NON-LINEAR DYNAMIC ANALYSIS OF LIGHT WEIGHT FLOOR SYSTEM WITH SSI

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***Abstract*: In** the present study the dynamic behavior of light weight floor building frames under seismic forces uniting soil structure interaction is considered. The analysis is carried out using FEM software STAAD-Pro. In interaction analysis of space frame, soil are considered as parts of a single compatible unit and soil is idealized using the soil models for analysis. The soil system below a raft footing is replaced by providing a true soil model (continuum model). In continuum model, soil is considered as homogeneous, isotropic, elastic of half space for which dynamic shear modulus and Poisson's ratio are the inputs. To estimate the Story drift, base shear and ground motion for earthquake zone IV and zone V structures considering situated in clayey and sandy soil To study the behavior of the building for ground motion displacement. To evaluate the various results by comparing normal concrete structure without SSI and normal concrete structure with clayey sand sandy soil structure interaction To evaluate the various results by comparing lightweight concrete structure without SSI and lightweight concrete structure with clayey sand sandy soil structure interaction.

***Keywords* -lightweight floor system, Normal concrete structure, soil structure interaction (SSI), Base isolation (BI), Ground motion, base shear, story drift.**

I. INTRODUCTION

Soil Structure Interaction (SSI) is the analysis to quantify the influence of soil on the response of a structure to the ground motions. Both, the structure displacement and ground motions are dependent on each other. [13]
The superstructure has an interface with underlying soil or rock through the foundation. Under static conditions, only vertical loads of structure need to be transferred to supporting rock. In a seismic environment, the loads imposed on a foundation of a structure under seismic excitation can greatly exceed the static vertical loads as even produce uplift; in addition, there will be horizontal forces and possibly movement at foundation level. The soil and rock at a site have specific characteristics that can significantly amplify the incoming earthquake motions travelling from the earthquake source. For structureswhere P delta effects play a significant role,SSI effects must be analysed structures with massive or deep seated foundations, slender tall structures and structures supported on very soft soil with average shear velocity less than 100 m/s. [1]

1.1 Problem statement

Much research is not done in finding the interaction of soil and the structure and vice versa. It is worthwhile to estimate the Story drift, base shear and ground motion for different earthquake zones. The structures considering situated in different types of soils are also needed to be investigated to assess the effect of soil properties on this interaction.
As an alternative to the normal RCC structure, these interactions are to be verified on light weight structures to have economy by reducing the seismic weight of the structure.

1.2 Objectives of Present study

- To perform parametric study of lightweight floor system and Normal Concrete considering soil structure system.
- To perform non-linear static (Time history Analysis) for the SMRF building models considered situated in seismic, Zone IV, Zone V as per IS 1893:2002(PART-1).
- To study the effect of Normal Concrete SMRF Building and light weight floor system Building for Story Drift, Base Shear and Ground motion
- To Study the effect of SSI on normal SMRF building and Light weight Floor system for Story Drift, Base Shear and Ground motion.
- To study the effect of Normal Concrete SMRF Building and light weight floor system Building with Base Isolation for Story Drift, Base Shear and Ground motion.
- To Study the effect of SSI on normal SMRF building and Light weight Floor system with Base Isolation for Story Drift, Base Shear and Ground motion.
- To extract and compare various results like point displacement, story drift, Base Shear for non-linear static analysis.

II. METHEDOLOGY

Soil-Structure Interaction Models Basically there are two types of derivation approaches used for models of SSI problems; structural and continuum approach. The structural approach has a rigid base from which subgrade and superstructure are built up with structural elements, such as flexural elements, springs, etc. The other alternative, continuum approach is based on three partially-differential equations (compatibility, constitutive and equilibrium) which are governing the behaviour for the subgrade as a continuum (Teodoro, 2009). When combining the two derivation approaches, the method is called a hybrid derivation approach. The two approaches have advantages as well as disadvantages. A structural model is easy to implement in practice, since modelling and solving are simple in available commercial analysis software. However, estimation of material parameters for the structural elements representing the subgrade is a well-known problem. In contrast to the structural approach the soil parameters are straight forward to specify for an elastic continuum model, but implementing such models in existing commercial software is problematic. Nonetheless both methods require geotechnical evaluation of the soil's parameters. (Horvath and Colasanti, 2011

2.1 Winkler Model

Today the most well-known and used foundation model for SSI analysis, by structural engineers, is the Winkler model. It is also the oldest and simplest method to model the subgrade which consists of infinite number of springs on a rigid base. For a structural model there will be a finite number of springs, see Fig-1. (Horvath and Colasanti, 2011)

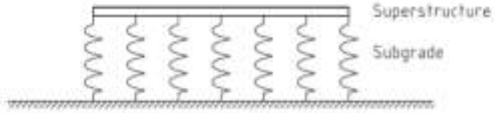

Fig-1 Visualization of a structural Winkler model.

The Winkler model is easy to implement in a structural system. In a 2D structure, beam elements on top of the subgrade are attached to a spring at each node. The springs are only affecting the structure in vertical direction. Every spring is attached to two nodes, but since the lower nodes are fixed, those nodes can be removed from the equations, i.e. no nodes "outside" the superstructure's geometry are added to the system of equations.

The stiffness matrix for the springs in a Winkler model consisting of four springs is for nodes with one-degree of freedom. For nodes of higher order, the matrix will be filled up with zeros at those degrees of freedom

The stiffness of a discrete spring ki can be estimated with different approaches, but is always defined as a relation between the settlement δi and reaction force Ri in a point. For one specific point the relation can be written as:

$$k_i = R_i / \delta_i \qquad \text{.........................(1)}$$

In a simple model, the spring stiffness can be assumed to be uniformly distributed. A normal approximation, presented by SGI (1993), for calculation of settlements is to assume a 2:1 stress distribution in the soil. The stiffness for discrete springs is calculated by dividing the vertical load affecting one spring q*s by the settlement δ, where s is the spacing between the springs. With uniform spring stiffness, constant EmodulusEs through the depth in the soil and assuming 2:1 stress distribution, the stiffness of discrete springs is determined with equation (2), where L is the length of thesuperstructure and H height of the subgrade.

$$k_i = \frac{q * s}{\delta} = \frac{E_s * s}{L * \ln\left(\frac{H+L}{L}\right)} \qquad \text{................ (2)}$$

Winkler model is the simplest structural model, but also the least accurate. The primary deficiency of the model is that the shear capacity of the soil is neglected. As a result of omitting the shear stresses, displacement has no spread in transverse direction. Therefore displacement discontinuity appears between loaded and unloaded surfaces. In reality soil has a shear capacity and no displacement discontinuity occurs, see Fig-2 and 3

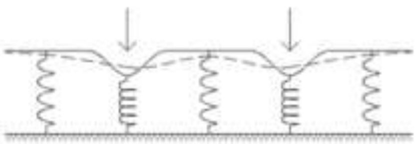

Fig-2 Continuous line: no shear transfer between springs. Dashed line: shear transfer between springs.

Fig-3 Left, Vertical displacement modelled according to the Winkler model. Right, Vertical displacement often observed in reality. Adapted from (Kerr, 1964).

2.2 Time history analysis

- Dynamic analysis shall be performed to obtain the design seismic force, and its distribution to different levels along the height of the building and to the various lateral load resisting elements.
- Dynamic analysis may be performed either by the Time History Method or by the Response Spectrum Method.
- Time History Method of analysis shall be based on an appropriate ground motion and shall be performed using accepted principles of dynamics.
- After applying the load combinations, time history analysis has been defined, while defining the time history EL-Centro earthquake data is used for analysis of result. And top nodal results are studied.

2.3 Determination of base shear

For the determination of seismic forces, the country is classified in four seismic zones as shown in Fig-4the total design lateral force or design base shear along any principal direction shall be determined by this expression

$$V_b = A_h * W \ldots\ldots\ldots \text{(A)}$$

Where, A_h = design horizontal seismic coefficient for a structure
W= seismic weight of building.
The design horizontal seismic coefficient for a structure A_h is given by
Z is the zone factor given in Table 2 of IS 1893:2002 (part 1) for the maximum considered earthquake (MCE) and service life o f a structure in a zone. The factor 2 is to reduce the MCE to the factor for design base earthquake (DBE)
I is the importance factor, depending upon the functional use of the structure, characterized by hazardous consequences of its failure, post-earthquake functional needs, historical or economic importance.
The minimum values of importance factor are given in table 6 of IS 1893:2002 R is the response reduction factor, depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations. The need for introducing R in base shear formula Sa/g is the average response acceleration coefficient for rock and soil sites as given in IS 1893:2002 (part 1). The values are given for 5 % of damping of the structure.

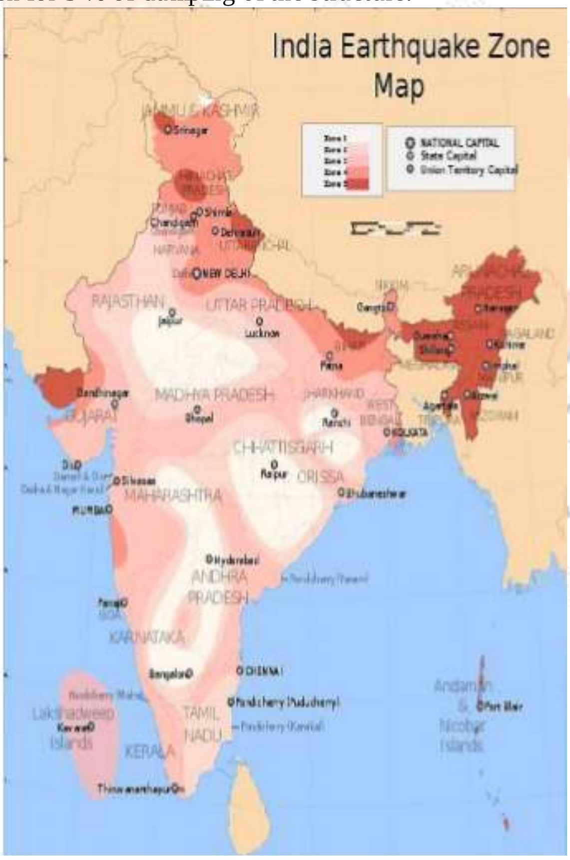

Fig-4 Earthquake zone map of India

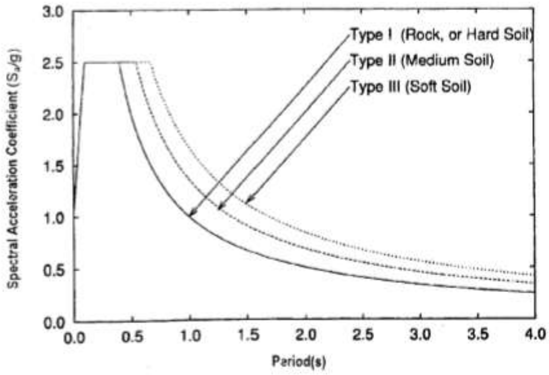

Fig-5 IS code spectra from IS 1893:2002 (Part-I)

2.4. Staad Pro Modelling

2.4.1 Earthquake Zone 4 Modelling.

Model 1: A Normal Conventional RCC structure considering without SSI.
Model 2: A Normal Conventional RCC structure considering with Clayey SSI.
Model 3: A Normal Conventional RCC structure considering with Sandy SSI.
Model 4: A Normal Conventional RCC structure considering without SSI and Base Isolation (BI).
Model 5: A Normal Conventional RCC structure considering with Clayey SSI and BI.
Model 6: A Normal Conventional RCC structure considering with Sandy SSI and BI.
Model 7: A Light weight floor system considering without SSI.
Model 8: A Light weight floor system considering with Clayey SSI.
Model 9: A Light weight floor system considering with Sandy SSI.
Model 10: A Light weight floor system considering without SSI and with Base Isolation (BI).
Model 11: A Light weight floor system considering with Clayey SSI and with BI.
Model 12: A Light weight floor system considering with Sandy SSI and with BI.

2.4.2 Earthquake Zone 5 Modelling.

Model 1: A Normal Conventional RCC structure considering without SSI.
Model 2: A Normal Conventional RCC structure considering with Clayey SSI.
Model 3: A Normal Conventional RCC structure considering with Sandy SSI.
Model 4: A Normal Conventional RCC structure considering without SSI and Base Isolation (BI).
Model 5: A Normal Conventional RCC structure considering with Clayey SSI and BI.
Model 6: A Normal Conventional RCC structure considering with Sandy SSI and BI.
Model 7: A Light weight floor system considering without SSI.
Model 8: A Light weight floor system considering with Clayey SSI.
Model 9: A Light weight floor system considering with Sandy SSI.
Model 10: A Light weight floor system considering without SSI and with Base Isolation (BI).
Model 11: A Light weight floor system considering with Clayey SSI and with BI.
Model 12: A Light weight floor system considering with Sandy SSI and with BI
The following data are taken for analysis of the frame

Table-1 Properties of structure in Staad pro

1)Grade of concrete	M30
2)Grade of steel	Fe415
3)Type of the structure	SMRF
4) Size of columns	0.230 m × 0.450m
5) Size of beams	0.230 m × 0.450m
6) Depth of slab	0.150 mm
7) Soil Property's	**a) Clayey Soil** Elasticity- 25000kN/M^2 Density - 17.5kN/M^3 Poisson's Ratio- 0.4
	b) Sandy Soil

	Elasticity - 20000kN/ M^2 Density - 17.5kN/M^3 Poisson's Ratio- 0.2
9) Light weight Concrete Structure	Elasticity- 25000 kN/M^2 Density - 17.5 kN/ M^3 Poisson's Ratio- 0.17

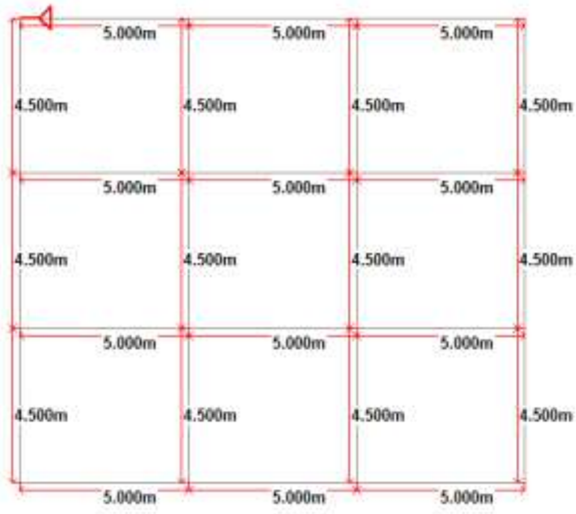

Fig-6 Plan of STAAD Pro Models

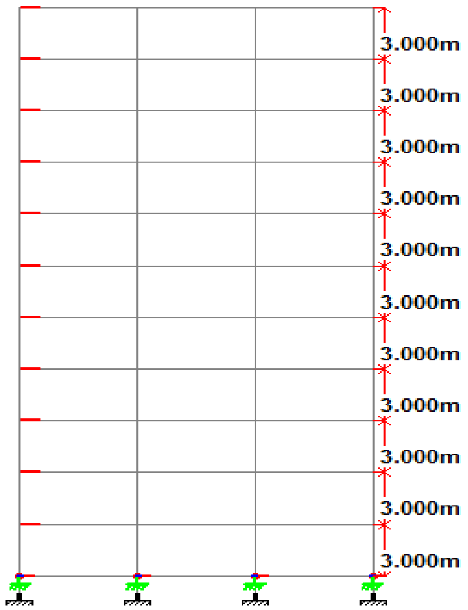

Fig-7 Elevation of STAAD Pro Models

Fig-8 SSI at Foundation Level STAAD Pro

Fig-9 SSI at Foundation Level with Base Isolation STAAD Pro

III. RESULT AND DISCUSSION

3.1 STORY DRIFT

3.1.1 Story drift in earthquake zone 4

Table-2 Story Drift Results From STAAD Pro For Normal Concrete Structures in Earthquake Zone 4 without Base Isolation

STORY NO	DRIFT -mm		
	Zone 4 without Base Isolation		
	Normal without SSI	Normal with Clayey SSI	Normal with Sandy SSI
0	0	0	0
1	0.394	0.777	14.725
2	4.68	9.32	37.911
3	9.996	19.875	62.31
4	15.446	30.66	86.704
5	20.852	41.31	110.624
6	26.109	51.617	133.67
7	31.107	61.371	155.397
8	35.725	70.339	175.31
9	39.82	78.258	192.86
10	43.241	84.845	207.46
11	45.818	89.799	218.497
12	47.512	93.015	225.737

Table-3 Story Drift Results From STAAD Pro For Lightweight Concrete Structures in Earthquake Zone 4 without Base Isolation

STORY NO	DRIFT X-mm		
	Zone 4 without Base Isolation		
	Lightweight without SSI	Lightweight with Clayey SSI	Lightweight with Sandy SSI
0	0	0	0
1	0.357	0.741	12.396
2	4.24	8.891	31.916
3	9.057	18.962	52.457
4	13.996	29.252	72.994
5	18.895	39.413	93.132
6	23.657	49.247	112.534
7	28.186	58.554	130.825

8	32.37	67.11	147.589
9	36.082	74.667	162.364
10	39.183	80.957	174.656
11	41.521	85.691	183.947
12	43.064	88.772	190.049

Table-4 Story drift Results from STAAD Pro for Normal Concrete Structures in earthquake zone 4 with Base Isolation

STORY NO	DRIFT X-mm		
	ZONE 4 with BASE ISOLATION		
	Normal without SSI	Normal with Clayey SSI	Normal with Sandy SSI
0	0	0	0
1	0.141	0.281	6.049
2	3.611	7.193	17.482
3	8.81	17.512	34.154
4	14.24	28.255	51.412
5	19.64	38.893	68.427
6	24.893	49.192	84.833
7	29.888	58.94	100.301
8	34.503	67.902	114.474
9	38.596	75.815	126.959
10	42.014	82.397	137.336
11	44.588	87.345	145.163
12	46.279	90.556	150.28

Table-5 Story Drift Results from STAAD Pro for Lightweight concrete structures in earthquake zone 4 with Base Isolation

STORY NO	DRIFT X-mm		
	Zone 4 with Base Isolation		
	Lightweight without SSI	Lightweight with Clayey SSI	Lightweight with Sandy SSI
0	0	0	0
0	0	0	0
1	0.127	0.267	6.973
2	3.271	6.86	20.272
3	7.983	16.706	39.904
4	12.902	26.956	60.249
5	17.795	37.105	80.311
6	22.555	46.932	99.655
7	27.081	56.233	117.894
8	31.262	64.783	134.608
9	34.971	72.335	149.332
10	38.07	78.62	161.575
11	40.405	83.349	170.817

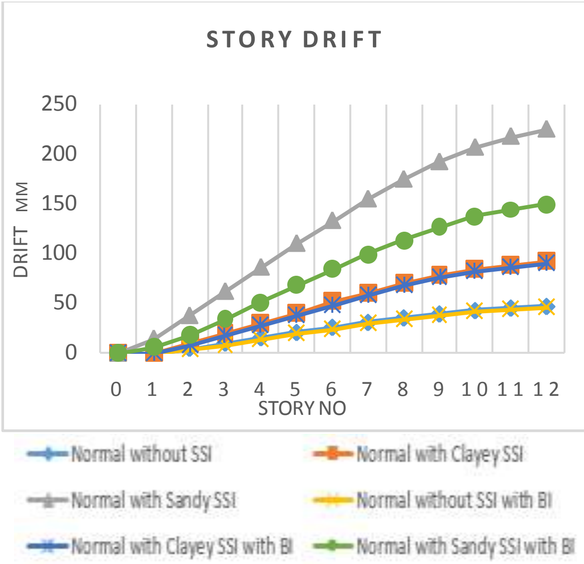

Fig-10 Comparison between Normal Concrete Structure without SSI and Normal Concrete Structures with Clayey and Sandy SSI

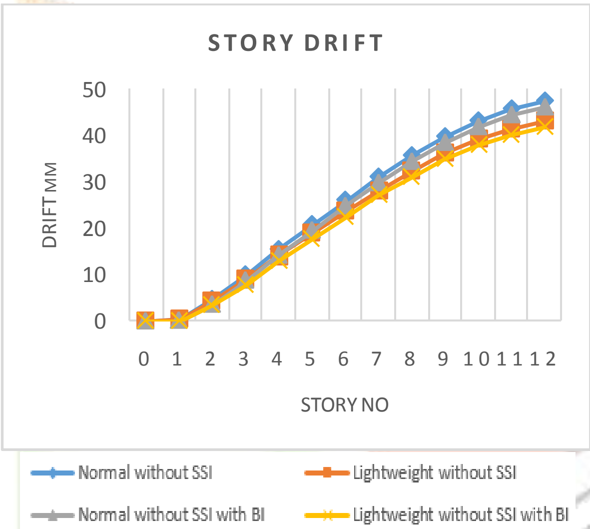

Fig-11 Comparison between Normal Concrete Structure without SSI and Lightweight Concrete Structures without SSI

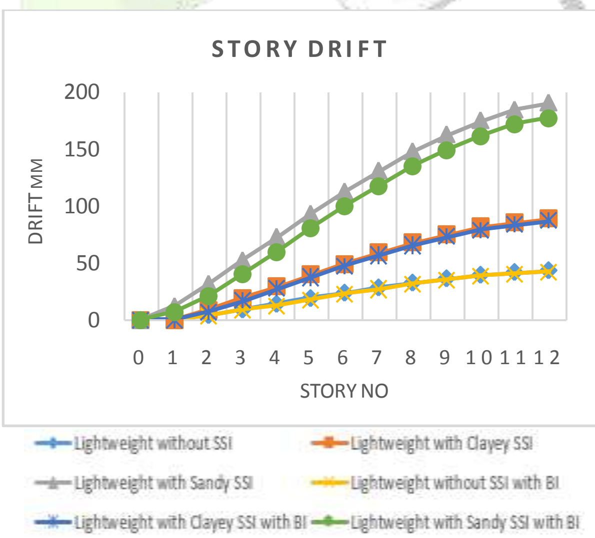

Fig-12 Comparison between Lightweight Concrete Structure without SSI and Lightweight Concrete Structures with Clayey and Sandy SSI

3.1.2 Story drift in earthquake zone 5

Table-6 Story Drift Results from Staad Pro for Normal Concrete Structures in Earthquake Zone 5 without Base Isolation

STORY NO	DRIFT -mm		
	ZONE 5 without BASE ISOLATION		
	Normal without SSI	Normal with Clayey SSI	Normal with Sandy SSI
0	0	0	0
1	0.587	1.163	13.252
2	7.021	13.981	34.12
3	14.994	29.813	56.079
4	23.17	45.991	78.033
5	31.279	61.966	99.562
6	39.164	77.426	120.303
7	46.662	92.058	139.857
8	53.587	105.509	157.779
9	59.731	117.387	173.574
10	64.862	127.267	186.714
11	68.73	134.702	196.646
12	71.253	139.508	203.167

Table-7 Story Drift Results From STAAD Pro For Lightweight Concrete Structures in Earthquake Zone 5 without Base Isolation

STORY NO	DRIFT -mm		
	Zone 5 without Base Isolation		
	Lightweight without SSI	Lightweight with Clayey SSI	Lightweight with Sandy SSI
0	0	0	0
1	0.587	1.108	11.155
2	7.021	13.337	28.724
3	14.994	28.444	47.211
4	23.17	43.879	65.694
5	31.279	59.121	83.819
6	39.164	73.871	101.28
7	46.662	87.831	117.743
8	53.587	100.666	132.83
9	59.731	112.001	146.128
10	64.862	121.435	157.19
11	68.73	128.54	165.551
12	71.253	133.144	171.047

Table-8 Story Drift Results from STAAD Pro for Normal Concrete Structures in Earthquake Zone 5 with Base Isolation

STORY NO	DRIFT -mm		
	Zone 5 with Base isolation		
	Normal without SSI	Normal with Clayey SSI	Normal with Sandy SSI
0	0	0	0

1	0.211	0.422	7.455
2	5.419	10.791	21.672
3	13.216	26.269	42.659
4	21.361	42.383	64.408
5	29.461	58.34	85.856
6	37.34	73.789	106.535
7	44.833	88.411	126.034
8	51.755	101.854	143.901
9	57.894	113.723	159.642
10	63.021	123.595	172.73
11	66.885	131.022	182.61
12	69.404	135.82	189.078

Table-9 Story Drift Results From STAAD Pro For Lightweight Concrete Structures in Earthquake Zone 5 with Base Isolation

STORY NO	DRIFT -mm		
	Zone 5 with Base Isolation		
	Lightweight without SSI	Lightweight with Clayey SSI	Lightweight with Sandy SSI
0	0	0	0
1	0.191	0.401	6.275
2	4.909	10.293	18.244
3	11.975	25.06	35.913
4	19.354	40.435	54.224
5	26.694	55.659	72.28
6	33.833	70.398	89.69
7	40.622	84.349	106.105
8	46.893	97.176	121.147
9	52.457	108.503	134.399
10	57.105	117.929	145.417
11	60.612	125.027	153.734
12	62.905	129.623	159.186

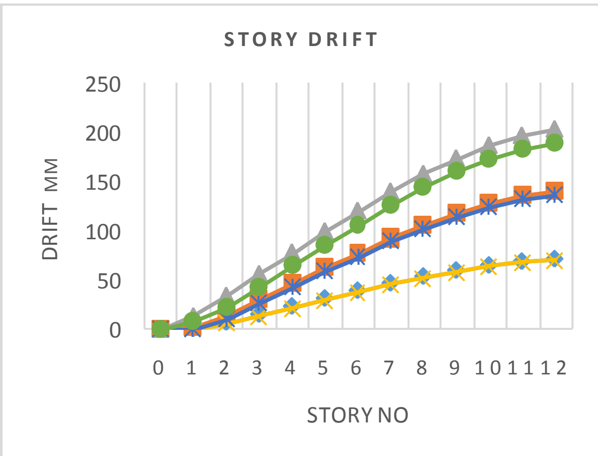

Fig-13 Comparison between Normal Concrete Structure without SSI and Normal Concrete Structures with Clayey and Sandy SSI

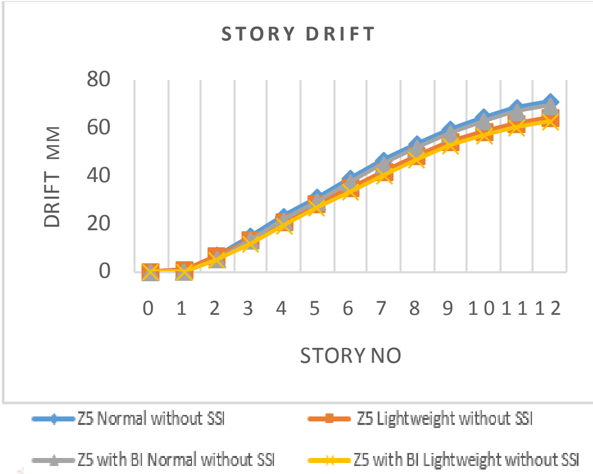

Fig-14 Comparison between Normal Concrete Structure without SSI and Lightweight Concrete Structures without SSI

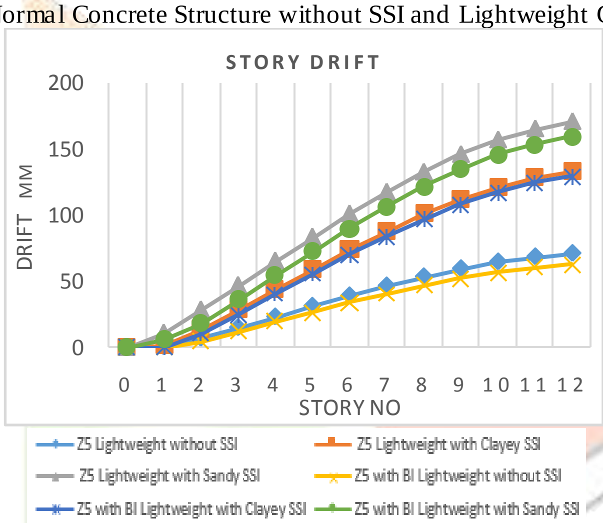

Fig-15 Comparison between Lightweight Concrete Structure without SSI and Lightweight Concrete Structures with Clayey and Sandy SSI

3.2 BASE SHEAR

3.2.1 Base shear for earthquake Zone 4

Table-10 Base Shear Results From STAAD Pro For Normal Concrete Structures in Earthquake Zone 4 without Base Isolation

STORY NO	BASE SHEAR X-kN		
	Zone 4 without Base Isolation		
	Normal without SSI	Normal with Clayey SSI	Normal with Sandy SSI
0	-3.537	-3.627	3.76
1	0.516	-0.295	-5.783
2	-2.761	-6.644	-15.034
3	-5.671	-12.735	-26.038
4	-9.292	-19.921	-38.522
5	-13.515	-28.106	-52.628
6	-18.333	-37.271	-68.234
7	-23.704	-47.324	-85.184
8	-29.32	-57.858	-102.911

9	-36.121	-69.718	-122.201
10	-38.866	-76.695	-134.97
11	-50.376	-95.508	-167.843

Table-11 Base Shear Results From STAAD Pro For Normal Concrete Structures in Earthquake Zone 4 without Base Isolation

STORY NO	BASESHEAR X-kN		
	Zone 4 without Base Isolation		
	Lightweight without SSI	Lightweight with Clayey SSI	Lightweight with Sandy SSI
0	-3.588	-3.673	3.253
1	0.529	-0.23	-4.909
2	-2.521	-6.356	-12.647
3	-5.151	-12.172	-21.922
4	-8.435	-19.032	-32.43
5	-12.261	-26.84	-44.307
6	-16.622	-35.579	-57.444
7	-21.485	-45.163	-71.717
8	-26.552	-55.192	-86.618
9	-32.777	-66.524	-102.985
10	-35.022	-73.061	-113.326
11	-45.98	-91.622	-141.518

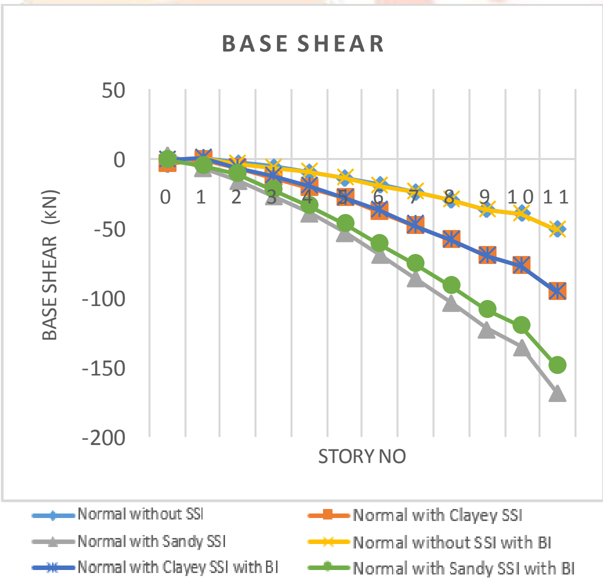

Fig-16 Comparison between Normal Concrete Structure without SSI and Normal Concrete Structures with Clayey and Sandy SSI

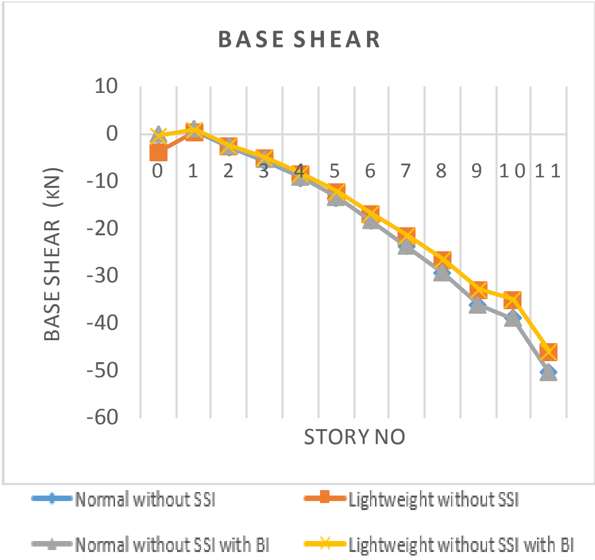

Fig-17 Comparison between Normal Concrete Structure without SSI and Lightweight Concrete Structures with Clayey and Sandy SSI

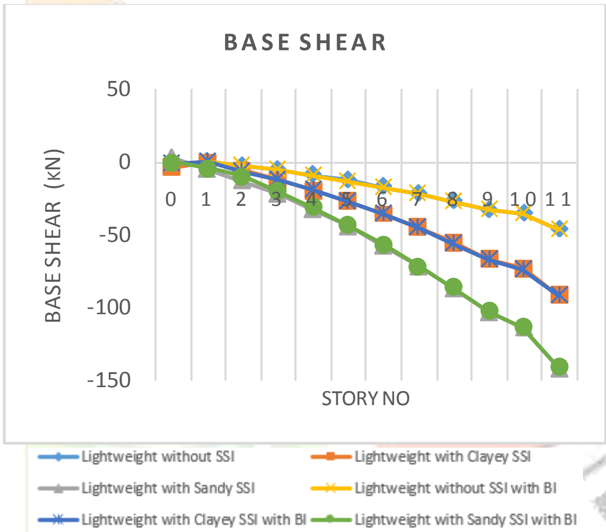

Fig-18 Comparison between Lightweight Concrete Structure without SSI and Lightweight Concrete Structures with Clayey and Sandy SSI

3.2.2 Base shear for earthquake Zone 5

Table-12 Base Shear Results From STAAD Pro For Normal Concrete Structures in Earthquake Zone 4 with Base Isolation

STORY NO	BASESHEAR X-kN		
	Zone 4 with BASE ISOLATION		
	Normal without SSI	Normal with Clayey SSI	Normal with Sandy SSI
0	0	0	0
1	1.13	1.045	-4.83
2	-2.475	-5.905	-10.334
3	-5.33	-12.079	-21.171
4	-9.088	-19.494	-32.945
5	-13.362	-27.792	-45.933
6	-18.221	-37.042	-60.154
7	-23.621	-47.155	-75.499
8	-29.257	-57.73	-91.466

9	-36.071	-69.617	-108.89
10	-38.83	-76.622	-120.119
11	-50.298	-95.352	-148.655

Table-13 Base Shear Results From STAAD Pro For Lightweight Concrete Structures in Earthquake Zone 4 with Base Isolation

STORY NO	BASESHEAR X-kN		
	Zone 4 with BASE ISOLATION		
	Lightweight without SSI	Lightweight with Clayey SSI	Lightweight with Sandy SSI
0	0	0	0
1	1.083	1.06	-4.311
2	-2.27	-5.65	-9.663
3	-4.837	-11.541	-19.889
4	-8.25	-18.623	-31.021
5	-12.121	-26.538	-43.275
6	-16.521	-35.359	-56.684
7	-21.41	-45	-71.145
8	-26.495	-55.069	-86.175
9	-32.732	-66.427	-102.619
10	-34.99	-72.992	-113.071
11	-45.909	-91.473	-140.749

Table-14 Base Shear Results From STAAD Pro For Normal Concrete Structures in Earthquake Zone 5 without Base Isolation

STORY NO	BASESHEAR kN		
	ZONE 5 without BASE ISOLATION		
	Normal without SSI	Normal with Clayey SSI	Normal with Sandy SSI
0	-3.499	-3.634	3.439
1	0.514	-0.702	-5.23
2	-4.098	-9.922	-13.524
3	-8.512	-19.109	-23.435
4	-13.938	-29.881	-34.669
5	-20.274	-42.16	-47.365
6	-27.501	-55.909	-61.41
7	-35.548	-70.979	-76.667
8	-44.042	-86.849	-92.607
9	-53.858	-104.253	-110.048
10	-59.213	-115.956	-121.281
11	-74.914	-142.613	-151.195

Table-15 Base Shear Results From STAAD Pro For Lightweight Concrete Structures in Earthquake Zone 5 without Base Isolation

STORY NO	BASESHEAR kN		
	ZONE 5 without BASE ISOLATION		
	Lightweight without SSI	Lightweight with Clayey SSI	Lightweight with Sandy SSI

0	-3.499	-3.683	2.982
1	0.514	-0.607	-4.444
2	-4.098	-9.49	-11.376
3	-8.512	-18.264	-19.731
4	-13.938	-28.548	-29.187
5	-20.274	-40.261	-39.876
6	-27.501	-53.371	-51.699
7	-35.548	-67.737	-64.547
8	-44.042	-82.85	-77.944
9	-53.858	-99.461	-92.754
10	-59.213	-110.508	-101.802
11	-74.914	-136.782	-127.502

Table-16 Base Shear Results From STAAD Pro For Normal Concrete Structures in Earthquake Zone 5 with Base Isolation

STORY NO	BASE SHEAR kN		
	ZONE 5 with BASE ISOLATION		
	Normal without SSI	Normal with Clayey SSI	Normal with Sandy SSI
0	-3.487	0	0
1	0.689	1.34	-4.637
2	-3.364	-8.746	-10.312
3	-7.997	-18.146	-21.266
4	-13.584	-29.237	-33.162
5	-20.016	-41.688	-46.263
6	-27.313	-55.566	-60.598
7	-35.408	-70.725	-76.056
8	-43.936	-86.657	-92.133
9	-53.774	-104.101	-109.657
10	-59.152	-115.848	-121.009
11	-74.789	-142.379	-150.372

Table-17 Base Shear Results From STAAD Pro For Lightweight Concrete Structures in Earthquake Zone 5 with Base Isolation

STORY NO	BASE SHEAR kN		
	ZONE 5 with BASE ISOLATION		
	Lightweight without SSI	Lightweight with Clayey SSI	Lightweight with Sandy SSI
0	-3.58	0	0
1	0.616	1.361	-3.839
2	-3.064	-8.363	-8.723
3	-7.262	-17.338	-17.893
4	-12.33	-27.93	-27.92
5	-18.156	-39.808	-38.947
6	-24.763	-53.041	-51.015
7	-32.092	-67.493	-64.032

8	-39.793	-82.666	-77.544
9	-48.764	-99.315	-92.425
10	-53.395	-110.404	-101.573
11	-68.205	-136.558	-126.81

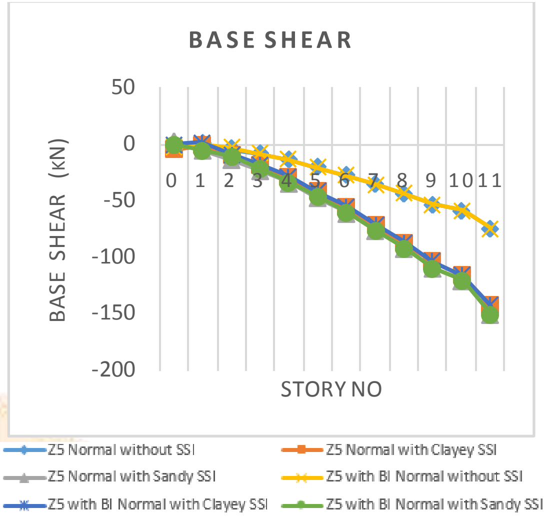

Fig-19 Comparison between Normal Concrete Structure without SSI and Normal Concrete Structures with Clayey and Sandy SSI

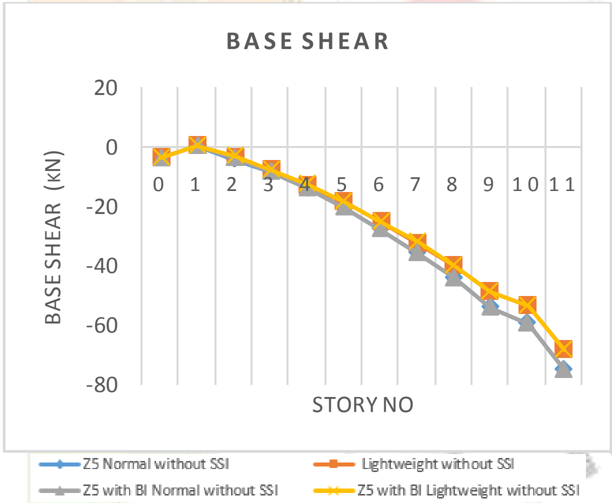

Fig-20 Comparison between Normal Concrete Structure without SSI and Lightweight Concrete Structures without SSI

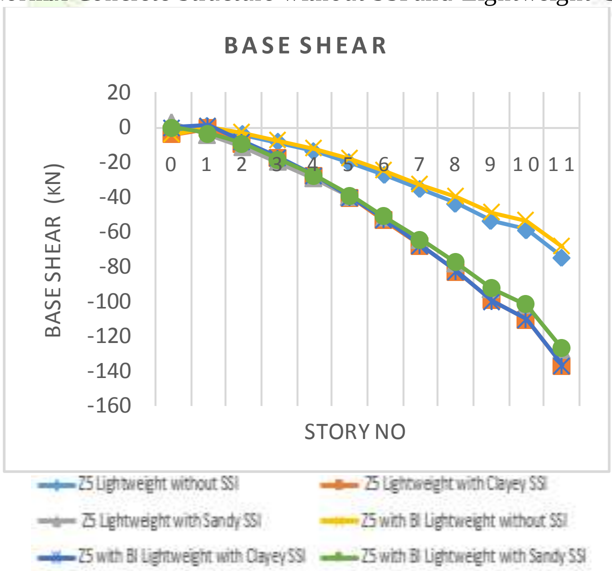

Fig-21 Comparison between Lightweight Concrete Structure without SSI and Lightweight Concrete Structures with Clayey and Sandy SSI

3.3 TIME HISTORY ANALYSIS

3.3.1 Ground motion for earthquake zone 4

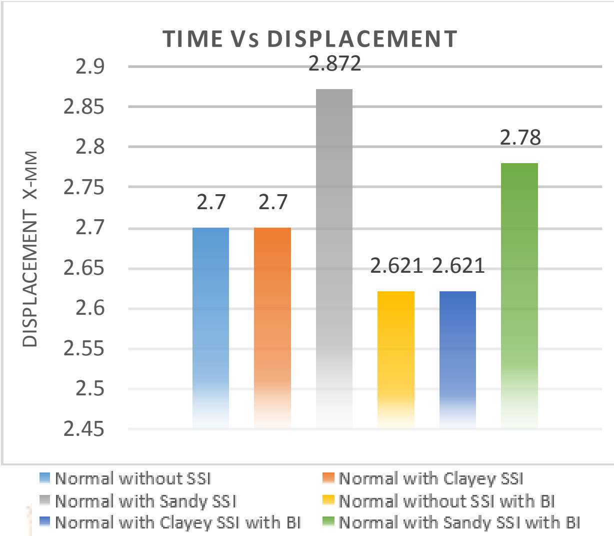

Fig-22 Comparison between Normal concrete structure without SSI and Normal concrete structure with SSI

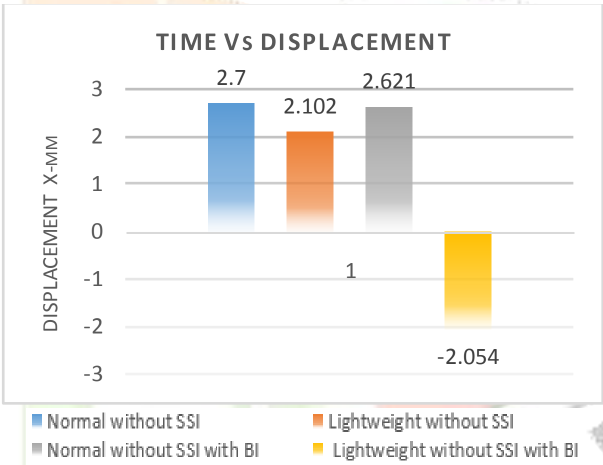

Fig-23 Comparison Normal concrete structure without SSI and Lightweight concrete structure without SSI

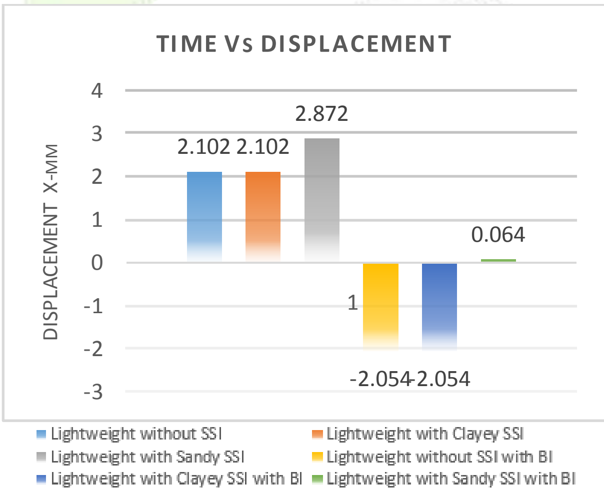

Fig-24 Comparison between Lightweightconcrete structure without SSI and Lightweightconcrete structure with SSI

3.3.2 Ground motion for earthquake zone 5

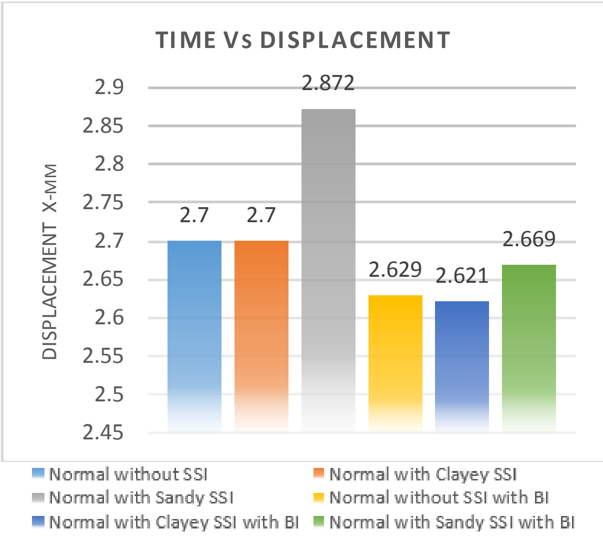

Fig-25 Comparison between Normal concrete structure without SSI and Normal concrete structure with SSI

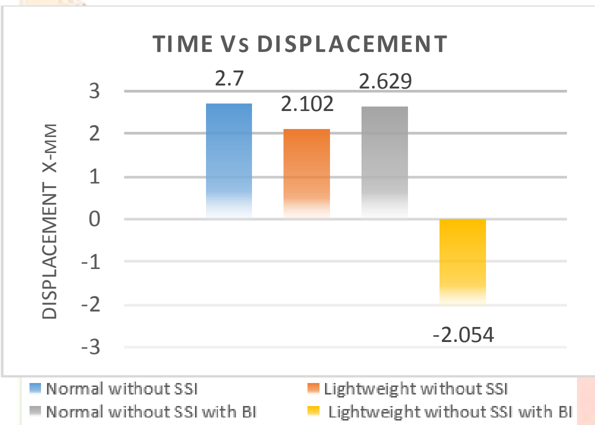

Fig-26 Comparison between Normal concrete structure without SSI and Lightweight concrete structure without SSI

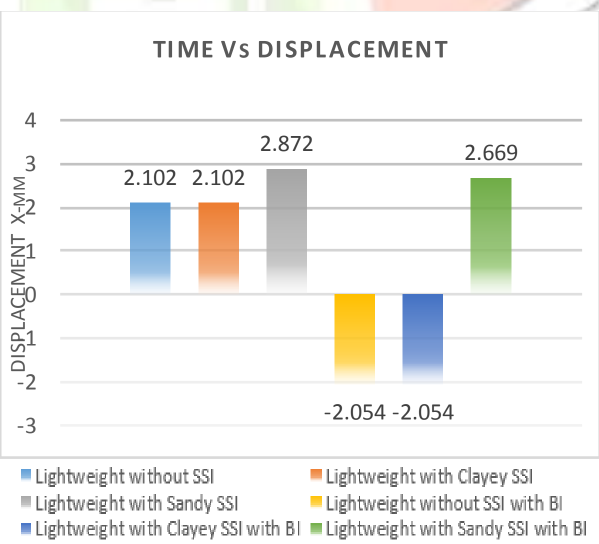

Fig-27 Comparison between Lightweight concrete structure without SSI and Lightweight concrete structure with SSI

IV. CONCLUSION

Analytical investigations have been carried out to study the behaviour of base isolated structure founded on different types of soil considering the soil structure interaction. Based on this work following conclusions can be drawn.

1) The story drift in earthquake Zone IV and V is observed 50% to 100% more in sandy SSI systems.
2) The base shear in Zone IV and V is observed 25% more in light weight SSI systems with sandy soil and normal concrete system with sandy SSI
3) In time history analysis it is observed that while comparing normal RCC frame with light weight frame the deformation is reduced by 13%,same results is obtained for static cases.
4) While comparing without SSI with SSI system in clayey soil results are observed same, while there is 50% higher displacement in sandy soil, indicatesthat SSI need to be considered in soft soil and for clayey soil it is not necessary.
5) The response quantities like displacements, acceleration and base shear are affected due to soil structure interaction. The responses of base isolated structure are amplified when soil behavior is taken into account in the analysis.
6) The deformation in soil at isolation level is significantly affected, so soil structure interaction should be considered for base isolated structures, essentially when founded on soft soils.
7) Effect of soil structure interaction is prominent in case of soft and medium soil with base isolation.
8) The codal provision is not available in Indian codes for Base Isolation design and it is necessary to add the same in seismic codes.

REFERENCE

[1]American Society of Civil Engineering - ASCE (2005). Minimum Design Loads for Buildings and Other Structures, ASCE-7-05, American Society of Civil Engineers,Reston, Virginia.

[2]M. Jawad Arefi. (2008) Effects of Soil-Structure Interaction on the Seismic Response of Existing R.C. Frame Buildings.

[3]Abdelrahman, A.A., Tadro, G., and Rizkalla, S.H., “Test Model for the First Canadian Smart Highway Bridge,” ACI Structural Journal, 1995, Vol. 92, No. 4, PP. 451-458.

[4]American Concrete Institute, “Guide for Structural Lightweight Aggregate Concrete,” ACI-213 R-87, 1987, Detroit, P. 27.

[5]Rossignolo, J.A.; Agnesini, M.V.C.; Morais, J.A. Properties of high-performance LWAC for precast structures with brazilian lightweight aggregates. Cem. Concr. Compos. 2003, 25, 77–82.

[6]Nguyen, L.H.; Beaucour, A.L.; Ortola, S.; Noumowe, A. Influence of the volume fraction and the nature of fine lightweight aggregates on the thermal and mechanical properties of structural concrete. Constr. Build. Mater. 2014, 51, 121–132.

[7]Sadr Momtazi , M.A.M. MirgozarLangroodi , A. KhodaparastHagi, Evaluation of mechanical properties of lightweight fiber-concrete contains of expanded polystyrene and attaining the optimum mix design, Fourth National Congress of Civil Engineering, Iran, University of Tehran, 1387

[8]DanetiSaradhiBabu , K. Ganesh Babu , Wee Tiong-Huan, Effect of polystyrene aggregate size on strength and moisture migration characteristics of lightweight concrete, Cement & Concrete Composites, 28,520-527,2004

[9]Chalimers: Structural Element Approaches for SSI by CASELUNGHE ARON & ERIKSSON JONAS 2012

[10]M. Jawad Arefi , S. Pampanin and M. Cubrinovski ,Effects of Soil-Structure Interaction on the Seismic Response of Existing R.C. Frame Buildings , , 2009 NZSEE Conference ,pp 43

[11] Kuladeepu M N , G Narayana , B K Narendra ‘SSI effect on dynamic Behaviour of 3D Building’, International Journal of Research in Engineering and Technology, Volume: 04, Issue: 07, July-2015,pp 87-91

[12] Bowles J.E, 1996. “Foundation Analysis and Design”, 5th Edition, McGraw-Hill International Editions, Civil Engineering Series, New York.

[13] Chandrasekhar. A, Jayalakshmi B.R, KattaVenkataramana, 2005. “Dynamic soil-structure interaction effects on multi storied RCC frames” Proceedings of International Conference on Advance to structural dynamics and its application7-9 December, ICASDA, 454–467.

[14] IS: 1893(part 1): 2002, “Criteria for Earthquake Resistant Design of Structures”, part 1-General provisions and buildings, fifth revision, Bureau of Indian Standards, New Delhi, India

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

[16] IS 383:1970 “Specifications for coarse and fine aggregates from natural sources for concrete”, Bureau of Indian Standards, New Delhi

[17] NEHRP Consultants Joint Venture A partnership of the Applied Technology Council and the Consortium of Universities for Research in Earthquake Engineering

[18]Veletsos, A. S., and Nair, V. V. (1975). "Seismic interaction of structures on hysteretic foundations." Journal of Structural Engineering - ASCE, 101(1), 109-129.

[19] Veletsos, A. S., and Prasad, A. M. (1989). "Seismic interaction of structures and soils: Stochastic approach." Journal of Structural Engineering - ASCE, 115, 935-956.

[20] Veletsos, A. S., Prasad, A. M., and Wu, W. H. (1997). "Transfer functions for rigid rectangular foundations." Journal of Earthquake Engineering & Structural Dyanmics, 26, 5-17.

[21] Veletsos, A. S., and Verbic, B. (1973). "Vibration of viscoelastic foundations." Journal of Earthquake Engineering & Structural Dyanmics, 2, 87–102.

[22] Vucetic, M., Dobry, R. (1991). "Effect of Soil Plasticity on Cyclic Response." Journal of Geotechnical Engineering, 117(1), 89-107.

[23] Wolf, J. P. (1994). Foundation vibration analysis using simple physical models, Prentice Hall, Englewood Cliffs.
[24] Wotherspoon, L., Pender, M., and Ingham, J. "Combined Modelling of Structural and Foundation Systems." 13th World conference on Earthquake Engineering, Vancouver, B.C., Canada.
[25] Zhao, X. (1989). "Seismic soil-structure interaction," Ph.D, University of Canterbury, Christchurch.