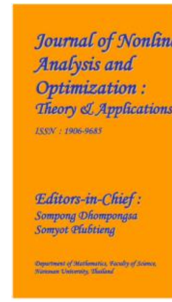

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EVALUATION AND COMPARITIVE STUDY OF DIFFERENT TYPE OF STRUCTURAL BUILDING SYSTEM AS PER NBC 105:2020 AND IS 1893:2016

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ABSTRACT

The construction of mid-rise reinforced concrete buildings are popular nowadays in city areas from commercial point of view. The popularity is leading to the construction of more numbers of commercial mid-rise buildings in city areas in countries like Nepal and India. This paper focuses on the selection of structure type of building with comparative study of seismic parameters on basis of seismic code Nepal National Building Code (NBC 105:2020) and Criteria for Earthquake Resistant Design of Structures (IS 1893:2016, part I). There are various structure types of buildings in the field of Structural Engineering but this study focuses only on mostly used three types of systems named as: Bare Frame Structure, Bracing + Frame Structure, Shear Wall + Frame Structure. In this paper 11-storied RCC building has been modelled, including staircase cover, one with bare RCC frame, second one with cross bracings and frame and third one with RC shear wall and frame. The analysis has been done by Modal Response Spectrum Method. The comparison of base shear, story displacement, story drift and mass participation ratio are done. Parameters such as section property, vertical loads (dead and live loads), and restrain conditions were taken constant. Codal provision followed were NBC 105:2020 and IS 1893:2016. The result of the study shows analysis done in NBC 105:2020 gives higher value of base shear than in IS 1893:2016 for all three-structure system. The story displacement, story drift were also found to be higher for bare frame system in comparison to Bracing + Frame system and also story displacement and story drift were found to be higher for Bracing + Frame system in comparison to Shear wall + Frame system as per both codes NBC 105:2020 and IS 1893:2016.

Keywords: *Modal Response Spectrum, NBC 105:2020, IS 1893:2016, Base Shear, Story displacement, Story Drift, Mass Participation Ratio*

INTRODUCTION

Structural systems play a pivotal role in the design and construction of buildings, influencing their stability, functionality, and overall performance. Among the various structural systems employed in modern architecture and structure design, frame structures stand out as a fundamental and widely used approach. Frame structures distribute loads efficiently by utilizing a network of vertical and horizontal elements, typically beams and columns, forming a skeletal framework that supports the building's weight. This system allows for open and flexible floor plans, making it adaptable to various architectural styles and applications.

Incorporating bracing into a frame structure enhances its stability and resilience against lateral forces such as wind or seismic activity. Bracing involves introducing diagonal, cross-braces, V braces and K braces within the frame, which effectively resist horizontal loads and prevent excessive sway. This combination of frame and bracing results in a robust structural system that not only provides vertical support but also ensures the building's lateral stability, critical for structures in regions prone to seismic events or high wind speeds.

Another prevalent structural system is the shear wall and frame structure, which combines the benefits of both shear walls and frame elements. Shear walls are vertical elements designed to resist lateral forces, and when integrated with a frame structure, they create a hybrid system that optimizes load distribution and lateral stability. This combination is particularly advantageous in high-rise buildings where both vertical and horizontal forces need careful consideration.

Shear walls alone, as a structural system, are vertical planes that provide lateral resistance to loads and are strategically placed throughout the building. These walls effectively counteract lateral movements, ensuring the building maintains its integrity during seismic events or high winds. The integration of shear walls with a frame structure enhances the overall performance of the building, making it a popular choice for tall and slender structures.

In essence, the choice of a structural system is a crucial decision in the structural as well as architectural design process, influencing not only the building's aesthetic but also its safety, functionality, and adaptability. Each system, whether it be a frame structure, braced frame, or shear wall and frame structure, brings unique advantages, and the selection depends on various factors such as the building's height, location, and intended use. The relationship between architectural vision and structural innovation plays a pivotal role in shaping the skylines of cities and defining the resilience of modern constructions.

1) **OBJECTIVE**

   The main objective of this research paper is to proper selection of structure type of building and analyze, compare the seismic parameters such as base shear, story displacements, story drifts and mass participation. The proper selection of structure type gives economic, safe and durable structure.

2) **METHODOLOGY**

   The mid-rise dummy building that are usually built in Kathmandu valley is selected for this study. Total of 6 models have been done using ETABS V.20. The 11 storied building is selected for study. The first model is Bare Frame model with column, beam, and slab elements. The second model is Frame model along with the bracing system at 4 corners of the building whereas, third model is Frame model along with the Shear walls at 4 corners of the building. Each model is done for both NBC 105:2020 and IS 1893:2016. Codal Provision followed were also NBC 105:2020 and IS 1893:2016. Model parameters such as section property, vertical load (dead and live loads), and restrain conditions were kept constant, though seismic parameters like zone factor, soil type, importance factor, response spectrum curve has been assigned as per respective seismic code. The support condition of building was assumed to be fixed support.

3) MODELING AND BUILDING FEATURES

11-Storied commercial building (including staircase cover) is selected for the study purpose. Three types of structural system has been modeled and analysis results were studied. Further, comparison of seismic parameters were observed. First model prepare was bare frame structure, second one is frame along with bracing on 4 corners of the building, third one is frame with shear walls on 4 corners of building. The building features are listed below:

Length of building = 24m
Breadth of building = 24m
Column to column span in X direction = 6m
Column to column span in Y direction = 6m
Story height all floors = 3m
Column size = 1500*1500mm (size fixed to satisfy drift for bare frame model as per NBC and kept constant for all other models as well)
Main Beam = 700*400mm
Secondary Beam = 350*230mm
Slab thickness = 150mm
Waist slab = 150mm
Cross Bracing size = 250*250*8 mm
Shear wall thickness = 400mm
Floor Finish = 1.2 KN/m2
Live Load (Rentable space) = 4Kn/m2
Live Load (Roof accessible) = 1.5 KN/m2
Light Partition wall load = 1.5 KN/m2
Wall load (9” without Opening) = 10.33 KN/m
Wall load (9” with opening) = 7.27 KN/m
Restrain condition at base = Fixed Support
Soil type = Soil D as per NBC, Zone V & Soil type III as per IS
Importance Factor = 1.25 as per NBC, 1.2 as per IS
Building Naming index

Naming	Description
BF-M1,NBC	Bare Frame Model No 1 (NBC 105:2020 105:2020)
BRF-M2,NBC	Bracing +Frame Model No 2 (NBC 105:2020)
SWF-M3, NBC	Shear wall + Frame Model No 3 (NBC 105:2020)
BF-M1,IS	Bare Frame Model No 1 (IS 1893:2016)
BRF-M2,IS	Bracing + Frame Model No 2 (IS 1893:2016)
SWF-M3, IS	Shear wall + Frame Model No 3 (IS 1893:2016)

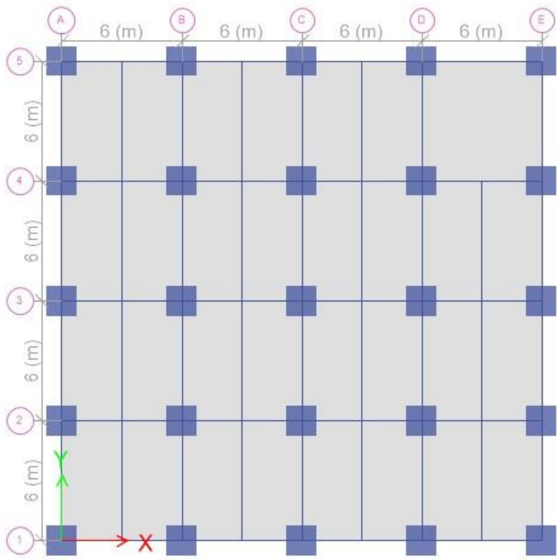

Figure 1: Typical Building Plan

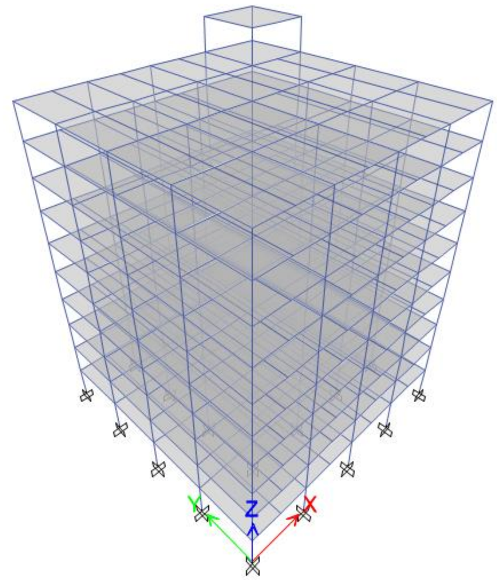

Figure 2: 3D view of Bare Frame Model

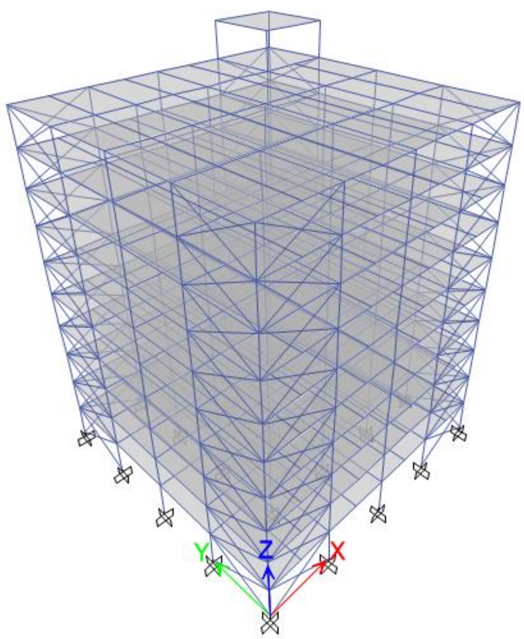

Figure 3: 3D view of Bracing with Frame Model

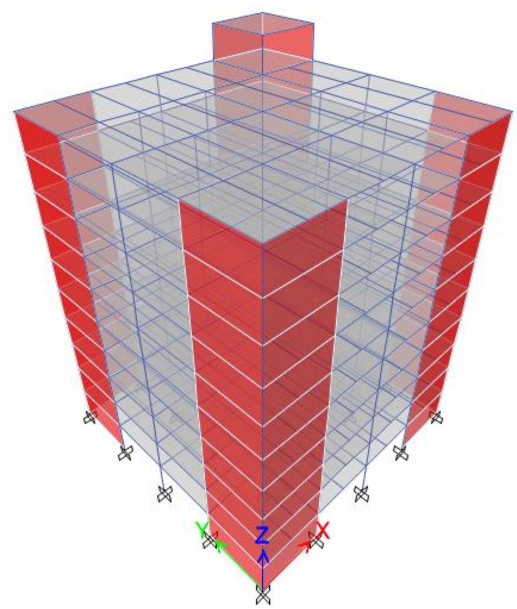

Figure 4: 3D view of Shear wall with Frame Model

4) RESULT AND DISCUSSION

NBC 105:2020 and IS 1893:2016 codes were used for analysis and design. Linear Modal Response spectrum Method is used for analysis. Graphical, tabular representation of results from model like base shear, story displacement, story drift, mass participation ratio is shown below.

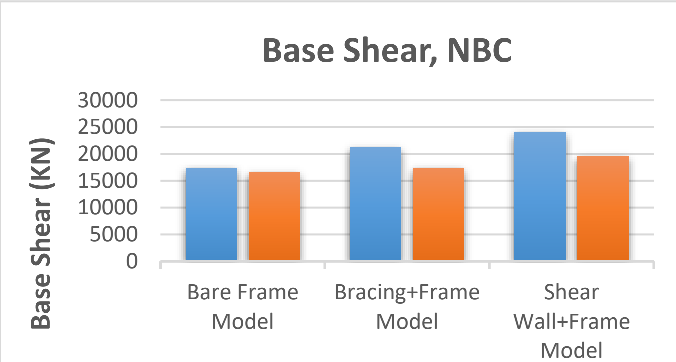

Figure 5: Base shear for different structure type using NBC 105:2020

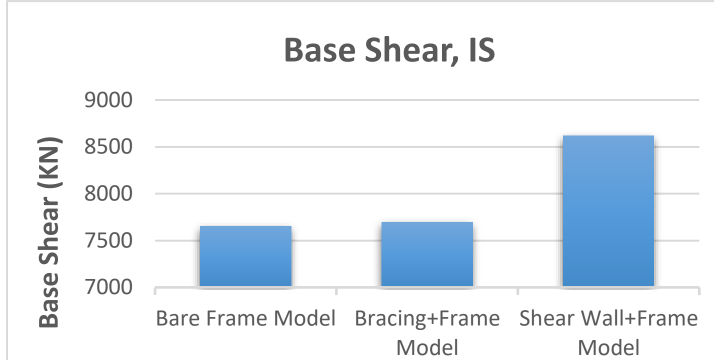

Figure 6: Base shear for different structure type using IS 1893:2016

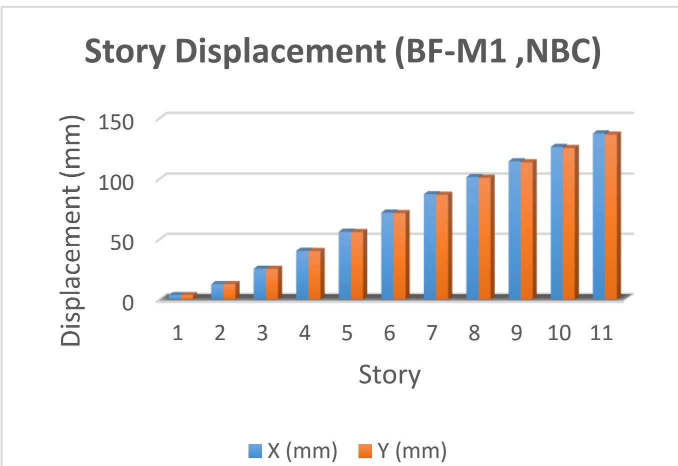

Figure 7: Story Displacement for Bare Frame Model using NBC 105:2020

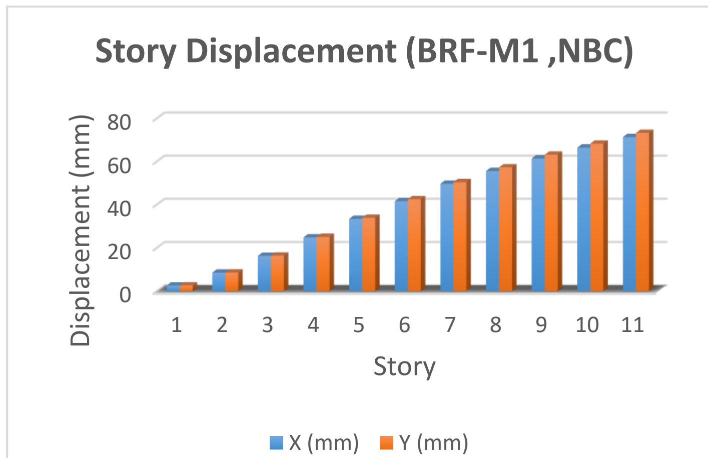

Figure 8: Story Displacement for Bracing with Frame Model using NBC 105:2020

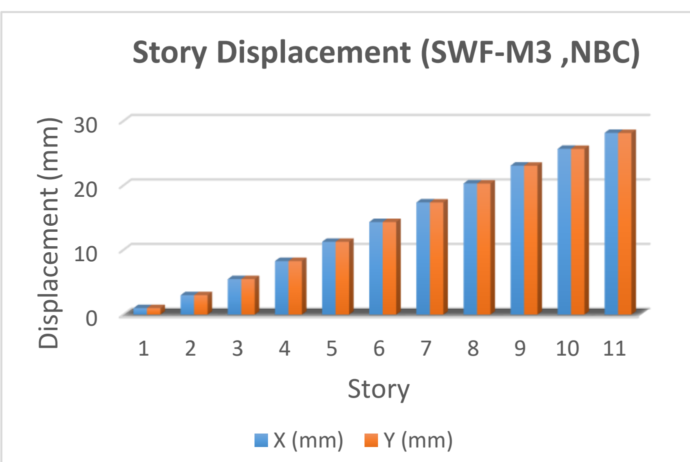

Figure 9: Story Displacement for Shear wall with Frame Model using NBC 105:2020

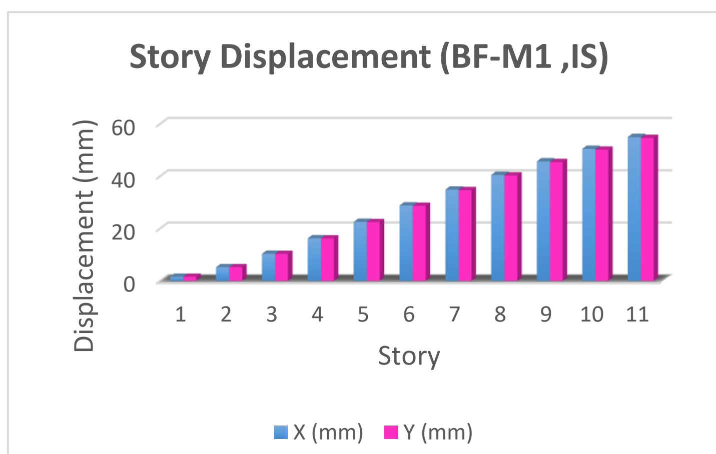

Figure 10: Story Displacement for Bare Frame Model using IS 1893:2016

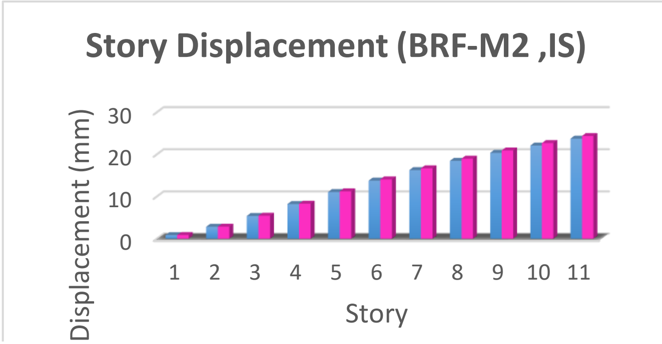

Figure 11: Story Displacement for Bracing with Frame Model using IS 1893:2016

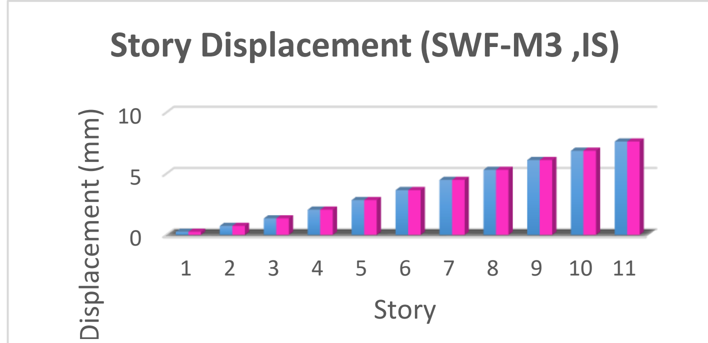

Figure 12: Story Displacement for Shear wall with Frame Model using IS 1893:2016

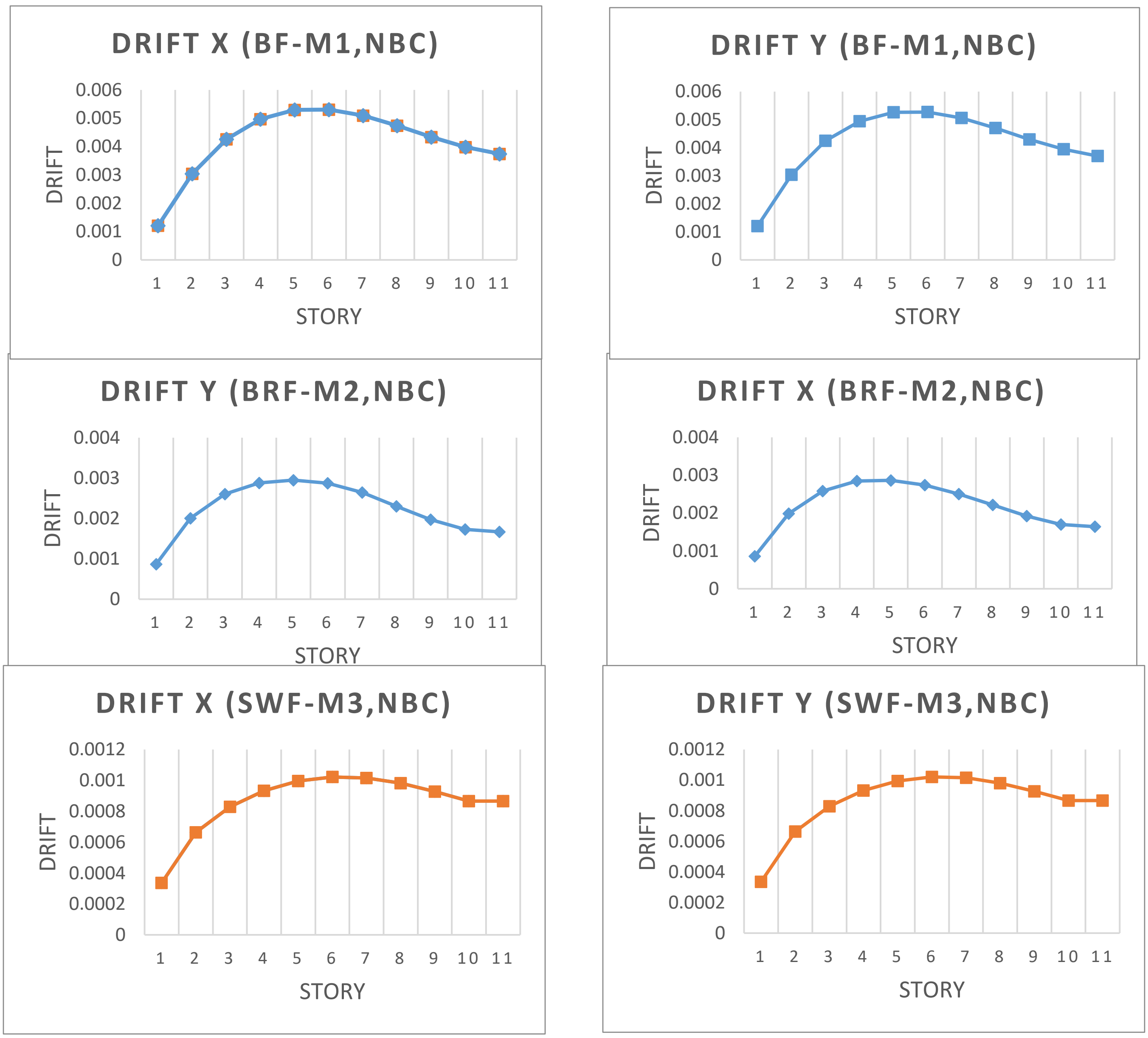

Figure 13: Story Drift for Shear for different structural system building using NBC 105:2020

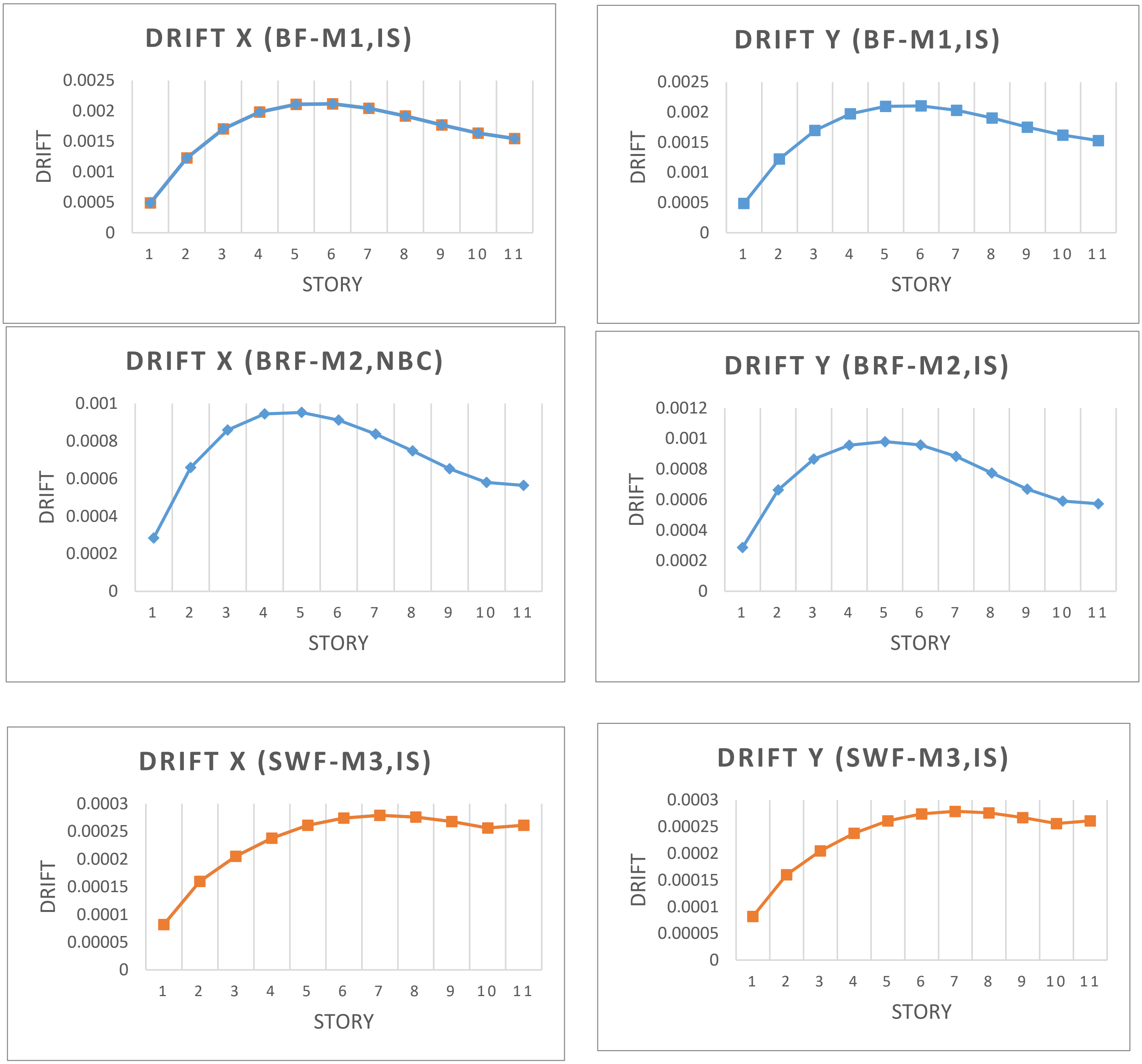

Figure 14: Story Drift for Shear for different structural system building using IS 1893:2016

TABLE: Modal Participating Mass Ratios (BF-M1, NBC)								
Case	**Mode**	**Period**	**UX**	**UY**	**SumUX**	**SumUY**	**RZ**	**f**
		sec						
Modal	1	1.179	0.6918	0.0093	0.6918	0.0093	0.0023	0.84818
Modal	2	1.173	0.0097	0.6925	0.7015	0.7017	0.0017	0.85251
Modal	3	0.911	0.0018	0.0021	0.7033	0.7039	0.7188	1.09769
Modal	4	0.296	0.1206	0.0236	0.8239	0.7275	0.003	3.37838
Modal	5	0.295	0.0252	0.1216	0.8491	0.849	0.0005	3.38983
Modal	6	0.247	0.002	0.0022	0.8511	0.8512	0.1292	4.04858
Modal	7	0.126	0.0325	0.0234	0.8836	0.8746	0.0054	7.93651
Modal	8	0.125	0.0263	0.0352	0.91	0.9098	0.0001	8

TABLE: Modal Participating Mass Ratios (BRF-M2, NBC)								
Case	**Mode**	**Period**	**UX**	**UY**	**SumUX**	**SumUY**	**RZ**	**f**
		sec						
Modal	1	0.811	0.004	0.7264	0.004	0.7264	0.0015	1.23305
Modal	2	0.808	0.7294	0.0039	0.7334	0.7303	0.0009	1.23762
Modal	3	0.564	0.0008	0.0019	0.7342	0.7322	0.7573	1.77305
Modal	4	0.229	0.0125	0.118	0.7467	0.8502	0.0014	4.36681
Modal	5	0.229	0.1166	0.0133	0.8633	0.8635	0.0002	4.36681
Modal	6	0.171	0.0008	0.0009	0.8641	0.8644	0.1136	5.84795
Modal	7	0.11	0.0092	0.0414	0.8733	0.9058	0.0023	9.09091
Modal	8	0.109	0.043	0.0101	0.9164	0.9159	0.0002	9.17431

TABLE: Modal Participating Mass Ratios (SWF-M3,NBC)								
Case	**Mode**	**Period**	**UX**	**UY**	**SumUX**	**SumUY**	**RZ**	**f**
		sec						
Modal	1	0.491	0.5781	0.1338	0.5781	0.1338	0.0015	2.03666
Modal	2	0.491	0.1343	0.5787	0.7123	0.7125	0.0002	2.03666
Modal	3	0.305	0.0009	0.001	0.7133	0.7135	0.7362	3.27869
Modal	4	0.132	0.0531	0.1234	0.7664	0.8369	4.8E-05	7.57576
Modal	5	0.132	0.1232	0.0526	0.8897	0.8895	0.001	7.57576
Modal	6	0.089	0.0005	0.0006	0.8902	0.89	0.1657	11.236
Modal	7	0.065	0.0012	0.0453	0.8914	0.9353	0.0004	15.3846
Modal	8	0.065	0.0453	0.001	0.9368	0.9363	0.0008	15.3846

Table 1: Mass Participation Ratio for different structural system building using NBC 105:2020

TABLE: Modal Participating Mass Ratios (BF-M1, IS)								
Case	**Mode**	**Period**	**UX**	**UY**	**SumUX**	**SumUY**	**RZ**	**f**
		sec						
Modal	1	1.198	0.6926	0.0086	0.6926	0.0086	0.0021	0.83472
Modal	2	1.192	0.009	0.6933	0.7016	0.7019	0.0016	0.83893
Modal	3	0.922	0.0017	0.002	0.7034	0.7039	0.7191	1.0846
Modal	4	0.301	0.122	0.0224	0.8254	0.7263	0.0028	3.32226
Modal	5	0.3	0.0239	0.1229	0.8493	0.8492	0.0005	3.33333
Modal	6	0.25	0.0019	0.0021	0.8511	0.8513	0.1294	4
Modal	7	0.128	0.0332	0.023	0.8843	0.8743	0.0051	7.8125
Modal	8	0.127	0.0258	0.0356	0.9101	0.91	0.0001	7.87402

TABLE: Modal Participating Mass Ratios (BRF-M2, IS)								
Case	**Mode**	**Period**	**UX**	**UY**	**SumUX**	**SumUY**	**RZ**	**f**
		sec						
Modal	1	0.824	0.0045	0.7261	0.0045	0.7261	0.0015	1.21359
Modal	2	0.821	0.7291	0.0043	0.7336	0.7304	0.0009	1.21803
Modal	3	0.571	0.0007	0.0019	0.7343	0.7323	0.7575	1.75131
Modal	4	0.233	0.0102	0.1204	0.7446	0.8527	0.0014	4.29185
Modal	5	0.233	0.1189	0.0109	0.8635	0.8636	0.0002	4.29185
Modal	6	0.173	0.0008	0.0009	0.8642	0.8645	0.1137	5.78035
Modal	7	0.112	0.0092	0.0415	0.8734	0.906	0.0022	8.92857
Modal	8	0.111	0.0431	0.01	0.9165	0.9161	0.0002	9.00901

TABLE: Modal Participating Mass Ratios (SWF-M3, IS)								
Case	**Mode**	**Period**	**UX**	**UY**	**SumUX**	**SumUY**	**RZ**	**f**
		sec						
Modal	1	0.433	0.4882	0.2083	0.4882	0.2083	0.0015	2.30947
Modal	2	0.433	0.2089	0.4889	0.6971	0.6973	0.0001	2.30947
Modal	3	0.26	0.0009	0.001	0.6981	0.6983	0.7152	3.84615
Modal	4	0.109	0.0541	0.1388	0.7522	0.8371	0.0001	9.17431
Modal	5	0.109	0.1387	0.0536	0.8909	0.8907	0.001	9.17431
Modal	6	0.071	0.0006	0.0006	0.8915	0.8913	0.187	14.0845
Modal	7	0.053	0.0004	0.0484	0.8919	0.9397	0.0011	18.8679
Modal	8	0.053	0.049	0.0006	0.9409	0.9403	0.0007	18.8679

Table 2: Mass Participation Ratio for different structural system building using IS 1893:2016

From above results, it is seen that structure system with bracings and shear walls comparatively gives good structural performance. In terms of base shear for both NBC and IS code, shear wall with frame has high base shear in comparison to bracing with frame model and bare frame model respectively. This indicates more force is attracted by stiffer elements like shear wall and bracing and force demand is reduced in RCC columns. The initial size of columns for bare frame were assigned to satisfy drift criteria for NBC and same size were chosen for all other models. While observing results we see significant decrease in story displacement and story drift for Shear wall with frame and Bracing with frame model. This clearly indicates we can reduce the sizes of the columns where bracing and shear wall systems are incorporated if same sizes of columns are used. The proper selection of structure system ensures economic design of structure, safety, durability construction. The over design of structural systems can be avoided. All the results are compared with both NBC and IS code. Further, base shear obtained from NBC is on higher side than IS code for all structural system as both code use different values of zone factor, importance factor, response spectrum curve, eccentricity ratio though similar soil type assigned for all models. The response of building in terms of mass participation ratio shows bracing with frame model has more mass participation ratio than bare frame model but shear wall with model has lesser mass participation which might be due to selection of proper location of shear wall and further extension of shear wall up to staircase level at only one side.

In above model the bare frame with such large sizes are not usually adopted in practice but if only bare frames to be used such larger size of columns are needed. Therefore in practice frames are incorporated with bracing and shear wall but poor planning leads to no proper execution so project become uneconomical.

It is also found that while designing/planning the architecture system of building, initially it is better to take suggestions from structure designer as well so possibility of structural system like shear walls, bracings can be decided at early stage so functions of building will not be hampered and leads us to economic and safer structural system.

CONCLUSION

From the above analysis and results following conclusion can be drawn:

- Base Shear NBC V/S IS: Among different type of structural system, all three type of system there is decrease in base shear of IS 1893:2016 than of NBC 105:2020. For bare frame model, bracing with frame model, shear wall with frame model base shear decrease up to 56%, 64% and 64% respectively.
- For NBC 105:2020, base shear is decreased up to 23% in case of bracing with frame system to bare frame system and 13% in case of shear wall with frame system to bracing with frame system.
- For IS 1893:2016, base shear is decreased only up to 0.6% in case of bracing with frame system to bare frame system and 11% in case of shear wall with frame system to bracing with frame system.
- Max Story displacement is decreased up to 48% in case of bare frame to bracing with frame system whereas there is decrease up to 61% in case of bracing with frame system to Shear wall with frame system for NBC 105:2020.
- Max Story displacement is decreased up to 57% in case of bare frame to bracing with frame system whereas there is decrease up to 68% in case of bracing with frame system to Shear wall with frame system for IS 1893:2016.
- Max Story drift is decreased up to 46% in case of bare frame to bracing with frame system whereas there is decrease up to 64% in case of bracing with frame system to Shear wall with frame system for NBC 105:2020.
- Max Story drift is decreased up to 55% in case of bare frame to bracing with frame system whereas there is decrease up to 70% in case of bracing with frame system to Shear wall with frame system for IS 1893:2016.

- Mass participation is higher in bracing with frame system than of bare frame system and lower than of shear wall system (might be due extension of shear wall up to staircase level only on one side).
- Sizes of sections can be reduced in bracing with frame structure and Shear wall with frame structure.

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Author contributions
First author: Conceptualization, Methodology, Investigation, Data curation, Writing – original draft.
Second Author: Conceptualization, Methodology, Supervision, Visualization, Resources, Writing – review & editing.

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Data Availability
All data generated or analyzed during this study are included in this article.

Declaration
The authors declare that this is an original work and bear no financial or personal relations with any party that could affect the outcome of this work.

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