TECHNIQUES FOR MITIGATION OF SOFT STORY ON TALL BUILDINGS UNDER LATERAL LOADS

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ABSTRACT

The soft story plays a significant role in its seismic success in high-rise construction. The framework's uniformity is discontinuous at the soft story level because of no infill walls or differences in floor height. This consistency causes the structural collapse of multi-stored buildings under the burdens of the earthquake. Severe structural damage sustained in recent earthquakes by many modern buildings highlights the significance of preventing sudden shifts in lateral rigidity and strength in this project with seismic zone V, and the structural Story is G+26.The study is carried out by considering earthquakes with a soft-story effect and mitigation techniques like BRB-brace, crescent brace, and combination to prevent soft story. Moreover, the displacement, story drift, and time period are compared after examining the above structure. There is also a study of different design parameters, and significant results have been obtained. Keywords: BRB- brace, crescent-brace, earthquake, soft-story

Keywords: soft story, BRB, and crescent brace.

1. Introduction

In other words, "soft stories" refer to stories in a structure with a lower level of stiffness or inadequate energy absorption (ductility). A building on a soft-story has a 70% less stiff floor than the floor above it. There's a lot of potential for damage in an earthquake because of this unstable floor. Soft stories tend to be on the bottom floors for commercial and garage spaces. If one falls, the whole structure would be destroyed, resulting in substantial structural damage that might render the structure entirely useless.

Researchers at the University of Bologna have recently suggested using the Crescent Shaped Braces (CSB) as an improved diagonal brace in framed buildings, following the Performance-Based Seismic Design framework. Concentric stiff diagonal braces are often used as lateral resisting systems. However, CSBs enable practical designers to select between several levels of side stiffness without compromising device yield strength, thanks to their unique, ad-hoc structure.

A concrete housing supports the slender steel core, which holds restrained bracelets (BRBs). The center and the casing are detached to avoid contact. The problems of standard braced frames may be avoided by adopting buckling reinforced braces, which prevent buckling in the theme brace during compression (BRBs). Buckling limits the appealing brace's energy dissipation capability, reducing steepness and strength. Inversely, buckling restrained braces have high stable hysteretic dissipation. Restraint buckling braces can be used in damage-controlled structures.

Literature Review

Niloufar Mashhadiali (Journal of Constructional Steel Research Volume 181, June 2021): Buildings often use steel concentric braced frames (CBFs). A large earthquake generates damage concentration in one or few stories due to the high nonlinear behavior of CBFs. Improved structural behavior and reduced soft-story processes are proposed in this article. The suggested system combines a restrained buckling brace (BRB) with a strong brace (SB). The robust braces are intended to flex during an earthquake. Tale by the story, BRB and SB zigzag in opposite directions. This design results in both stiffness and ductility. This enhances CBFs' soft narrative mechanisms and buckling capability. The nonlinear static (pushover) and dynamic studies of a series of 6-story structural models with various bracing patterns (inverted-V, multi-X, zipper, and Hexa) were performed in this work (IDA). The seismic behavior of conventional CBFs with the comparable bracing arrangement was compared to the collapse performance of structural models. Using collapse fragility curves, the hybrid bracing system outperformed standard CBFs in strong earthquakes.

Panumas Saingam (2020 Published by Elsevier): It is possible to seismically retrofit reinforced concrete (RC) buildings using buckling-restrained braces (BRBs) and elastic steel frames. While analogous linearization may be used to distribute BRB sizes vertically, it ignores the extra stiffness owing to the composite behavior between RC and elastic steel frames, leading to an unduly cautious assessment of BRB stiffness needs. An approach to retrofit design using composite behavior is proposed. The detailed composite behavior is modeled numerically and calibrated against quasi-static cyclic loading experiments. The suggested retrofit design technique is verified using a nonlinear response history analysis on a four-story RC school building.

Hanqin Wang,1 Yulong Feng (Hindawi Advances in Civil Engineering Volume 2019): Because buckling-restrained braces have low post-yield stiffness, multi-story buckling-restrained braced frames (BRBFs) exposed to earthquakes are prone to lateral deformations and damage concentrations at particular stories (DCE). The DCE of BRBFs is investigated using nonlinear pushover and response history analysis. The DCE is compared for two different constructions and beam-to-column connections in the mainframe (MF). According to these analyses, BRBFs fitted with BRBs have a higher DCE than traditional moment-resisting or conventional braced frames, and MF stiffness affects residual structural displacement and DCE. On the DCE of a 6-story BRBF dual system constructed to the Chinese seismic code, parametric studies are used to explore the influence of two stiffness distribution parameters (horizontal and vertical). They found that boosting MF stiffness and minimizing BRB stiffness variations across tales reduced the DCE of BRBFs. Finally, several damage performance measures are correlated. BRBFs show little statistical correlation between peak and residual drift responses. Thus, the DCE should be addressed in the BRBF design.

2. Module And Building Configuration

A reinforced concrete frame building with a located in zone II is studied in the first model. The building's plan area is 13 x 19 m, with each typical storey being 3m tall. It has 8 bays in the X direction and 10 bays in the Y direction.

The Plan configuration consists of

Model 1: G+26 with soft story

Model 2: G+26 with a soft story with BRB Braces

Model 3: G+26 with a soft story with Crescent braces

Model 4: G+26 with a soft story with crescent and BRB brace

Columns- 300 mm x 600 mm

Beams- 230 mm x 500 mm

Crescent brace 500 mm x 500 mm

BRB Star brb 20

Slab thickness- 150 mm

Concrete grade- M30

Grade of steel - HYSD415

Building design code- IS 456-2000

The seismic data used for modelling are as below:

a. Seismic zone- IV

b. Soil type- I

c. Response reduction factor- 5

d. Importance factor- 1

The load combinations considered are as given below.

a. 1.5(DL +LL)

b. 1.5(DL-EQX)

c. 1.2(DL+LL+EQX)

d. 1.2(DL+LL-EQX)

The plan and 3D view of the building used for the modelling is as below:

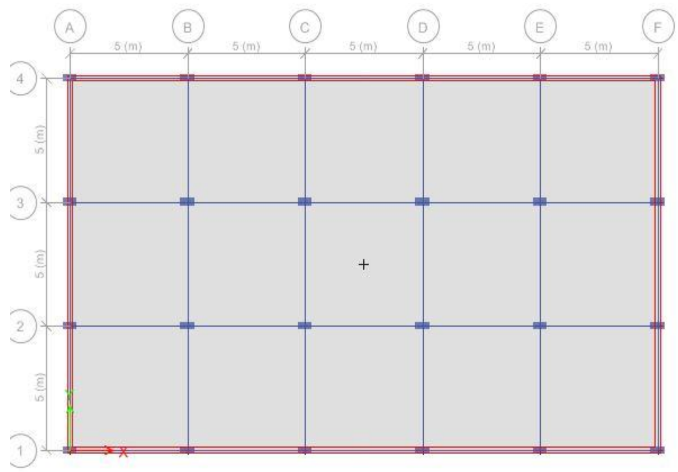


Figure 1: Plan view of G+26 storey building

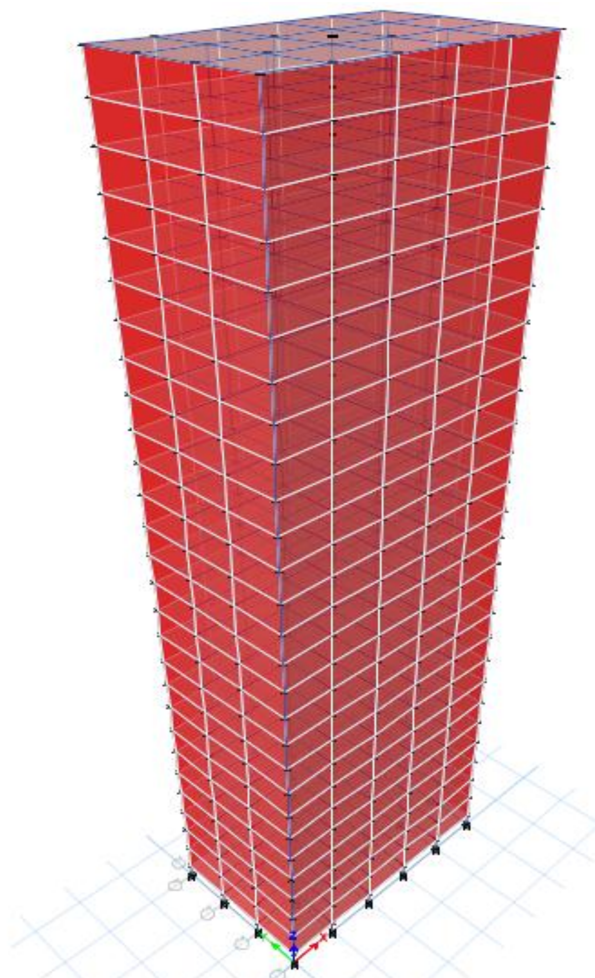


Figure 2: Isometric view of G+26 building

3. Methodology

Various parameters, such as story deformation, story drift, base shear, modal periods, and so on, have been analysed. Linear static analysis for G+26, Storey Buildings, generated the results. Results Obtained based on story drifts (time period, displacement, and stiffness) and the Storey effect of Symmetric buildings by comparing the structure's reactions to a 26-story building were discussed in detail in subsequent talks.

4. RESULTS FOR MODELS

STORY DISPLACEMENT WITH RESPONSE SPECTRUM METHOD

STORY DISPLACEMENT									
		NORMAL WITH SOFT STORY		SOFT STORY WITH BRB		SOFT STORY WITH CRESCENT BRACE		SOFT STORY WITH BRB & CRESCENT BRACE	
Story	Elevation	X-Dir	Y DIR	X DIR	Y DIR	X DIR	Y DIR	X DIR	Y DIR
	m	mm	mm	mm	mm	mm	mm	mm	mm
Base	0	0	0	0	0	0	0	0	0
Story1	1.5	0.627	1.399	0.25	0.383	0.14	0.188	0.171	0.229
Story2	4.5	0.857	1.712	0.473	0.699	0.348	0.481	0.382	0.526
Story3	7.5	1.103	2.051	0.722	1.059	0.584	0.822	0.622	0.872
Story4	10.5	1.379	2.432	0.999	1.461	0.85	1.206	0.89	1.262
Story5	13.5	1.678	2.848	1.301	1.901	1.141	1.629	1.185	1.69
Story6	16.5	2.001	3.297	1.626	2.373	1.455	2.086	1.503	2.153
Story7	19.5	2.344	3.775	1.972	2.875	1.792	2.574	1.842	2.647
Story8	22.5	2.706	4.281	2.337	3.405	2.148	3.091	2.201	3.168
Story9	25.5	3.086	4.813	2.719	3.959	2.523	3.633	2.578	3.715
Story10	28.5	3.482	5.368	3.117	4.536	2.914	4.198	2.971	4.286
Story11	31.5	3.892	5.945	3.529	5.133	3.319	4.784	3.379	4.877
Story12	34.5	4.316	6.542	3.954	5.749	3.738	5.39	3.8	5.487
Story13	37.5	4.75	7.157	4.391	6.381	4.169	6.012	4.233	6.113
Story14	40.5	5.195	7.788	4.837	7.028	4.61	6.649	4.675	6.755
Story15	43.5	5.649	8.434	5.292	7.688	5.059	7.3	5.126	7.409
Story16	46.5	6.109	9.093	5.753	8.359	5.516	7.961	5.585	8.075
Story17	49.5	6.576	9.763	6.22	9.039	5.978	8.632	6.048	8.75
Story18	52.5	7.047	10.442	6.692	9.727	6.445	9.311	6.517	9.433
Story19	55.5	7.521	11.128	7.166	10.421	6.915	9.995	6.988	10.122
Story20	58.5	7.997	11.819	7.642	11.119	7.386	10.684	7.46	10.814
Story21	61.5	8.474	12.514	8.118	11.82	7.858	11.374	7.934	11.509
Story22	64.5	8.95	13.211	8.594	12.521	8.328	12.065	8.406	12.204
Story23	67.5	9.424	13.907	9.067	13.22	8.797	12.755	8.876	12.898
Story24	70.5	9.895	14.601	9.538	13.917	9.263	13.441	9.343	13.589
Story25	73.5	10.363	15.291	10.005	14.61	9.724	14.123	9.806	14.275
Story26	76.5	10.826	15.977	10.467	15.297	10.181	14.8	10.265	14.956
Story27	79.5	11.284	16.656	10.923	15.978	10.632	15.469	10.717	15.63
Story28	82.5	11.736	17.33	11.374	16.652	11.076	16.132	11.164	16.297

Table 1: story displacement for G+26 building

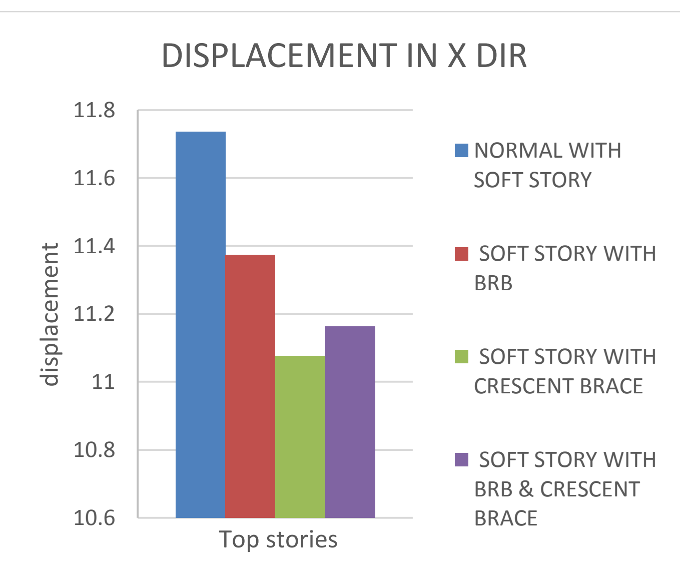


Figure 3: story displacement G+26 in the X direction

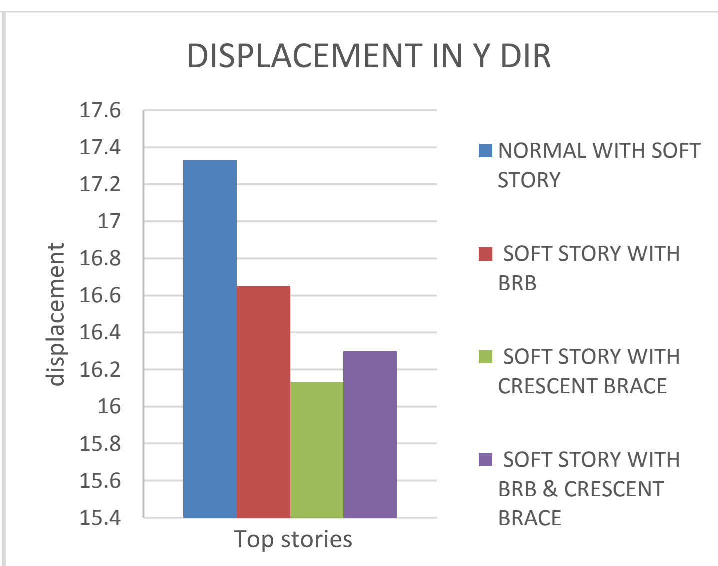


Figure 4: story displacement G+26 in Y direction

STORY DRIFT									
		NORMAL WITH SOFT STORY		SOFT STORY WITH BRB		SOFT STORY WITH CRESCENT BRACE		SOFT STORY WITH BRB & CRESCENT BRACE	
Story	Elevation	X-Dir	Y DIR	X DIR	Y DIR	X DIR	Y DIR	X DIR	Y DIR
	m	mm	mm	mm	mm	mm	mm	mm	mm
Base	0	0	0	0	0	0	0	0	0
Story1	1.5	0.000418	0.000933	0.000167	0.000256	9.30E-05	0.000125	0.000114	0.000153
Story2	4.5	7.90E-05	0.000111	7.50E-05	0.000108	7.00E-05	0.0001	7.10E-05	0.000101
Story3	7.5	8.40E-05	0.000121	8.40E-05	0.000122	7.90E-05	0.000115	8.00E-05	0.000117
Story4	10.5	9.40E-05	0.000135	9.30E-05	0.000136	8.90E-05	0.000129	9.00E-05	0.000131
Story5	13.5	0.000102	0.000147	0.000101	0.000148	9.70E-05	0.000142	9.90E-05	0.000144
Story6	16.5	0.00011	0.000158	0.000109	0.000159	0.000105	0.000154	0.000107	0.000156
Story7	19.5	0.000117	0.000168	0.000116	0.00017	0.000113	0.000164	0.000114	0.000166
Story8	22.5	0.000123	0.000178	0.000123	0.000179	0.00012	0.000174	0.000121	0.000176
Story9	25.5	0.000129	0.000187	0.000129	0.000188	0.000126	0.000183	0.000127	0.000185
Story10	28.5	0.000135	0.000195	0.000134	0.000196	0.000131	0.000191	0.000132	0.000193
Story11	31.5	0.00014	0.000203	0.000139	0.000203	0.000137	0.000199	0.000137	0.000201
Story12	34.5	0.000144	0.00021	0.000143	0.00021	0.000141	0.000206	0.000142	0.000207
Story13	37.5	0.000148	0.000216	0.000147	0.000216	0.000145	0.000212	0.000146	0.000213
Story14	40.5	0.000151	0.000222	0.000151	0.000221	0.000149	0.000217	0.000149	0.000219
Story15	43.5	0.000154	0.000227	0.000154	0.000226	0.000152	0.000222	0.000152	0.000224
Story16	46.5	0.000157	0.000231	0.000156	0.00023	0.000154	0.000226	0.000155	0.000228
Story17	49.5	0.000159	0.000235	0.000158	0.000234	0.000156	0.00023	0.000157	0.000231
Story18	52.5	0.00016	0.000238	0.00016	0.000236	0.000158	0.000232	0.000158	0.000234
Story19	55.5	0.000161	0.00024	0.000161	0.000238	0.000159	0.000235	0.000159	0.000236
Story20	58.5	0.000162	0.000241	0.000161	0.00024	0.000159	0.000236	0.00016	0.000237
Story21	61.5	0.000162	0.000242	0.000161	0.00024	0.000159	0.000236	0.00016	0.000238
Story22	64.5	0.000162	0.000242	0.000161	0.00024	0.000159	0.000236	0.00016	0.000238
Story23	67.5	0.000161	0.000241	0.00016	0.000239	0.000158	0.000235	0.000159	0.000237
Story24	70.5	0.00016	0.000239	0.000159	0.000238	0.000157	0.000234	0.000158	0.000235
Story25	73.5	0.000158	0.000237	0.000157	0.000236	0.000155	0.000232	0.000156	0.000233
Story26	76.5	0.000156	0.000235	0.000155	0.000233	0.000153	0.000229	0.000154	0.000231
Story27	79.5	0.000154	0.000232	0.000153	0.00023	0.000151	0.000226	0.000152	0.000228
Story28	82.5	0.000152	0.000229	0.000151	0.000227	0.000149	0.000223	0.00015	0.000225

Table 2: story drift for G+26 building

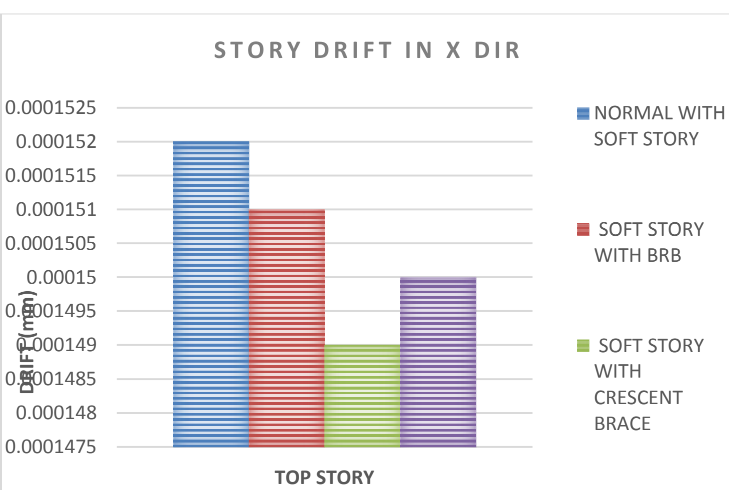


Figure5: story drift G+26 in the x-direction

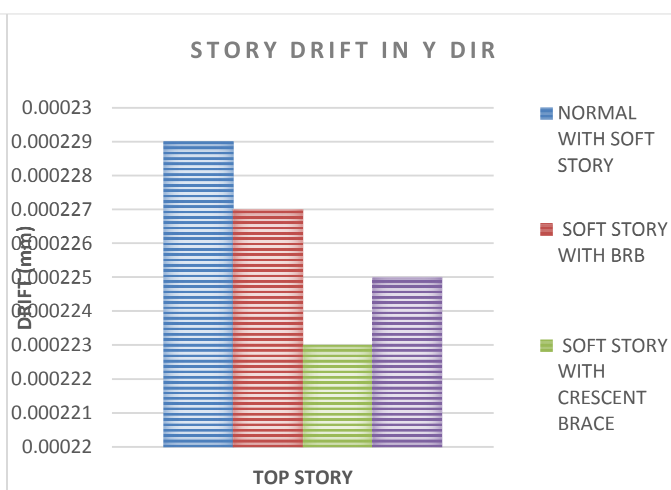


Figure6: story drift G+26 in the y-direction

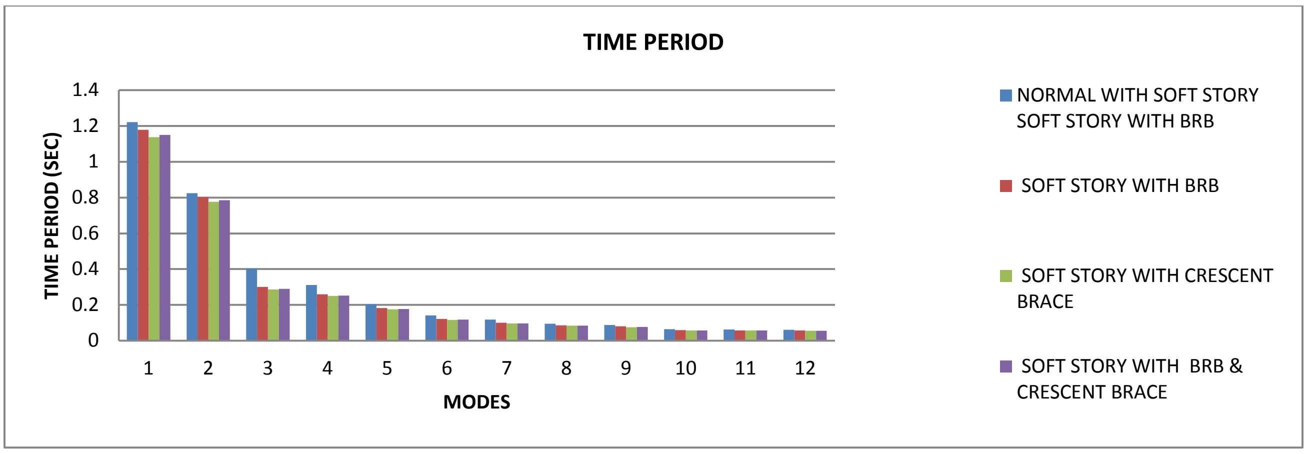
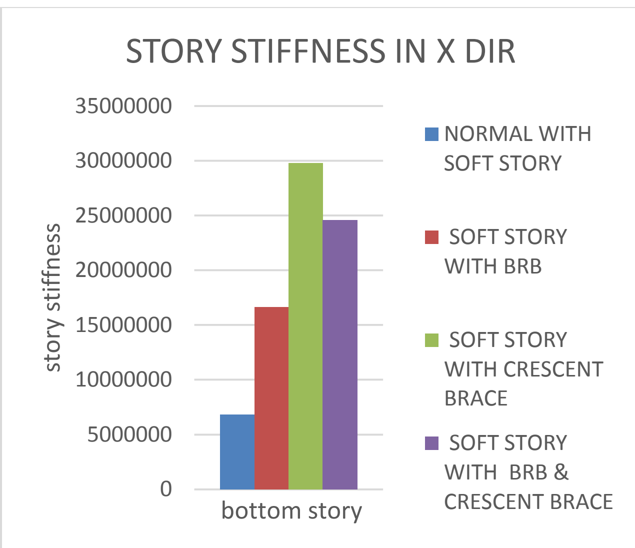


Figure7: Time Period for G+26



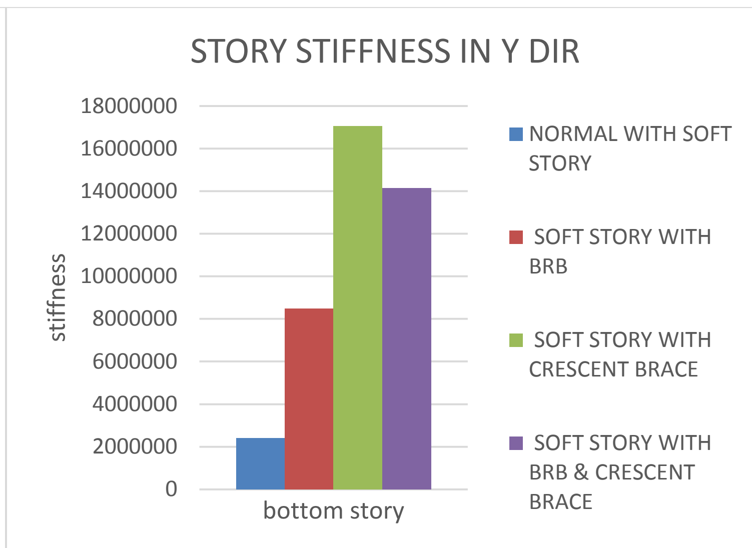


Figure8: Story stiffness for G+26 in x dir **Figure9: Story stiffness for G+26 in x dir**

5. CONCLUSION

As the soft story occurs in the building, the story displacement grows. Because of the soft story, the structure's rigidity is lowered, which increases the maximum story displacement.

• The increased BRBs can provide the MRF with initial stiffness and energy dissipation, minimizing structural displacement reaction during earthquakes. The BRB stiffness ratio between stories has an impact on the frame's damage mechanism.

• The total stiffness of the column is added to the lateral strength; bracing is applied at each story. As a result, the lowest floor's poor strength causes failure, especially during an earthquake. A building's strength is considered weak and easy to fail during an earthquake if it lacks any lateral load resistance components, such as bracing.

• The soft story's findings significantly impact the structural behavior and capability of the structure when subjected to seismic forces.

• Displacement and story drift has grown due to structural flaws; displacement rose on specific floors when the soft story lowered the inertia force.

• Story drift values are within the 1893 allowed limit, which is 0.004 times the story height.

• Because soft-story has limited flexibility to sustain lateral loads, the period of the structure is determined by its stiffness.

6. SCOPE OF FURTHER STUDY

- In the present thesis, an analysis of a multi-story building under the effect of discontinuity in stiffness, which is the soft story, is studied.

- The present work can extend to an exhaustive study of various types of irregulars. A generalized conclusion for the design of such irregular buildings can be made, which can help understand the behavior of such irregular building.

7. REFERENCES

- Hybrid braced frame with buckling-restrained and strong braces to mitigate soft-story Author links open overlay panel, Niloufar Mashhadiali, Research, Volume, June 2021, 106610.

- Composite behavior in RC buildings retrofitted using buckling-restrained braces with elastic steel frames, Panumas Saingam, All Science Journal Classification (ASJC) codes.

- Damage Concentration Effect of Multi-storey Buckling-Restrained Braced Frames Hanqin Wang, Advances in Civil Engineering / 2019

- Ashwini S Gudur1 Prof. H S Vidyadhar2: Dynamic Wind Analysis of Tall Building Provided with Steel Bracing as Per Proposed Draft for Indian Wind Code and Effect of Soft Storey (Part 2)

- Inel M., Özmen H.B., Bilgin H., Re-Evaluation of Building Damage During Recent Earthquakes in Turkey, *Engineering Structures*, Vol.30, No.2, (412-427), 2008

- Inel M. And Ozmen H., Effects of Plastic Hinge Properties in Nonlinear Analysis of Reinforced Concrete Buildings, *Engineering Structures* Vol.28(1494-1502), 2006

- Athanassiadou C.J., Seismic Performance of Rcc Plane Frames Irregular in Elevation *EngineeringStructures*,Doi:10.1016/J.Engstruct.2007.07.015, 2007

- Ruiz E. And Diederich R., The Mexico Earthquake of September 19, 1985 –The Seismic Performance of Buildings with Weak First Story, *Earthquake Spectra* Vol.5 No:1 1989

- Esteva L., Nonlinear Seismic Response of Soft First Story Buildings Subjected to Narrow Band Accelograms, *10th World Conference of Earthquake Engineering*, Rotterdam, 1992.

- Chang S. And Kim. S. Structural Behaviour of Soft-Story Buildings, *National Earthquake Engineering Congress*, (449-459), 1994.89

- Chopra A., Clough D.P. And Clough R.W., Earthquake Resistance of Buildings with A Soft First Story, *Earthquake Engineering and Structural Dynamics* Vol.1 (347-355), 1973.

- Mezzi M., Enhancing the Seismic Performance of Existing "Pilotis" Configurations, Case Study Report, 2006.

- Dr. Mizan Doğan Dr. Nevzat Kiraç Dr. Hasan Gönen "Soft-Story Behavior in an Earthquake and Samples of Izmit-Duzce" *Ecas 2002* Pp. 43-49

- **Dr. Saraswati Setia and Vineet Sharma "Seismic** Response of RCC Building with Soft Story" *International Journal of Applied Engineering Research, ISSN 0973-4562 Vol.7 No.11 (2012)*.

- Enhanced Seismic Structural Reliability on Reinforced Concrete Buildings by Using Buckling Restrained Braces, Hindawi Shock and Vibration, Article ID 8816552, 12 pages.

- Liang Li, Guoqiang Li, and Tianhua Zhou, "Experimental Study on the Seismic Behavior of a Steel-Concrete Hybrid Structure with Buckling Restrained Braces," Hindawi Advances in Civil Engineering Volume 2020, Article ID 9232138, 20 pages.

- Deepak VasantraoPatil and C. M. Deshmukh, "Comparative Study of Conventional Braces and Buckling Restrained Braces in Steel Frame Structure," International Journal of Engineering Research and Technology (IJERT), Vol. 8 Issue 11, November-2019.