Seismic Behavior of High Rise Building for Soft Soil in All Seismic Zones

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Abstract— A high rise residential building (tall building) design is governed by lateral loads, i.e. wind load, seismic load. Performance of structures under frequently occurring earth quake ground motions resulting in structural damages as well as failures have repeatedly demonstrated the seismic vulnerability of existing buildings, due to their design which based on only gravity loads or inadequate levels of lateral forces. Infills, Bracings systems are one of the most commonly used lateral load resisting systems in high rise buildings (HRB). This paper presents a comprehensive comparative study of the Dynamic loads and their effects on tall buildings using Response spectrum method. The results of the Structural response on various parameters such as storey drift, Structural lateral displacements, Base shear, Stiffness for Normal Building and different Load resisting systems have been compared and discussed. An analytical study on multi-Storey building of 30 stories was carried out for different seismic zones and soft soil type using different bracing systems i.e., X-brace, V-brace, inverted V or chevron brace and infills are introduced in these analytical models. These building models are analyzed using E Tabs 2015 software employing Response Spectrum method as per IS 1893 (Part I): 2002.

Key words: Seismic Design, Response Spectrum Method, Seismic Behavior, Infill Walls, Bracings, Lateral Structural Response, Dynamic Load, Base Shear, Stiffness

I. INTRODUCTION

From a structural engineer's point of view the tall building or high rise building (HRB) can be defined as one that, by virtue of its height, is affected by lateral forces due to wind or earthquake or both to an extent that they play an important role in the structural design. Tall structures have fascinated mankind from the beginning of civilisation. The Egyptian Pyramids, one among the seven wonders of world, constructed in 2600 B.C. are among such ancient tall structures. Such structures were constructed for defence and to show pride. The process of urbanisation that started with the age of industrialisation is still in progress in developing countries like India. Industrialisation causes migration of people to urban centres where job opportunities are significant. The land available for buildings to accommodate this migration is becoming scarce, resulting in rapid increase in the cost of land. The growth in modern multi-storeyed building construction, which began in late nineteenth century, is intended largely for commercial and residential purposes. Tall buildings are the most complex built structures since there are many conflicting requirements and complex building systems to integrate. Today's tall buildings are becoming more and more slender, leading to the possibility of more sway in comparison with earlier high-rise buildings. Thus the impact of wind and seismic forces acting on them becomes an important aspect of the design. Improving the structural systems of tall buildings can control their dynamic response. A tall building may be defined as a building whose design is governed by the lateral forces induced due to wind and earthquake.

Beyond 10 stories, the lateral drift starts controlling the design, the stiffness rather than strength becomes the dominant factor. Different structural forms of tall buildings can be used to improve the lateral stiffness and to reduce the drift index. Drift in building frames is a result of flexural and shear mode contributions, due to the column axial deformations and to the diagonal and girder deformations, respectively. Several Lateral resisting systems (such as introduction of frame-wall, framed tube, belt truss with outrigger, tube in tube and bundled tube systems) can be used to resist the lateral loads acting on the structure.

This study seeks to understand the different lateral systems that have emerged and its associated structural behavior for soil type 3 (i.e., soft soil type) in all four zones. The different types of bracings are introduced in RCC building model at the same location to understand the suitability of the systems with respect to the seismic motions while other properties of the structural members in the building are remain constants such as the size of the columns, beams, bracings and thickness of slabs. Analytical modelling is done in ETABS 2015 software. The major goal is to appraise the lateral displacements, drift, Base shear and stiffness occurs by considering the above parameters employing Response Spectrum method as per IS 1893 (Part I): 2002.

II. SEISMIC ANALYSIS

Earthquake and its occurrence and measurements, its vibration effect and structural response have been continuously studied for many years in earthquake history and thoroughly documented in literature. Since then the structural engineers have tried hard to examine the procedure, with an aim to counter the complex dynamic effect of seismically induced forces in structures, for designing of earthquake resistant structures in a refined and easy manner. Linear static analysis or equivalent static analysis can only be used for regular structures with limited height. Linear dynamic analysis can be performed in two ways either by mode superposition method or response spectrum method and elastic time history method. This analysis will produce the effect of the higher modes of vibration and the actual distribution of forces in the elastic range in a better way. They represent an improvement over linear static analysis. Main features of seismic method of analysis based on Indian Standard 1893 (Part I): 2002 are described as follows as Response Spectrum Analysis. This paper presents a comprehensive comparative study of the Dynamic loads and their effects on tall buildings using Response spectrum method. The Structural responses on various parameters such as storey drift, Structural lateral displacements, Base shear, Stiffness for Normal Building and different Load resisting systems are analysed.

III. ANALYTICAL MODELING

A plan of 45mx45m is taken into consideration having 5mx5m bays on both the sides. The High rise building (HRB) of 30 stories in which floor to floor height is taken as 3m for all the models. The plan and elevation is shown. An analytical study on multi-Storey building of 30 stories was carried out for different seismic zones and soft soil type using different bracing systems i.e., X-brace, V-brace, inverted V or chevron brace and infills are introduced in these analytical models. The different types of Bracings (X, V, Inverted V), Infills are introduced in the system at center in 3 bays. These building models are analyzed, using E Tabs 2015 software employing Response Spectrum method as per IS 1893 (Part I): 2002.

A. Material and Geometrical Properties:

Following material properties are considered for the modeling of the proposed structure frame:-

Floor to Floor height	3.0 m
Grade of concrete	M 40
Type of steel	Fe 415
Column size (Bottom 7 storeys)	800mm x 1000mm
Column size (From 08 to 17 storeys)	700mm x 850mm
Column size (From 18 to 25 storeys)	600mm x 800mm
Column size (From 26 to30 storeys)	400mm x 600mm
Brace	230mm x 230mm
Beam size	500mm x 850mm
Slab thickness	130 mm
Shear wall thickness	230 mm

Table 3.1: Details of material and geometrical properties

B. Loading Conditions:

Following loadings are adopted for analysis:-

Design variable	Value	Reference
Masonry	20 kN/m^3	IS 875:1987 (part 1)
Concrete	40 kN/m^3	
Floor load	2 kN/m^2	IS 875:1987 (part 2)
Roof load	1.0 kN/m^2	
Floor Finishes	0.6 kN/m^2	
Importance factor	1	IS 1893:2002
Response Reduction Factor	5	IS 1893:2002

Table 3.2: Design Variable for analysis

C. Response Spectrum Analysis

The Dynamic load case i.e., Response spectrum method is adopted for analyses. This method is applicable for those structures where modes other than the fundamental one significantly the response of the structure.

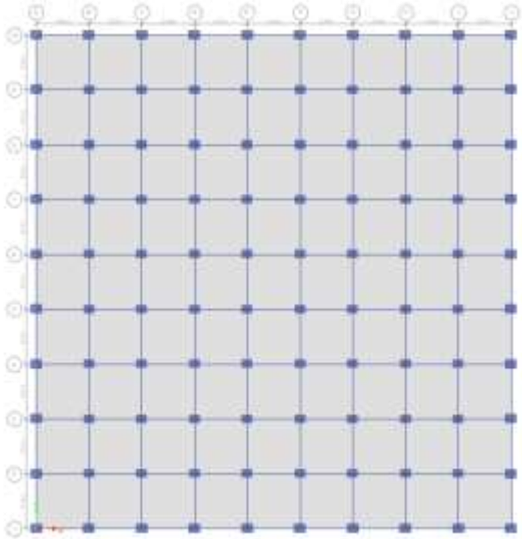

Fig 3.1: Building plan dimension 45m x 45m.

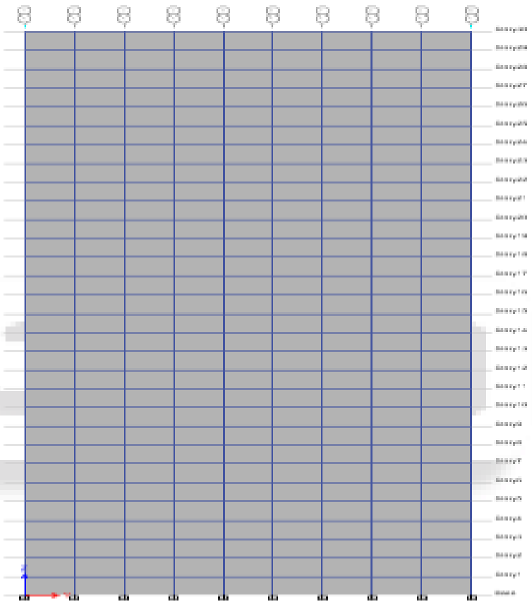

Fig 3.2: Elevation of 30 storey model showing Normal HRB.

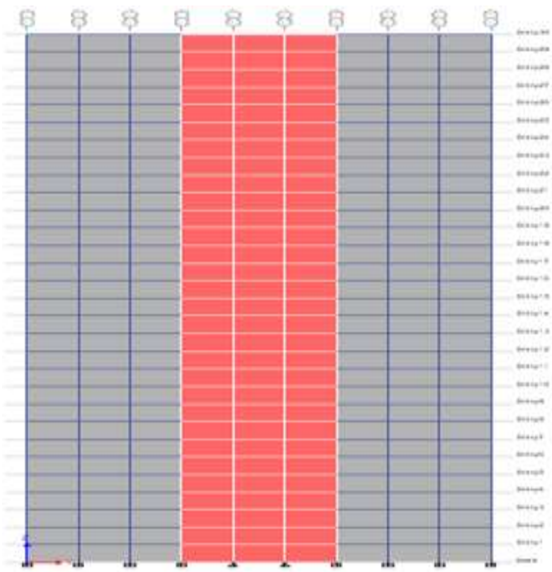

Fig 3.3: Elevation of 30 storey model HB showing infill (Shear wall) in three central bays at outer periphery.

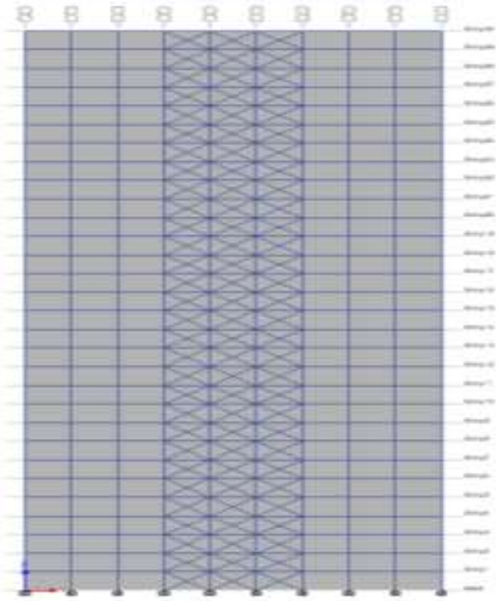

Fig 3.4: Elevation of 30 storey model HRB showing X-Bracing in three central bays at outer periphery.

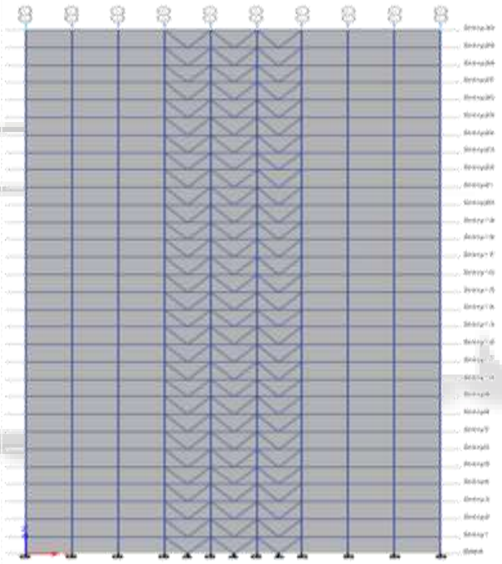

Fig 3.5: Elevation of 30 storey model HRB showing V-Bracing in three central bays at outer periphery.

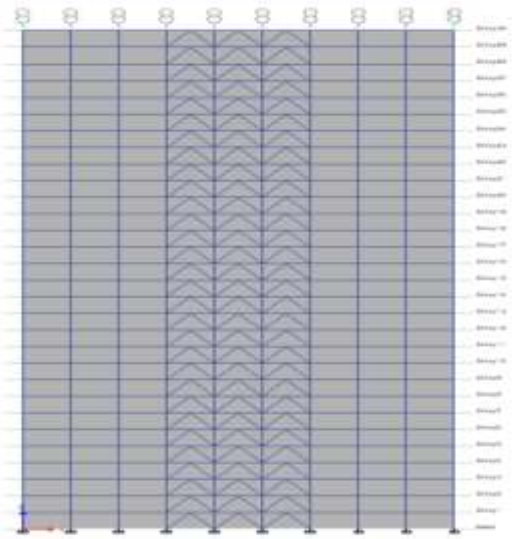

Fig 3.6: Elevation of 30 storey model HRB showing inverted V-Bracing in three central bays at outer periphery.

IV. RESULTS & DISCUSSION

An analytical study on multi-Storey building of 30 stories was carried out for different seismic zones and soft soil type using different bracing systems i.e., X-brace, V-brace, inverted V or chevron brace and infills are introduced in these analytical models. The Structural responses on storey drift, Structural lateral displacements, Base shear, Stiffness for Normal Building and different Load resisting systems are analysed using Response spectrum method for dynamic load for soil type 3 i.e., soft soil in all four seismic zones and are presented below.

A. For Lateral Drift:

The variation in the storey drift is compared for different structural lateral resisting systems. The drifts of all four zones for soil type 3 are tabulated and graphs are drawn for the values and presented below. After comparing, lateral resisting systems are more efficient to reduce the lateral drift than normal high rise building (i.e., moment resisting system). The efficiency to control drift is in the order of shear wall system is better than bracing system. In case of bracing system, X-bracing system is better than inverted V-bracing system which in turn better than V-bracing system to control the drift due to lateral loads. But this trend follows upto certain structure height only. After that height, the trend to control the drift varies in the order of bracings are better than shear wall. In bracing system, inverted V-bracing system is better than X-bracing system which in turn better than V-bracing system to control the drift due to lateral loads. This type of both trends is observed in all the zones for soil type 3 i.e., soft soil. The first trend type control of deflection is observed upto 28th Storey, thereafter with increase in storeys the second trend type follows.

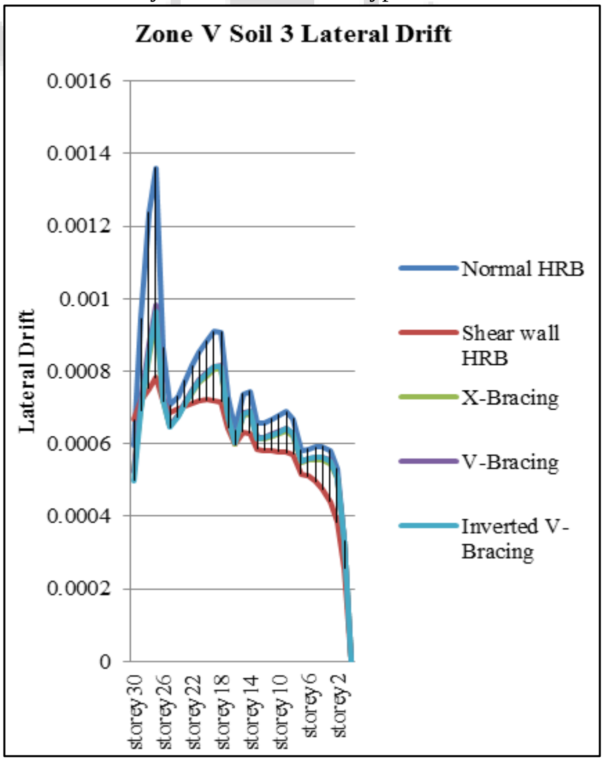

Fig 4.1: Lateral Drift for Dynamic Loading for Zone V Soil type 3 in UX Direction.

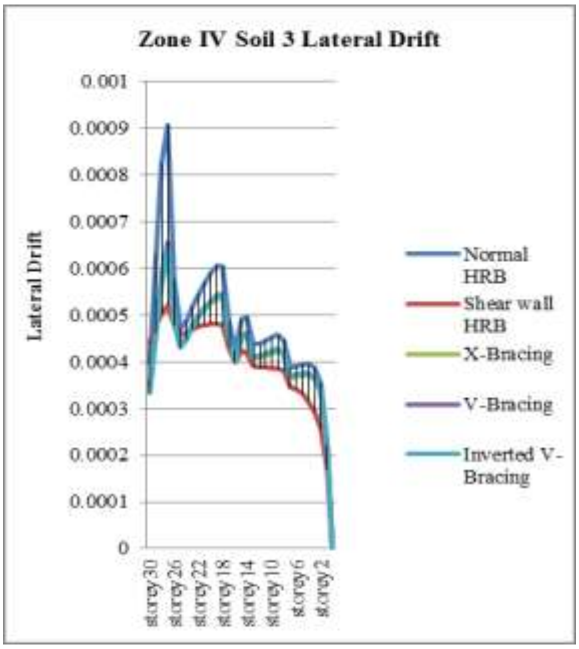

Fig 4.2: Lateral Drift for Dynamic Loading for Zone IV Soil type 3 in UX Direction.

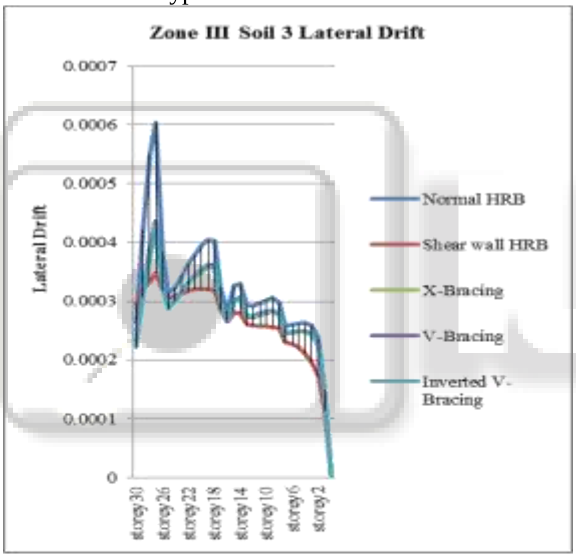

Fig 4.3: Lateral Drift for Dynamic Loading for Zone III Soil type 3 in UX Direction.

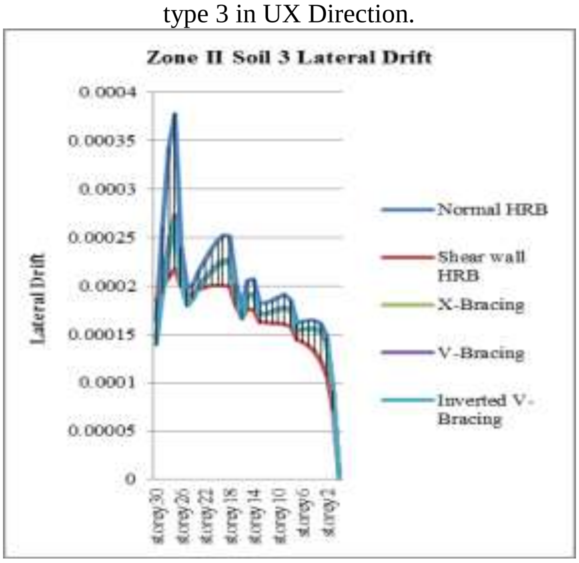

Fig 4.4: Lateral Drift for Dynamic Loading for Zone II Soil type 3 in UX Direction.

B. Top Floor Lateral Displacements:

The variation in the top floor lateral displacements is compared for different structural lateral resisting systems. The drifts of all four zones for soil type 3 are tabulated and graphs are drawn for the values and shown. The top floor displacement is high for zone V in normal HRB for soil type 3 (soft soil). The control in displacement is better in lateral load resisting systems when compared to normal HRB. The degree of control in displacement is better in shear wall resisting system than that of bracing system. Next to shear wall system, X-bracing system is good in resisting the lateral displacement of the high rise building then after inverted V-bracing system and then V-bracing system. There is no significant variation in resisting displacement for X-bracing system and inverted V-bracing system. To control displacement or deflection in high rise building due to lateral loads i.e., (earthquake, wind loads), shear wall system controls deflection by resisting the lateral loads to great extent.

C. Base Shear:

The variation in the Base shear is compared for different structural lateral resisting systems. The base shears of all four zones for soil type 3 are tabulated and graphs are drawn for the values and shown. The base shear is high for shear wall system in all zones when compared with other systems. Base shear for X-bracing system, V-bracing system and inverted V bracing system doesn't show much variation.

D. Stiffness:

The variation in the stiffness is compared for different structural lateral resisting systems. The stiffness of all four zones for soil type 3 are tabulated and graphs are drawn for the values and shown. The stiffness is significantly high for shear wall system in all zones. Stiffness for normal high rise building (HRB) is almost equal in all zones. Similarly shear wall HRB, X-bracing system, V-bracing system and inverted V bracing system are almost identical in all zones respectively.

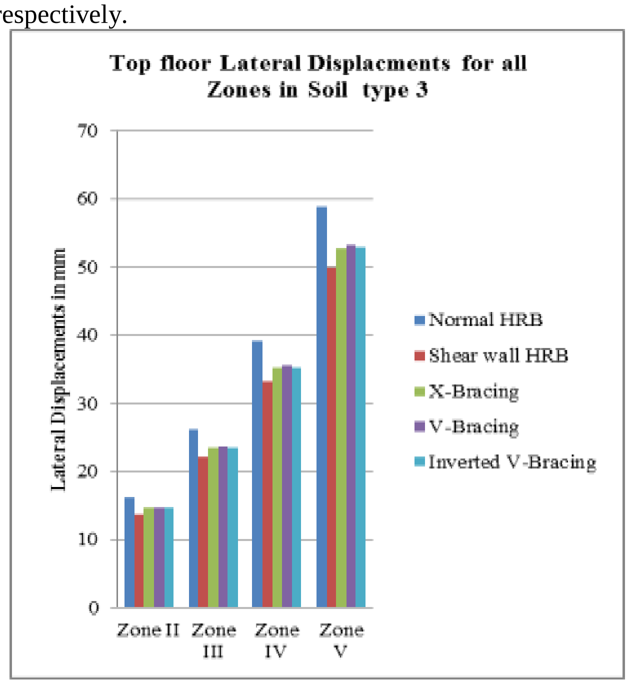

Fig 4.5: Lateral Displacement for Dynamic Loading for Zone V Soil type 3 in UX Direction.

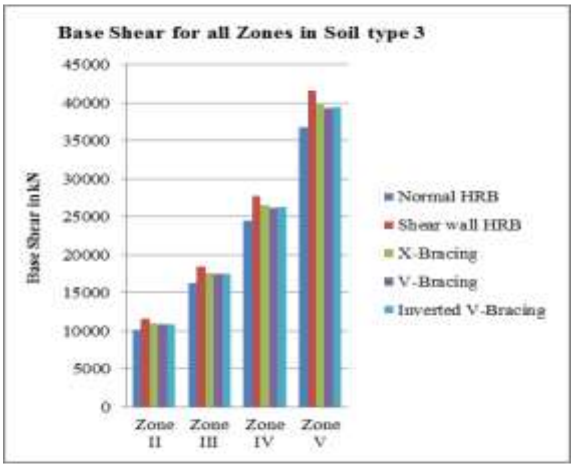

Fig 4.6: Base Shear for Dynamic Loading for Zone II Soil type 3 in UX Direction.

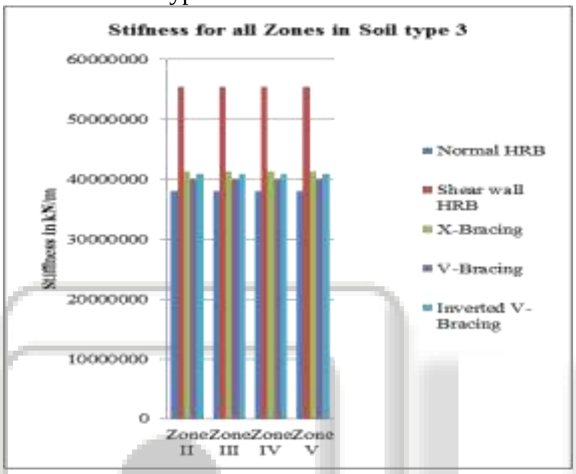

Fig 4.7: Stiffness for Dynamic Loading for Zone II Soil type 3 in UX Direction.

V. CONCLUSIONS

- To control drift, shear wall system is better than bracings system, normal HRB (moment resisting system).
- compared to Bracing system (i.e., X, inverted V and V) and Normal HRB (Moment resisting system)
- Inverted V-bracing system acts better to control drift above 28 storeys compared to shear wall system, X-bracing system, V-bracing system and normal bracing system which is contrast to shear wall system which acts better upto 28 storeys in controlling drift.
- The degree of control in displacement is better in shear wall resisting system than that of bracing system.
- There is no significant variation in resisting displacement for X-bracing system and inverted V-bracing system.
- The bracing systems, infills (shear wall) system were found to be much effective in reducing the displacement, drift and thereby increasing the base shear, stiffness of the structure (HRB).
- Base shear is high for shear wall system. For X-bracing system, V-bracing system and inverted V bracing system the base shear is in the sane range.
- Stiffness for shear wall resisting system is high when compared to other systems. Stiffness of each system is different and the value which is same in all zones respectively.

APPENDIX

Storey	Storey Drift for Lateral Load Resisting Systems				
	Normal HRB	Shear wall HRB	X-Bracing HRB	V-Bracing HRB	Inverted V-Bracing HRB
Storey30	0.000596	0.000666	0.000526	0.000522	0.000499
Storey29	0.000946	0.000718	0.000701	0.000716	0.000692
Storey28	0.001238	0.000752	0.000842	0.000876	0.000853
Storey27	0.00136	0.000782	0.000944	0.000984	0.000964
Storey26	0.000865	0.000717	0.000723	0.000732	0.000723
Storey25	0.000707	0.000685	0.00065	0.000651	0.000645
Storey24	0.00073	0.000695	0.000678	0.000679	0.000674
Storey23	0.000774	0.000704	0.000712	0.000715	0.000711
Storey22	0.000816	0.000713	0.000742	0.000747	0.000744
Storey21	0.000853	0.000719	0.000768	0.000775	0.000772
Storey20	0.000884	0.000722	0.000788	0.000797	0.000795
Storey19	0.000909	0.00072	0.000804	0.000814	0.000812
Storey18	0.000907	0.000715	0.000804	0.000815	0.000813
Storey17	0.000729	0.000644	0.000671	0.000676	0.000674
Storey16	0.000638	0.000598	0.0006	0.000602	0.000601
Storey15	0.000737	0.000632	0.000679	0.000685	0.000683
Storey14	0.000744	0.000628	0.000683	0.00069	0.000689
Storey13	0.000656	0.000585	0.000612	0.000616	0.000615
Storey12	0.000656	0.000582	0.000613	0.000617	0.000616
Storey11	0.000669	0.000581	0.000621	0.000627	0.000626
Storey10	0.000679	0.000579	0.000628	0.000634	0.000633
Storey9	0.000688	0.000577	0.000635	0.000642	0.000641
Storey8	0.000669	0.00057	0.000622	0.000629	0.000628

Storey7	0.000581	0.000517	0.000548	0.000553	0.000553
Storey6	0.000586	0.000511	0.000554	0.000559	0.000558
Storey5	0.00059	0.000496	0.000556	0.000562	0.000561
Storey4	0.000592	0.000474	0.000555	0.000562	0.000561
Storey3	0.000582	0.000441	0.000546	0.000554	0.000552
Storey2	0.000531	0.000385	0.000504	0.00051	0.000509
Storey1	0.000332	0.000255	0.00033	0.000331	0.000331
Base	0	0	0	0	0

Table 4.1: Lateral Drift Analysis in Response Spectrum Method (i.e., for Dynamic Loading) for Zone V Soil type 3 in UX Direction.

Storey	Storey Drift for Lateral Load Resisting Systems				
	Normal HRB	Shear wall HRB	X-Bracing HRB	V-Bracing HRB	Inverted V-Bracing HRB
Storey30	0.0004	0.00044	0.00035	0.00035	0.00033
Storey29	0.00063	0.00048	0.00047	0.00048	0.00046
Storey28	0.00083	0.0005	0.00056	0.00058	0.00057
Storey27	0.00091	0.00052	0.00063	0.00066	0.00064
Storey26	0.00058	0.00048	0.00048	0.00049	0.00048
Storey25	0.00047	0.00046	0.00043	0.00043	0.00043
Storey24	0.00049	0.00046	0.00045	0.00045	0.00045
Storey23	0.00052	0.00047	0.00048	0.00048	0.00047
Storey22	0.00054	0.00048	0.0005	0.0005	0.0005
Storey21	0.00057	0.00048	0.00051	0.00052	0.00052
Storey20	0.00059	0.00048	0.00053	0.00053	0.00053
Storey19	0.00061	0.00048	0.00054	0.00054	0.00054
Storey18	0.0006	0.00048	0.00054	0.00054	0.00054
Storey17	0.00049	0.00043	0.00045	0.00045	0.00045
Storey16	0.00043	0.0004	0.0004	0.0004	0.0004
Storey15	0.00049	0.00042	0.00045	0.00046	0.00046
Storey14	0.0005	0.00042	0.00046	0.00046	0.00046
Storey13	0.00044	0.00039	0.00041	0.00041	0.00041
Storey12	0.00044	0.00039	0.00041	0.00041	0.00041
Storey11	0.00045	0.00039	0.00041	0.00042	0.00042
Storey10	0.00045	0.00039	0.00042	0.00042	0.00042
Storey9	0.00046	0.00039	0.00042	0.00043	0.00043
Storey8	0.00045	0.00038	0.00042	0.00042	0.00042
Storey7	0.00039	0.00035	0.00037	0.00037	0.00037
Storey6	0.00039	0.00034	0.00037	0.00037	0.00037
Storey5	0.00039	0.00033	0.00037	0.00038	0.00037
Storey4	0.0004	0.00032	0.00037	0.00038	0.00037
Storey3	0.00039	0.00029	0.00036	0.00037	0.00037
Storey2	0.00035	0.00026	0.00034	0.00034	0.00034
Storey1	0.00022	0.00017	0.00022	0.00022	0.00022
Base	0	0	0	0	0

Table 4.2: Lateral Drift Analysis in Response Spectrum Method (i.e., for Dynamic Loading) for Zone IV Soil type 3 in UX Direction.

Storey	Storey Drift for Lateral Load Resisting Systems				
	Normal HRB	Shear wall HRB	X-Bracing HRB	V-Bracing HRB	Inverted V-Bracing HRB
Storey30	0.00027	0.0003	0.00023	0.00023	0.00022
Storey29	0.00042	0.00032	0.00031	0.00032	0.00031
Storey28	0.00055	0.00033	0.00037	0.00039	0.00038
Storey27	0.0006	0.00035	0.00042	0.00044	0.00043
Storey26	0.00038	0.00032	0.00032	0.00033	0.00032
Storey25	0.00031	0.00031	0.00029	0.00029	0.00029
Storey24	0.00032	0.00031	0.0003	0.0003	0.0003
Storey23	0.00034	0.00031	0.00032	0.00032	0.00032
Storey22	0.00036	0.00032	0.00033	0.00033	0.00033
Storey21	0.00038	0.00032	0.00034	0.00034	0.00034
Storey20	0.00039	0.00032	0.00035	0.00035	0.00035
Storey19	0.0004	0.00032	0.00036	0.00036	0.00036
Storey18	0.0004	0.00032	0.00036	0.00036	0.00036

Storey17	0.00032	0.00029	0.0003	0.0003	0.0003
Storey16	0.00028	0.00027	0.00027	0.00027	0.00027
Storey15	0.00033	0.00028	0.0003	0.0003	0.0003
Storey14	0.00033	0.00028	0.0003	0.00031	0.00031
Storey13	0.00029	0.00026	0.00027	0.00027	0.00027
Storey12	0.00029	0.00026	0.00027	0.00027	0.00027
Storey11	0.0003	0.00026	0.00028	0.00028	0.00028
Storey10	0.0003	0.00026	0.00028	0.00028	0.00028
Storey9	0.00031	0.00026	0.00028	0.00029	0.00029
Storey8	0.0003	0.00025	0.00028	0.00028	0.00028
Storey7	0.00026	0.00023	0.00024	0.00025	0.00025
Storey6	0.00026	0.00023	0.00025	0.00025	0.00025
Storey5	0.00026	0.00022	0.00025	0.00025	0.00025
Storey4	0.00026	0.00021	0.00025	0.00025	0.00025
Storey3	0.00026	0.0002	0.00024	0.00025	0.00025
Storey2	0.00024	0.00017	0.00022	0.00023	0.00023
Storey1	0.00015	0.00011	0.00015	0.00015	0.00015
Base	0	0	0	0	0

Table 4.3: Lateral Drift Analysis in Response Spectrum Method (i.e., for Dynamic Loading) for Zone III Soil type 3 in UX Direction

Storey	Storey Drift for Lateral Load Resisting Systems				
	Normal HRB	Shear wall HRB	X-Bracing HRB	V-Bracing HRB	Inverted V-Bracing HRB
Storey30	0.00016	0.00019	0.00015	0.00015	0.00014
Storey29	0.00026	0.0002	0.0002	0.0002	0.00019
Storey28	0.00034	0.00021	0.00023	0.00024	0.00024
Storey27	0.00038	0.00022	0.00026	0.00027	0.00027
Storey26	0.00024	0.0002	0.0002	0.0002	0.0002
Storey25	0.0002	0.00019	0.00018	0.00018	0.00018
Storey24	0.0002	0.00019	0.00019	0.00019	0.00019
Storey23	0.00022	0.0002	0.0002	0.0002	0.0002
Storey22	0.00023	0.0002	0.00021	0.00021	0.00021
Storey21	0.00024	0.0002	0.00021	0.00022	0.00021
Storey20	0.00025	0.0002	0.00022	0.00022	0.00022
Storey19	0.00025	0.0002	0.00022	0.00023	0.00023
Storey18	0.00025	0.0002	0.00022	0.00023	0.00023
Storey17	0.0002	0.00018	0.00019	0.00019	0.00019
Storey16	0.00018	0.00017	0.00017	0.00017	0.00017
Storey15	0.00021	0.00018	0.00019	0.00019	0.00019
Storey14	0.00021	0.00018	0.00019	0.00019	0.00019
Storey13	0.00018	0.00016	0.00017	0.00017	0.00017
Storey12	0.00018	0.00016	0.00017	0.00017	0.00017
Storey11	0.00019	0.00016	0.00017	0.00017	0.00017
Storey10	0.00019	0.00016	0.00017	0.00018	0.00018
Storey9	0.00019	0.00016	0.00018	0.00018	0.00018
Storey8	0.00019	0.00016	0.00017	0.00018	0.00017
Storey7	0.00016	0.00014	0.00015	0.00015	0.00015
Storey6	0.00016	0.00014	0.00015	0.00016	0.00016
Storey5	0.00016	0.00014	0.00016	0.00016	0.00016
Storey4	0.00016	0.00013	0.00015	0.00016	0.00016
Storey3	0.00016	0.00012	0.00015	0.00015	0.00015
Storey2	0.00015	0.00011	0.00014	0.00014	0.00014
Storey1	0.000092	0.000071	0.000092	0.000092	0.000092
Base	0	0	0	0	0

Table 4.4: Lateral Drift Analysis in Response Spectrum Method (i.e., for Dynamic Loading) for Zone II Soil type 3 in UX Direction.

Zone	Maximum Storey Displacement for Lateral Load Resisting System in mm				
	Normal HRB	Shear wall HRB	X-Bracing HRB	V-Bracing HRB	Inverted V-Bracing HRB
Zone II	16.3	13.8	14.7	14.8	14.7
Zone III	26.1	22.2	23.5	23.7	23.5
Zone IV	39.2	33.2	35.2	35.6	35.3

Zone V	58.8	49.9	52.8	53.3	52.9

Table 4.5: Comparison of top floor Lateral Displacement values in Response Spectrum Method (i.e., for Dynamic Loading) for Zone V Soil type 3 in UX Direction.

Zone	Maximum Storey Displacement for Lateral Load Resisting System in mm				
	Normal HRB	Shear wall HRB	X-Bracing HRB	V-Bracing HRB	Inverted V-Bracing HRB
Zone II	10159.4	11551.9	11039.5	10911.2	10944.8
Zone III	16317.3	18483	17663.2	17457.9	17511.7
Zone IV	24476	27724.5	26494.8	26186.8	26267.6
Zone V	36714	41586.8	39742.2	39280.2	39401.4

Table 4.6: Base shear Analysis in Response Spectrum Method (i.e., for Dynamic Loading) for Zone II Soil type 3 in UX Direction.

Zone	Maximum Storey Displacement for Lateral Load Resisting System in mm				
	Normal HRB	Shear wall HRB	X-Bracing HRB	V-Bracing HRB	Inverted V-Bracing HRB
Zone II	37979413	55363281	41298377	39961999	40835490
Zone III	37997779	55363281	41298377	39961999	40835490
Zone IV	37997779	55363281	41298377	39961999	40835490
Zone V	37979413	55363281	41303306	39961999	40835490

Table 4.7: Stiffness Analysis in Response Spectrum Method (i.e., for Dynamic Loading) for Zone II Soil type 3 in UX Direction.

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