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PUSHOVER ANALYSIS OF RC BUILDINGS WITH SHORT LEG SHEAR WALL ON PLAN SYMMETRY AND VARRYING SOIL TYPE IN ZONE II REGION

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Abstract - *In most of the RCC framed buildings irregularities are commonly observed. And the buildings with irregularities are most subjected to earthquake forces than buildings with regular configuration. The irregularities are of two types i.e, plan and vertical irregularity. For the assessment of the buildings behavior under earthquake forces Non-linear static analysis methods are adopted. In this case non linear static Pushover analysis method is used. The main objective of the paper is to study the performance level and behavior of structure in presence of short leg shear wall for plan symmetry building with re-entrant corners. The parameters considered in this paper are Base shear, Displacement and performance levels of the structure. The seismic codes for irregularities are as per the clauses defined in IS-1893:2002 and pushover analysis procedure is followed as per the prescriptions in ATC-40.*

Key Words: *Seismic, Pushover analysis, Base shear, Displacement, Shear wall, Equivalent Static Analysis (ESA) and Response Spectrum Analysis (RSA).*

1. **INTRODUCTION** As a result of the rapidly incremental demand of residence and the under-supply of land for building, high-rise building has become the first choice to developers.So there has been a considerable increase in the tall buildings both residential and commercial and the modern trend is towards more tall and slender structures. Thus the effects of lateral loads like wind loads, earthquake loads etc. are attaining increasing importance and almost every designer is faced with the problems of providing adequate strength and stability against lateral loads. In earlier days, structures were designed without considering seismic loading. Later, it was observed that the structures designed for some lateral loads like wind etc. performed significantly well than those designed for gravity loading only. With the immense loss of life and property witnessed in the last couple of decades alone in India, due to failure of structures caused by earthquakes, attention is now being given to the evaluationof the adequacy of strength in framed RC structures to resist strong ground motions. Hence, the importance of considering earthquake forces in the design process is realized and seismic resistant design became a practice.In the recent earthquakes in which many concrete structures have been severely damaged or collapsed, have indicated the need for evaluation in the seismic adequacy of buildings. To make such assessment, simplified linear-elastic methods are not adequate. Further, with more understanding of structural behavior at micro-level or element level, the concept of "capacity design" was introduced and this forced to decide the required performance of the structure right at the design stage itself.

2. LITERATURE SURVEY

Nikhil Agrawal et al. (2013) carried out analysis of masonry in filled R.C. frame with and without opening including soft storey by using equivalent diagonal strut method. It is an attempt to highlight the performance of masonry in filled reinforced concrete (RC) frames including open first storey of with and without opening. This opening is expressed in terms of various percentages. Symmetrical frame of college building (G+5) located in seismic zone-III is considered by modeling of initial frame according to FEMA-273 and ATC-40 which contain the provisions of calculation of stiffness of in filled frames by modeling infill as Equivalent diagonal strut method. This analysis is to be carried out on the models such as bare frame, strut frame, strut frame with 15% centre and corner opening, which is performed by using computer software STAAD-Pro from which different parameters are computed. In which it shows that infill panels increase the stiffness of the structure.

D'Ayala et al. (2014) have given guidelines and methodology for the analytical vulnerability assessment of low and mid-rise buildings within the frame work of Global Earthquake Modeling (GEM). The aim of this document is to provide guidelines for the Non-linear modeling and analysis for low and mid-rise RC buildings and to develop fragility curves based on the global damage states. Further, guidelines are also presented to determine the vulnerability of the building to assess the monitory risk associated with the building by adopting suitable damage factor values for damage states.

Yasser (2014) carried out pushover analysis of R.C. short leg shear wall structural system in multistory buildings. In this study the effect of seismic zone, type of soil, masonry infill, number of stories, and effect of coupling beam, combination of different shapes and positions of short leg shear wall on the performance of the building is determined. From the study it is brought out that for tall buildings the performance of short leg shear wall is comparatively better than a general shear wall, in terms of status of plastic hinges and better ductility characteristics. Study on effect of masonry infill revealed that its presence significantly increases the base shear carrying capacity and performance of the structure. Study on effect of combination of different shapes of short leg shear wall revealed that the short leg shear wall has many advantages in comparison with general shear wall.

3. BUILDING DETAIL AND INPUT DATA

In this study eight models are considered. All the models have the same plan dimensions of 25m x 25m with 5 bays in each direction as shown in Fig. 6.1. Three different heights (five, ten and twenty stories) are considered in each model as shown in Fig. 6.2. These represent low-rise, medium-rise and high-rise structures. Of the 8 models, the first four models are the basic models comprising of bare frame, shear wall and short leg shear walls, whereas the next four models are the replication of the basic models with brick masonry wall along outer periphery as shown in Figs. 6.3a and 6.3b. All the eight models are described in the Table 6.1.

The eight models considered are analyzed for different combinations of gravity and earthquake loads. These models are designed according to the Indian Standard code IS 456:2000 in ETABS (v 13.2.2). Equivalent Static Analysis and the Response Spectrum Analysis are carried out as per IS-1893-Part I: 2002. After the design is carried out, default plastic hinge properties available in ETABS as per ATC-40 are assigned to the frame elements, and then the models are subjected to pushover analysis. The target displacement for pushover analysis is taken as 4% of the total height of the model. Parameters such as base shear carried, roof displacement experienced, status of the performance point and the number and status of plastic hinges formed in the structure are used to judge the performance of the models. All the four seismic zones are considered in the analysis. The frame elements are modeled as one-dimensional line-element, and the slabs and walls (both shear wall and masonry infill) as two-dimensional area elements. The slab and the masonry infill are assigned to have membrane properties and the shear wall is assigned to have shell properties. The coupling beam of the short leg shear wall is modeled both as a frame element and a shell element. The models are considered to rest on three different types of soil (Type 1- Hard rock, Type 2 - Medium stiff, Type 3 - Soft soil) during the analysis. The details of the building data are shown in Table 1.

In most of the RCC framed buildings irregularities are commonly observed. And the buildings with irregularities are most subjected to earthquake forces than buildings with regular configuration. The irregularities are of two types i.e, plan and vertical irregularity. For the assessment of the buildings behavior under earthquake forces Non-linear static analysis methods are adopted. In this case non linear static Pushover analysis method is used. The main objective of the paper is to study the performance level and behavior of structure in presence of shear wall for plan irregular building with re-entrant corners. The parameters considered in this paper are Base shear, Displacement and performance levels of the structure. The seismic codes for irregularities are as per the clauses defined in IS-1893:2002 and pushover analysis procedure is followed as per the prescriptions in ATC-40.

Table 1.Building Detail And Input Data

MODEL	MODEL DESCRIPTION
Model 1	*R.C. BARE FRAME*
Model 2	*R.C. FRAME WITH SHEAR WALL AT CORNERS*
Model 3	*R.C. FRAME WITH SHORT LEG SHEAR WALL AT CORNERS. THE COUPLING BEAM IS MODELLED AS FRAME ELEMENT (BEAM TYPE)*
Model 4	*R.C. FRAME WITH SHORT LEG SHEAR WALL AT CORNERS. THE COUPLING BEAM IS MODELLED AS SHELL ELEMENT (SPANRDEL TYPE)*
Model 5	*R.C. FRAME WITH OUTER PERIPHERY MASONRY WALL*
Model 6	*R.C. FRAME WITH SHEAR WALL AT CORNERS AND OUTER PERIPHERY MASONRY WALL*
Model 7	*R.C. FRAME WITH SHORT LEG SHEAR WALL AT CORNERS (**COUPLING BEAM-BEAM TYPE**) AND OUTER PERIPHERY MASONRY WALL*
Model 8	*R.C. FRAME WITH SHORT LEG SHEAR WALL AT CORNERS (**COUPLING BEAM - SPANRDEL TYPE**) AND OUTER PERIPHERY MASONRY WALL*

PARAMETER	TYPE / VALUE
Number of Stories	5- Storey, 10- Storey and 20-Storey
Typical Storey Height	3.2 m

Initial grid size	25 m x 25 m
Bay width in both directions	5 m
Grade of Concrete	M40 – for Beams, Walls and Columns M25 – for Roof Slabs
Grade of Reinforcing Steel	Fe–500-for Beams, Walls and Columns,Fe–415- for Roof Slabs
Beam sizes	0.2 m x 0.45 m (5 - Storey),0.3 m x 0.6 m (10 - and 20 - Stories)
Coupling Beam sizes	0.2 m x 0.6 m (5 - Storey),0.2 m x 0.75 m (10 - and 20 - Stories)
Column sizes	0.4 m x 0.4 m (5 - Storey) 0.5 m x 0.5 m (10 - Storey) 0.7 m x 0.7 m (20 - Storey)
Thickness of Slab	0.150 m
Thickness of Shear Wall	0.2 m
Thickness of Brick Masonry Wall	0.23 m
Floor finishes	1 kN/m^2
Live Load on all Floors	3.5 kN/m^2
Live Load on Roof Slab	1.5 kN/m^2
Wall Load on Beams	13 kN/m
Parapet Wall Load	7 kN/m
Seismic Zone and Zone factor (Z)	a) Zone 2, Z= 0.10 b) Zone 3, Z= 0.16 c) Zone 4, Z= 0.24 d) Zone 5, Z= 0.36
Importance Factor "I"	1.0
Response Reduction Factor "R"	a) 3.0 (for Zone 2) b) 5.0 (for Zones 3,4 and 5)
Soil Type	a) Type I (Hard rock) b) Type II (Medium stiff) c) Type III (Soft soil)

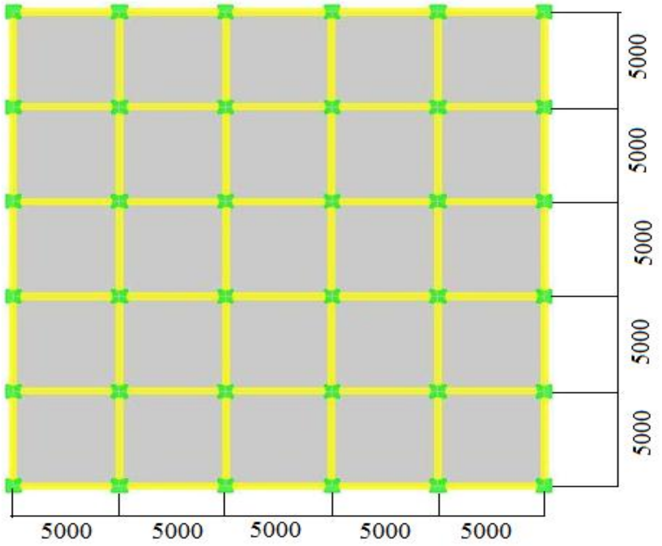


Fig. 1 Typical plan of 5, 10 and 20 storey models considered for study (Dimensions in mm)

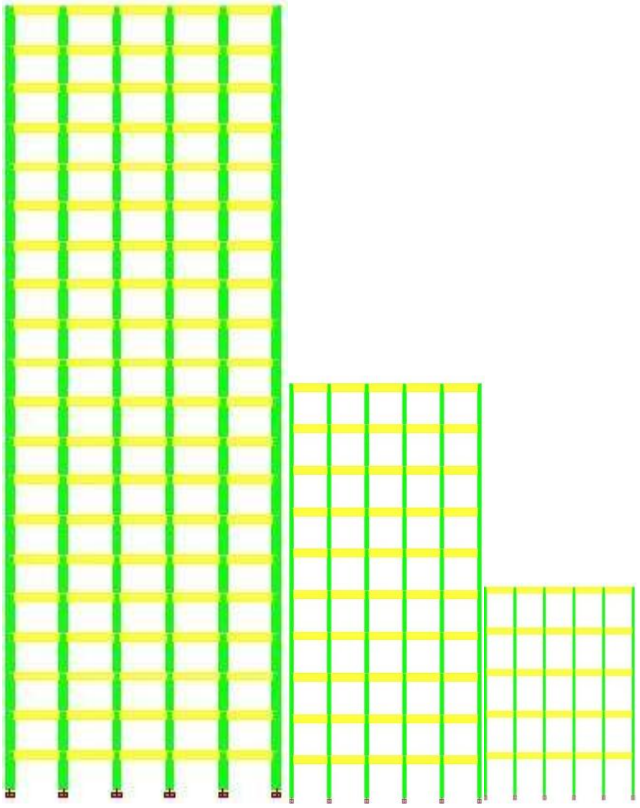
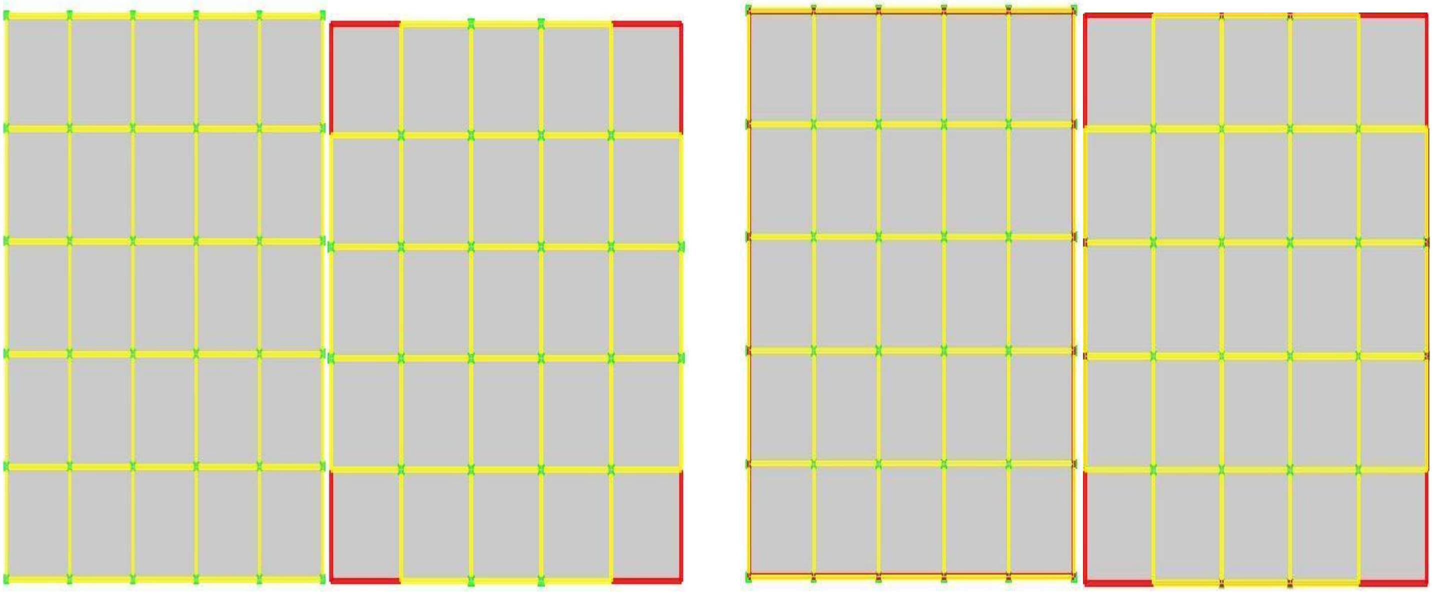
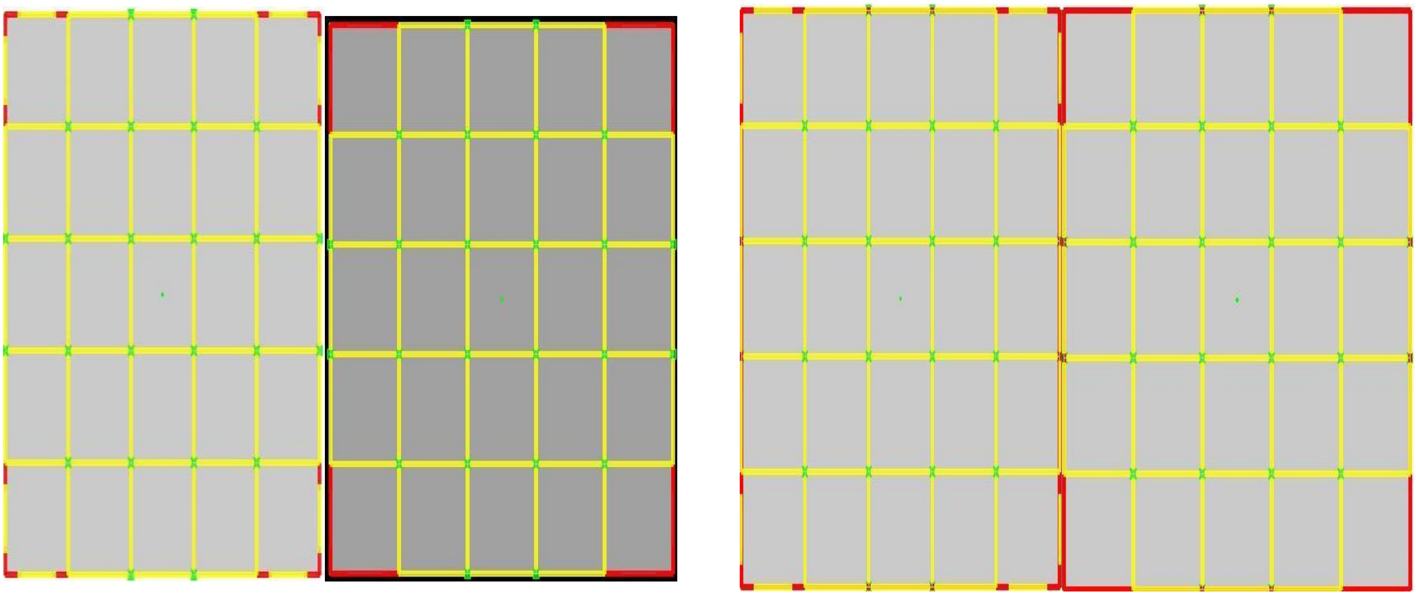


Fig. 2 Typical elevation of 20-storey, 10-storey and 5-storey models



i) Model 1 ii) Model 2 v) Model 5 vi) Model 6



iii) Model 3 iv) Model 4 vii) Model 7 viii) Model 8

Fig.3 Typical plans of all 10-storey models

4. RESULTS AND DISCUSSIONS

4.1 Results for 5 - Storey Models in Zone 2

The results of base shear from ESA, RSA and pushover analysis, displacement at maximum base shear, the spectral acceleration and spectral displacement at performance point for 5 storey models for soil type 1, 2 and 3 in zone 2 are shown in Tables 2, 3 and 4 respectively. **Table 2 Analysis results of base shear and performance point - Type 1 Soil for 5 storey models**

Model No.	**Base Shear (kN)**				**Ratio $\left(\frac{Vpo}{Ve}\right)$**	**Displacement at maximum Base Shear(mm)**	**Performance Point**			
	ESA (Ve)	**RSA (Vr)**	**Scale Factor**	**Pushover (Vpo)**			**V (kN)**	**D (mm)**	**Sa (g)**	**Sd (mm)**
1	1613	648.02	4070	3725.56	2.309	278.79	2537.02	51.6	0.052	41.2
2	1655	1780.50	1635	6955.60	4.203	12.68	6952.61	12.3	0.152	8.7
3	1643	776.38	3455	3408.85	2.075	60.43	2813.87	36.9	0.062	26
4	1589	1300.30	1999	5242.16	3.299	25.31	4387.05	16.3	0.097	11.8
5	2550	886.09	4706	4993.49	1.958	60.51	3990.50	32.3	0.074	26.7
6	2562	1902.30	2203	8444.35	3.296	12.45	8217.60	11.3	0.172	8.1
7	2544	916.59	4538	4224.23	1.660	29.60	3885.57	25	0.079	18.5
8	2463	1491.08	2703	7331.82	2.977	20.69	6251.28	15.4	0.131	11.4

Table 3 Analysis results of base shear and performance point - Type 2 Soil for 5 storey models

Model No.	**Base Shear (kN)**				**Ratio $\left(\frac{Vpo}{Ve}\right)$**	**Displacement at max Base Shear (mm)**	**Performance Point**			
	ESA (Ve)	**RSA (Vr)**	**Scale factor**	**Pushover (Vpo)**			**V (kN)**	**D (mm)**	**Sa (g)**	**Sd (mm)**
1	2193	849.44	4220	3738.13	1.705	281.46	2536.59	51.6	0.052	41.2
2	2251	1823.79	2019	6955.60	3.09	12.68	6952.61	12.3	0.152	8.7
3	2235	984.49	3714	3414.45	1.528	60.87	2813.87	36.9	0.062	26
4	2161	1751.95	2018	5242.16	2.426	25.31	4387.06	16.3	0.097	11.8
5	2550	1177.55	3543	4993.49	1.958	60.51	3990.55	32.3	0.075	26.7
6	2562	1902.32	2203	8444.36	3.296	12.45	8217.62	11.3	0.172	8.1

7	2544	1194.24	3484	4224.22	1.660	29.60	3885.57	25	0.079	18.5
8	2463	1919.15	2099	7331.82	2.98	20.69	6251.29	15.4	0.131	11.4

Table 4 Analysis results of base shear and performance point - Type 3 Soil for 5 storey models

Model No.	**Base Shear (kN)**				**Ratio** $\left(\frac{Vpo}{Ve}\right)$	**Displacement at maximum Base Shear (mm)**	**Performance Point**			
	ESA (Ve)	**RSA (Vr)**	**Scale factor**	**Pushover (Vpo)**			**V (kN)**	**D (mm)**	**Sa (g)**	**Sd (mm)**
1	2419	1023.25	3866	3738.13	1.545	281.46	2536.59	51.6	0.052	41.2
2	2491	1829.85	2227	6942.43	2.787	12.58	6941.24	12.3	0.151	8.7
3	2466	1172.26	3441	3414.45	1.385	60.87	2813.87	36.9	0.062	26
4	2384	1828.46	2133	5241.93	2.199	25.31	4387.05	16.3	0.097	11.8
5	2550	1432.24	2912	4993.49	1.958	60.51	3990.55	32.3	0.074	26.7
6	2569	1908.36	2202	8428.64	3.281	12.45	8211.18	11.3	0.172	8.2
7	2544	1466.54	2838	4224.23	1.660	29.60	3885.57	25	0.079	18.5
8	2463	1919.15	2099	7331.82	2.977	20.69	6251.28	15.4	0.131	11.4

From Tables 2, 3 and 4 it can be inferred that

- The value of base shear obtained from ESA in general is greater than RSA for all models. The corresponding scale factor for RSA is also shown in the Tables.
- The value of base shear for models without infill is less than those of models with infills. However the value of base shear for models without infill approaches the value of base shear with infill as the soil type changes from 1 to 3.
- In case of 5 storey, the base shear is almost same for all models under with and without infills and it increases in the presence of infill in both ESA and RSA cases. However pushover base shear is highest for shear wall models and lowest for SLSW-beam type models (with and without infill).
- In ESA, the soil type does not influence the base shear for models with infill.
- The ratio of pushover base shear to ESA base shear, (Vpo/Ve) is highest for shear wall model and lowest for SLSW-beam type model. For models with infill, the ratio is lesser than models without infill for soil type 1 and it is more for soil type 2 and type 3.

6.4 RESULTS AND DISCUSSIONS FOR 10 - STOREY MODELS

6.4.1 Results for 10 - Storey Models in Zone 2

The results of base shear from ESA, RSA and pushover analysis, displacement at maximum base shear, the spectral acceleration and spectral displacement at performance point for 10 storey models for soil type 1, 2 and 3 in zone 2 are shown in Tables 5, 6 and 7 respectively.

Table 5 Analysis results of base shear and performance point - Type 1 Soil for 10 storey models

Model No.	Base Shear (kN)				Ratio $\left(\frac{Vpo}{Ve}\right)$	Displacement at maximum Base Shear (mm)	Performance Point			
	ESA (Ve)	RSA (Vr)	Scale factor	Pushover (Vpo)			V (kN)	D (mm)	Sa (g)	Sd (mm)
1	2266	1151.99	3220	6837.5	3.02	358.42	4675.54	59.2	0.039	51.0
2	2267	1777.27	2086	7644.5	3.37	32.04	7447.54	32.3	0.073	22.3
3	2273	1164.29	3193	5684.5	2.50	82.13	4979.89	46.8	0.044	36.8
4	2183	1502.76	2376	7724.5	3.54	55.91	6804.85	40.5	0.066	29.4
5	4180	1367.04	5000	6877.3	1.65	42.28	6143.55	35.8	0.049	29.0
6	4097	1945.01	3444	9324.1	2.28	29.83	9305.88	29.9	0.087	21.1
7	4108	1301.69	5160	6441.8	1.56	46.08	6365.46	45	0.055	35.6
8	3950	1650.51	3915	9414.7	2.38	40.26	9026.81	37.5	0.082	28.1

Table 6 Analysis results of base shear and performance point - Type 2 Soil for 10 storey models

Model No.	Base Shear (kN)				Ratio $\left(\frac{Vpo}{Ve}\right)$	Displacement at maximum Base Shear (mm)	Performance Point			
	ESA (Ve)	RSA (Vr)	Scale factor	Pushover (Vpo)			V (kN)	D (mm)	Sa (g)	Sd (mm)
1	3082	1552.61	3246	6824.4	2.214	354.83	4676.39	59.2	0.039	51.0
2	3083	2193.33	2299	7644.5	2.479	32.04	7447.54	32.3	0.073	22.3
3	3092	1550	3260	5684.5	1.838	81.52	4953.32	46.9	0.044	36.9
4	2969	1873.63	2592	7724.5	2.602	52.95	6804.85	40.5	0.066	29.4
5	5685	1825.24	5092	6877.3	1.209	42.28	6143.55	35.8	0.049	29.0

6	5572	2453.73	3714	9324.1	1.673	29.83	9305.88	29.9	0.087	21.1
7	5587	1717.84	5321	6441.8	1.148	46.08	6365.46	45	0.055	35.6
8	5372	2108.47	4167	9414.7	1.753	40.26	9026.81	37.5	0.082	28.1

Table 7 Analysis results of base shear and performance point - Type 3 Soil for 10 storey models

Model No.	**Base Shear (kN)**				**Ratio** $\left(\frac{Vpo}{Ve}\right)$	**Displacement at maximum Base Shear (mm)**	**Performance Point**			
	ESA (Ve)	**RSA (Vr)**	**Scale factor**	**Pushover (Vpo)**			**V (kN)**	**D (mm)**	**Sa (g)**	**Sd (mm)**
1	3784	1864.82	3320	6824.4	1.803	354.83	4676.39	59.2	0.039	51.0
2	3790	2575.48	2407	7653.91	2.019	32.16	7448.89	32.5	0.073	22.5
3	3796	1842	3370	5684.5	1.49	82.13	4979.89	46.8	0.045	36.8
4	3645	2212.28	2695	7724.5	2.12	52.95	6804.85	40.5	0.066	29.4
5	6019	2191.16	4492	6877.3	1.143	42.28	6143.55	35.8	0.049	29.0
6	5907	2914.45	3316	9316.71	1.577	29.86	9287.71	29.9	0.087	21.1
7	5916	2050.02	4719	6441.8	1.084	46.08	6365.46	45	0.054	35.6
8	5688	2519.46	3692	9414.7	1.655	40.26	9026.81	37.5	0.082	28.1

From Tables 5, 6, 7 it can be inferred that

- The value of base shear obtained from ESA is greater than RSA for all models. The corresponding scale factor for RSA is also shown in the Table.
- In case of 10 storey, the base shear is almost same for all models without infill and it increases in the presence of infill in both ESA and RSA cases. However pushover base shear is highest for SLSW-spandrel type models and lowest for SLSW-beam type models (with and without infill).
- The ratio of pushover base shear to ESA base shear, (Vpo/Ve) is highest for SLSW-spandrel type model and lowest for SLSW-beam type model. For models with infill this ratio is lesser than models without infill for soil type 1 and it is more for soil types 2 and 3.

6.5 COMPARISON OF RESULTS FOR 20 - STOREY MODELS

6.5.1 Results for 20 - Storey Models in Zone 2

The results of base shear from ESA, RSA and pushover analysis, displacement at maximum base shear, the spectral acceleration and spectral displacement at performance point for 20 storey models for soil type 1, 2 and 3 in zone 2 are shown in Tables 8, 9 and 10 respectively.

Table 8 Analysis results of base shear and performance point - Type 1 soil for 20 storey models

Model No.	Base Shear (kN)				Ratio $\frac{(V_{po})}{(V_e)}$	Displacement at maximum Base Shear (mm)	Performance Point			
	ESA (Ve)	RSA (Vr)	Scale factor	Pushover (Vpo)			V (kN)	D (mm)	Sa (g)	Sd (mm)
1	2983	1412.16	3445	7500.54	2.514	680.353	5007.03	79.2	0.019	64.8
2	2900	1796.24	2641	8295.03	2.86	92.603	7637.88	78.8	0.035	56.6
3	2963	1348.47	3594	6268.11	2.115	270.229	4799.13	84.9	0.019	68.6
4	2797	1514.83	3019	8002.88	2.86	145.22	6665.29	83.6	0.03	62.5
5	4641	1632.91	4650	5867.89	1.264	51.29	5778.19	51.7	0.022	41.4
6	4420	2003.96	3608	9287.96	2.101	66.03	8667.22	60.4	0.038	44.6
7	4514	1484.64	4972	5563.74	1.233	68.33	5483.19	66.2	0.022	52.5
8	4268	1726.97	4041	8831.89	2.07	75.36	8562.16	72.7	0.037	55.5

Table 9 Analysis results of base shear and performance point - Type 2 Soil for 20 storey models

Model No.	Base Shear (kN)				Ratio $\frac{(V_{po})}{(V_e)}$	Displacement at maximum Base Shear (mm)	Performance Point			
	ESA (Ve)	RSA (Vr)	Scale factor	Pushover (Vpo)			V (kN)	D (mm)	Sa (g)	Sd (mm)
1	4057	1909.62	3475	7497.18	1.848	672.22	5007.03	79.2	0.019	64.8
2	3944	2322.04	2778	8295.03	2.103	92.603	7637.88	78.8	0.035	56.6
3	4032	1819	3624	6322.081	1.568	280.37	4799.13	84.9	0.019	68.6
4	3804	1995.96	3117	8002.88	2.103	145.22	6665.29	83.6	0.03	62.5
5	6312	2203.16	4685	5879.01	0.931	53.24	5778.19	51.7	0.022	41.4

6	6011	2635	3730	9287.96	1.545	66.03	8667.22	60.4	0.038	44.6
7	6139	2001.37	5016	5563.74	0.906	68.325	5483.19	66.2	0.022	52.5
8	5805	2282.29	4160	8831.89	1.52	75.36	8562.16	72.7	0.037	55.5

Table 10 Analysis results of base shear and performance point - Type 3 Soil for 20 storey models

Model No.	**Base Shear (kN)**				**Ratio (Vpo) (Ve)**	**Displacement at maximum Base Shear (mm)**	**Performance Point**			
	ESA (Ve)	**RSA (Vr)**	**Scale factor**	**Pushover (Vpo)**			**V (kN)**	**D (mm)**	**Sa (g)**	**Sd (mm)**
1	4981	2321.67	3509	7497.18	1.51	672.22	5007.03	79.2	0.019	64.8
2	4846	2768.73	2862	8310.68	1.72	93.298	7712.46	78.7	0.036	56.6
3	4949	2207.09	3667	6322.081	1.277	280.37	4799.13	84.9	0.019	68.6
4	4671	2404.73	3177	8002.88	1.713	145.22	6665.29	83.6	0.03	62.5
5	7751	2675.15	4738	5879.01	0.758	53.24	5778.19	51.7	0.022	41.4
6	7386	3151.82	3833	9285.47	1.257	66.05	8665.48	60.4	0.038	44.6
7	7538	2425.48	5085	5563.74	0.738	68.33	5483.19	66.2	0.022	52.5
8	7128	2763.47	4218	8831.89	1.239	75.36	8562.16	72.7	0.037	55.5

From Tables 8, 9 and 10 it can be inferred that

- The value of base shear obtained from ESA is greater than RSA for all models. The corresponding scale factor for RSA is also shown in the tables.
- In case of 20 storey, the base shear is highest for bare frame models and lowest for SLSW-Spandrel type models (with and without infill). However pushover base shear is highest for Shear wall models and lowest for SLSW-beam type models (with and without infill).

For models without infill, the ratio of pushover base shear to ESA base shear, (Vpo/Ve) remains same for shear wall model and SLSW-spandrel type model and it increases for models with infill.

5. CONCLUSIONS

1] In each zone the base shear increases from Type-1 soil to Type-3 soil for all models. As the number of storey increases the base shear obtained from equivalent static analysis and response spectrum analysis increases. The base shear obtained from equivalent static analysis is greater than that obtained from response spectrum analysis for all models.

2) There is a prominent decrease in pushover base shear in case of models with infill from 10-storey to 20-storey.

3) In case of 5-storey models, the large ratio of pushover base shear to elastic base shear (Vpo/Ve) for shear wall model indicates that large amount of reserve strength is unutilized. Thus a shear wall model fails earlier than that of a short leg shear wall (spandrel type) owing to its lesser ductility than a short leg shear wall. However, these ratios decrease as the number of storey increases (i.e., in 10 and 20-storeyed models). Also as the soil type changes from Type 1 to Type 3, the Vpo/Ve ratio decreases.

4) The pushover curves indicate that the behavior of short leg shear wall models is in between that of shear wall model and bare frame model for 5-storey models. This indicates that SLSW models have higher stiffness than bare frame model but lesser than that of a shear wall model. Also SLSW models have more ductility than shear wall model but less than that of a bare frame model. But for 10 and 20 storey models SLSW-beam type model has the least stiffness among all models.

5) The modeling of the coupling beam in case of short leg shear wall plays an important role in determining the performance of the building. If the shell element is used for modeling the coupling beam (spandrel type), then the behavior of the model tends to be similar to that of a general shear wall having higher stiffness and lesser ductility. If the coupling beam is assigned as a frame element (beam type), then the behavior of the model tends to be similar to that of a general bare frame having lesser stiffness and higher ductility.

6) The presence of masonry infill along outer periphery greatly improves the lateral strength and stiffness of each model. But in case of 20-storey, the pushover base shear reduces for models with infill for shear wall models and SLSW-spandrel type models.

7) The behavior of models with masonry infill along outer periphery is linear for all cases owing to its greater lateral strength and stiffness. Thus its performance point is in the elastic range (operational stage) for all cases. However, as the number of storey increases the demand curve shifts towards the non-linear range and thus the failure changes to a more ductile mode.

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