 DL+ LL+ EQZ+
117 DL+ LL+ EQZ-
FACTOR LOAD COMB
201 1.5(DL+LL)
202 1.5(DL+ EQX+)
203 1.5(DL+ EQX-)
204 1.5(DL+ EQZ+)
205 1.5(DL+ EQZ-)
206 1.5(DL+ WLX+)
207 1.5(DL+ WLX-)
208 1.5(DL+ WLZ+)
209 1.5(DL+ WLZ-)
210 1.2(DL+LL+WLX+)
211 1.2(DL+LL+WLX-)
212 1.2(DL+LL+WLZ+)
213 1.2(DL+LL+WLZ-)
214 1.2(DL+LL+EQX+)
215 1.2(DL+LL+EQX-)
216 1.2(DL+LL+EQZ+)
217 1.2(DL+LL+EQZ-)
218 0.9DL + EQX+
219 0.9DL + EQX-
220 0.9DL + EQZ+
221 0.9DL + EQZ-

D. Residential Building Staad Model: Following are the images of the model in modelled in Staad.pro for analysis in figure 1, 2 & 3.

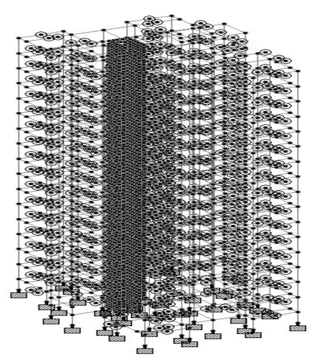

Figure 1. Fixed Condition

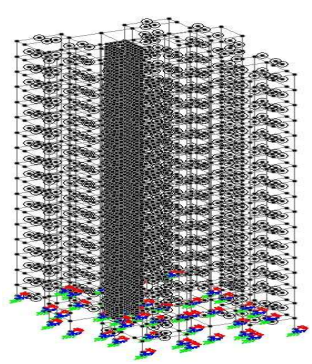

Figure 2. Medium Dense Sand

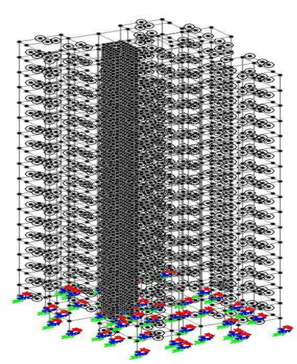

Figure 3. Clayey Soil

E. Residential Building Nodel Displacement: Max Nodel Displacement of residential building in different soil are shown in following images in figure 4, 5 & 6.

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	5237	202 1.5 DL +	**302.757**	-23.257	47.905	307.405	-0.003	0.004	-0.004
Min X	5237	219 0.9 DL +	**-266.875**	-21.997	-39.416	270.665	-0.002	-0.005	0.002
Max Y	2417	218 0.9 DL +	99.198	**6.037**	15.192	100.536	0.000	0.003	-0.004
Min Y	5122	202 1.5 DL +	232.293	**-77.762**	-14.561	245.395	0.001	0.004	-0.006
Max Z	5247	204 1.5 DL +	41.980	-18.402	**281.589**	285.295	0.003	-0.002	0.001
Min Z	5253	221 0.9 DL +	9.999	-6.570	**-262.750**	263.022	-0.003	0.002	0.001
Max rX	539	202 1.5 DL +	5.697	-25.470	-5.810	26.738	**0.018**	0.001	0.000
Min rX	269	201 1.5 DL +	0.037	-25.964	0.638	25.972	**-0.016**	0.000	0.006
Max rY	4630	218 0.9 DL +	199.194	0.551	16.994	199.918	0.001	**0.004**	-0.005
Min rY	5253	203 1.5 DL +	-219.726	-13.447	35.561	222.991	-0.001	**-0.005**	0.002
Max rZ	4821	204 1.5 DL +	47.108	-14.530	234.362	239.491	0.004	-0.002	**0.010**
Min rZ	249	201 1.5 DL +	-0.154	-33.057	0.122	33.057	-0.001	-0.000	**-0.022**
Max Rst	5237	202 1.5 DL +	302.757	-23.257	47.905	**307.405**	-0.003	0.004	-0.004

Figure 4. Fixed Condition

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	5237	202 1.5 DL +	**391.947**	-39.301	14.627	394.184	-0.003	0.001	-0.005
Min X	5237	219 0.9 DL +	**-344.858**	-40.308	-46.577	350.315	-0.002	-0.003	0.003
Max Y	1652	220 0.9 DL +	14.547	**2.768**	116.989	117.923	0.008	-0.001	-0.001
Min Y	5122	202 1.5 DL +	365.074	**-120.268**	-9.195	384.484	0.003	0.001	-0.008
Max Z	5247	220 0.9 DL +	43.144	-19.623	**423.512**	426.156	0.004	-0.003	0.002
Min Z	5253	205 1.5 DL +	32.410	-29.666	**-427.629**	429.880	-0.006	0.001	0.001
Max rX	539	202 1.5 DL +	29.405	-61.435	-2.873	68.170	**0.021**	0.000	-0.002
Min rX	269	202 1.5 DL +	8.818	-56.396	0.146	57.081	**-0.018**	0.000	0.002
Max rY	4020	218 0.9 DL +	272.205	-12.810	6.513	272.584	0.001	**0.002**	-0.007
Min rY	4780	203 1.5 DL +	-275.091	-28.135	-30.550	278.208	-0.000	**-0.004**	0.004
Max rZ	4821	204 1.5 DL +	69.881	-30.264	359.378	367.358	0.005	-0.003	**0.012**
Min rZ	249	201 1.5 DL +	0.547	-60.784	-0.605	60.790	-0.001	-0.000	**-0.025**
Max Rst	5247	205 1.5 DL +	33.200	-50.179	-427.620	**431.832**	-0.005	0.001	-0.001

Figure 5. Medium Dense Sand

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	5250	202 1.5 DL +	**414.413**	-54.566	-4.266	418.012	-0.001	0.001	-0.004
Min X	5237	219 0.9 DL +	**-361.137**	-47.478	-47.485	367.327	-0.002	-0.003	0.004
Max Y	276	218 0.9 DL +	10.754	**0.639**	-0.119	10.774	-0.000	0.000	0.001
Min Y	5122	202 1.5 DL +	392.425	**-135.554**	-11.202	415.328	0.003	0.001	-0.009
Max Z	5247	220 0.9 DL +	44.949	-24.309	**448.772**	451.672	0.004	-0.003	0.002
Min Z	5253	205 1.5 DL +	38.437	-36.750	**-457.287**	460.369	-0.006	0.000	0.001
Max rX	539	202 1.5 DL +	32.523	-75.156	-2.771	81.938	**0.021**	0.000	-0.003
Min rX	269	202 1.5 DL +	9.823	-68.455	0.146	69.156	**-0.019**	-0.000	0.000
Max rY	4020	218 0.9 DL +	291.516	-18.186	3.585	292.104	0.001	**0.002**	-0.007
Min rY	4780	203 1.5 DL +	-288.915	-36.913	-33.234	293.153	-0.000	**-0.004**	0.005
Max rZ	4821	204 1.5 DL +	74.183	-37.189	380.222	389.172	0.006	-0.003	**0.012**
Min rZ	249	201 1.5 DL +	0.620	-71.678	-0.698	71.684	-0.001	-0.000	**-0.025**
Max Rst	5247	205 1.5 DL +	40.220	-59.401	-457.278	**462.871**	-0.005	0.000	-0.001

Figure 6. Clayey Soil

F. Residential Building Beam & Column Results: The max reaction & bending moment occurring in the beam and column are shown below in figure 7,8 & 9.

	Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kN-m	My kN-m	Mz kN-m
Max Fx	4258	202 1.5 DL +	29	**6903.706**	44.042	-193.894	1.835	136.827	60.357
Min Fx	4364	218 0.9 DL +	278	**-1944.533**	65.613	-5.196	-1.526	-2.950	-32.696
Max Fy	538	202 1.5 DL +	893	0.000	**601.421**	0.000	-4.138	0.000	181.755
Min Fy	131	203 1.5 DL +	277	92.574	**-530.432**	21.683	-0.549	5.736	129.976
Max Fz	4321	203 1.5 DL +	1500	2198.726	-2.315	**145.310**	4.113	-95.511	-26.822
Min Fz	4258	201 1.5 DL +	29	6699.419	31.320	**-199.049**	2.128	150.724	21.562
Max Mx	2547	205 1.5 DL +	3966	0.000	1.877	-0.000	**104.842**	0.000	0.000
Min Mx	1949	205 1.5 DL +	3052	0.000	437.659	-0.000	**-62.053**	0.000	252.006
Max My	4260	204 1.5 DL +	580	5534.979	26.045	-146.111	0.531	**229.908**	42.123
Min My	4258	202 1.5 DL +	271	6893.687	44.042	-193.894	1.835	**-270.350**	-32.130
Max Mz	212	202 1.5 DL +	271	63.820	-411.254	3.345	-3.233	5.152	**470.501**
Min Mz	212	202 1.5 DL +	251	63.820	-401.605	3.345	-3.233	-2.459	**-454.126**

Figure 7. Fixed Condition

	Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kN-m	My kN-m	Mz kN-m
Max Fx	4258	202 1.5 DL +	29	**6502.982**	86.292	-167.934	6.113	110.515	176.495
Min Fx	4153	220 0.9 DL +	75	**-512.290**	36.674	-1140.773	-6.105	-31.784	21.350
Max Fy	119	205 1.5 DL +	248	168.441	**896.709**	-140.903	-2.100	46.990	367.919
Min Fy	131	203 1.5 DL +	277	211.245	**-1170.572**	51.427	3.984	13.823	246.242
Max Fz	4275	205 1.5 DL +	30	-32.208	5.111	**1481.966**	-4.883	-483.339	3.830
Min Fz	4153	220 0.9 DL +	10	-511.288	36.674	**-1140.773**	-6.105	367.487	34.186
Max Mx	2147	205 1.5 DL +	3356	0.000	1.877	0.000	**127.704**	0.000	0.000
Min Mx	1749	205 1.5 DL +	2747	0.000	478.979	0.000	**-70.241**	-0.000	276.407
Max My	4171	204 1.5 DL +	15	38.996	163.437	-849.256	-4.682	**385.005**	92.712
Min My	4293	205 1.5 DL +	31	257.663	1.497	1286.836	3.145	-508.647	1.864
Max Mz	4381	202 1.5 DL +	39	1386.286	320.740	0.997	1.393	-1.157	**474.845**
Min Mz	4171	203 1.5 DL +	15	737.620	-865.040	46.738	-1.434	-29.275	**-464.875**

Figure 8. Medium Dense Sand

	Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kN-m	My kN-m	Mz kN-m
Max Fx	4258	202 1.5 DL +	29	**6321.277**	84.177	-156.347	6.242	98.156	183.791
Min Fx	4153	220 0.9 DL +	75	**-515.353**	39.578	-1263.964	-7.109	-33.790	23.262
Max Fy	4171	218 0.9 DL +	15	1269.412	**880.055**	-116.229	-8.699	36.001	511.583
Min Fy	131	203 1.5 DL +	277	183.003	**-1121.690**	45.285	4.643	12.153	228.435
Max Fz	4275	205 1.5 DL +	30	-59.430	7.627	**1636.690**	-5.050	-534.881	6.539
Min Fz	4153	220 0.9 DL +	10	-514.351	39.578	**-1263.964**	-7.109	408.597	37.114
Max Mx	2147	205 1.5 DL +	3356	0.000	1.877	0.000	**132.598**	-0.000	0.000
Min Mx	1549	205 1.5 DL +	2442	0.000	481.926	-0.000	**-71.179**	0.000	278.091
Max My	4171	204 1.5 DL +	15	63.431	175.412	-934.567	-6.047	**423.641**	99.772
Min My	4293	205 1.5 DL +	31	241.116	3.887	1413.043	2.878	**-558.650**	4.543
Max Mz	4381	202 1.5 DL +	39	1379.518	349.847	2.174	1.823	-3.390	**522.322**
Min Mz	4171	219 0.9 DL +	15	235.091	-917.003	71.356	1.877	-34.552	**-503.118**

Figure 9. Clayey Soil

VI. CONCLUSION

In this study, we found the gap in previous research that the previous SSI based research work were based on advanced tools like ABAQUS etc., which are not in practice for major work because of their complexity. Since STAAD Pro is used in the industry so SSI based research work based on STAAD Pro needs to be worked out. This study shows the critical necessity of SSI in determining structural analysis and design under both seismic and wind loads with comparison of with & without SSI consideration using STAAD Pro as analysis tool. Comparative analysis across diverse soil conditions reveals that SSI significantly affects key response parameters, including lateral displacements and the stresses induced in beams and columns. These findings strongly advocate for the SSI considerations into routine analysis & design workflows, ensuring the development of structural solutions that are not only safer and more resilient but also economically optimized and performance driven.

REFERENCE

[1] Ravi Kant, Wesam Al Agha, Waleed Alozzo Almorad, M.S. Thakur, Nambiappan Umamaheswari, "Study on seismic performance of reinforced concrete multi-storey building considering soil-structure interaction effect," Elsevier; 2021, December 2021.

[2] Amar R Chougule, S S Dyavanal, "Seismic Soil Structure Interaction of Buildings with Rigid and Flexible Foundation," IJERT ISSN (Online): 2319-7064 Volume 4 Issue 6, June 2015.

[3] Dhritiman Mondal, "Soil Structure Interaction Effect on Dynamic Behavior of a Building," IJERT ISSN (Online): 2278-0181 Vol. 8 Issue 08, August-2019.

[4] Kamala Kumari G, Dr. S. R. K. Reddy, "Influence of Soil-Structure Interaction on Response of a Multi-Storied Building against Earthquake Forces," IJSR ISSN (Online): 2319-7064 Volume 5 Issue 6, June 2016.

[5] Prof. Dilip J. Chaudhari, Nikhil N. Chopade, "Performance Based Seismic Design of RC Building with Consideration Of Soil Structure Interaction," IRJET e-ISSN: 2395-0056 Volume: 05 Issue: 05 May 2018.

[6] Jitendra Shrivastava, Prof. Gaurav Shrivastava, "Comparative study of building analysis with and without SSI effect by using ABAQUS software," IJRAR E-ISSN 2348-1269, P- ISSN 2349-5138 Volume 9, Issue 3 2022.

[7] IS 456:2000, Plain and Reinforced Concrete - Code of Practice, Bureau of Indian Standards, New Delhi, India, 2000.

[8] IS 875 (Part 1):1987. Code of practice for design loads (other than earthquake) for buildings and structures: Part 1 dead loads—Unit weight of building materials and stored materials. Bureau of Indian Standards, New Delhi, India, 1987. (Reaffirmed 2018).

[9] IS 875 (Part 2):1987. Code of practice for design loads (other than earthquake) for buildings and structures: Part 2 imposed loads. Bureau of Indian Standards, New Delhi, India, 1987. (Reaffirmed 2022).

[10] IS 875 (Part 3):2015. Code of practice for design loads (other than earthquake) for buildings and structures: Part 3 wind loads. Bureau of Indian Standards, New Delhi, India, 2015. (Amendment 1: 2016).

[11] IS 1893 (Part 1):2025. Design earthquake hazard and criteria for earthquake resistant design of structures: Part 1 General provisions. Bureau of Indian Standards, New Delhi, India, 2025.