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Performance of Eccentrically Braced Frames under the Action of Lateral Load

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Abstract: This paper presents a performance of eccentrically braced frame under the action of unexpected seismic event. To control the lateral displacements, initially researchers started experimental investigations on concentric braces to steel moment resisting frames. During severe earthquake, moment resisting frames undergo large lateral displacement and it requires special concentration to control lateral displacement and to limit the damage to non-structural elements. The concept of incorporating braces eccentrically attracted the interest of researchers and which behave excellent energy dissipation both in tension and compression in accepts of seismic performance seems to improve ductile strength in concern with shear or flexural yielding of a link element. This paper attempts to study the seismic performance of steel moment resisting frames with eccentric braces to target the lesser storey maximum displacement compared to the conventional braced system during undesirable earthquakes. In the previous research recommended that the influence of controlled yielding in the beams is not determined to EBF performance as long as stability of the beam is maintained. The provided EBF models were selected and investigated through three dimensional, linear analyses. Three steel framed structures (6 story, 9 story and 15 story) are designed as per IS 1893-2002 for calculating seismic loads by the equivalent lateral force procedure and their final performances of structure are evaluated through linear analysis using ETABS 2015.

Keywords: *steel moment resisting frame, eccentric brace, seismic performance, lateral displacement*

1. Introduction

An eccentric braced frame (EBF) has been considered as the primary source of energy dissipation under the severe seismic event. When such steel braced frames experiences large axial force, bending moments are produced outside of the beam link. In general, capacity design principles involved to maintain the stability of beam is to be remain elastic under the seismic forces and attained fully yielded and strain hardened links. A past experimental research from the 80s observed that introducing braced frames on steel structures which governs enhanced strength as well prime source of energy dissipation to control the severe damages under major earthquakes. Experimental evaluation was reported from the University of California at Berkeley and the National Taiwan University which stated that limited yielding outside the link may not cause any severe effects on EBF behavior. The comprehensive assessment study was carried out by Chen and Mahin [2] on performance based seismic demand of 2-, 3-, 5-, and 16- story special concentrically frames that were designed based on ASCE7-05[3].

In this paper, we present a study to reveal seismic loading patterns on the braced frames and discuss the impacts of yielding beams on critical components such as braces and connections. The realistic seismic response loading patterns on weak and strong beams can be examined. In the following, three steel framed buildings with 6, 9 and 15 storeys are designed as per IS 1893-2002; the consequent discussions allows for assessing the performance of steel braced frames structures.

2. Literature Review

Gul Yigitsoy et al reported that the stability of beams in steel eccentrically braced frames when subjected to severe seismic event introduced large axial force and bending moment in the beam outside the link [1]. It is formed that controlled yielding in the beams is not detrimental to EBF performance as long as stability of beam is maintained. A total of 51 EBF sub assemblage models were analyzed in the computational study carried out by them which did not satisfy capacity based design requirements. The results indicate that the link over strength factor should be a function of link length for performing capacity based design of beam outside of the link. This is because flexure yielding links, which are problematic to beam stability, tend to develop smaller over strength compared to shear yielding link.

Chen C-H, Mahin SA (2012) performed evaluation of seismic design parameters for 2,3,6,12 and 16 storey steel braced frames which demonstrated that short period braced frame system had higher probabilities of collapse than longer period braced framed system.

Jay Shen et al in their paper reported the study of braced intersected beams in two-storey X-braced frames. They did dynamic analysis to determine the actual mechanisms and impact of a yielding beam on non-structural components such as braces and connections. As a results yielding of such brace-intersected frames further increases inelastic deformation of the beam. Vertical inelastic displacement at the mid span of beam causes predominant ductility demand on braces, gusset plates and beam to column connections are not involved in current design practice. This was found helpful in the redistribution of the total input energy demand.

Gary S et al studied the performance and economy aspects of EBF. Eccentric braced frames have few limitations such as links to column connections are required so to counteract this effect of eccentric braced frames. The analytical study was carried out, as the results are obtained from the non-linear time history analyses which indicate residual drifts in EBF.

3. Seismic study on SMRF

3.1. Selection of Structures

A typical office building with 6, 9 and 15 stories respectively as shown in Figs. 1 and 2 are selected for the study. The study involves special concentrically braced frame (SCBF), eccentrically braced frames (EBF) incorporating with chevron braces in alternating stories. To resist seismic force bracings in both orthogonal directions are arranged on the perimeter of the building. The floor system consists of a 120mm thick concrete slab cast in situ place concrete. Dead and live loads of $4kN/m^2$and $2.50kN/m^2$respectively were considered in the design. It is assumed to locate the buildings at hard soil category and falls under the category of zone –IV as per IS 1893-2002.

3.1.1. Structural model of the frames parameters

The three buildings symmetric plan dimensions of 47.5mx47.5m with storey height of 3.5m are to be considered in the design and evaluation. The structure has 5 bays at 9.5m in each direction of buildings. Seismic weights for the 6-, 9-, and 15- storey buildings as computed as per IS 1893-2002 are 107539.131kN, 235890 kN and 628916.751 kN respectively. The beams and columns are steel wide flange sections with specific yielding strength, F_Y = 250 MPa and the braces of steel angle sections are chosen.

4. Seismic Performance of Braced System

4.1. Modeling and Analysis

The seismic performance was evaluated by linear analysis using ETABS 2015 V.15 software. Beams and columns are modeled as standard frame elements. Then the braced frames of SCBF and EBF elements are chosen with respect to Indian standard angle section. Frame properties of column ISHB 450, beam ISMB 400 and ISMB 225 are chosen respectively for modeling and design. Similar configuration is used for 9 and 15 storey structure also.

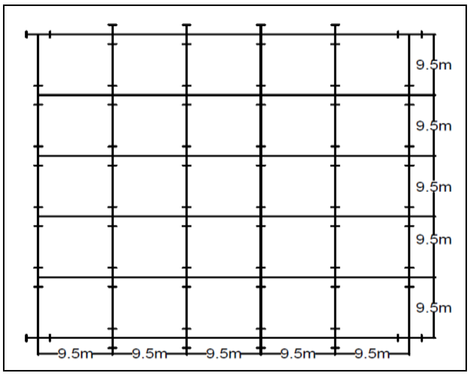

Figure 1 *Plan of the building*

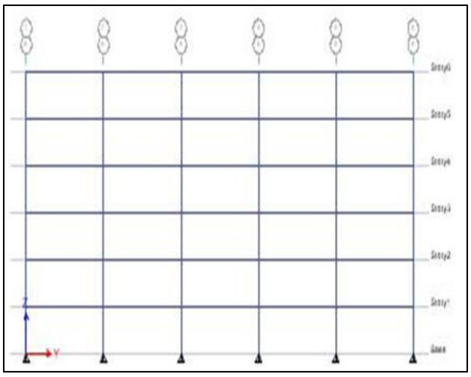

Figure 2 *6 storey plane frame (without bracing)*

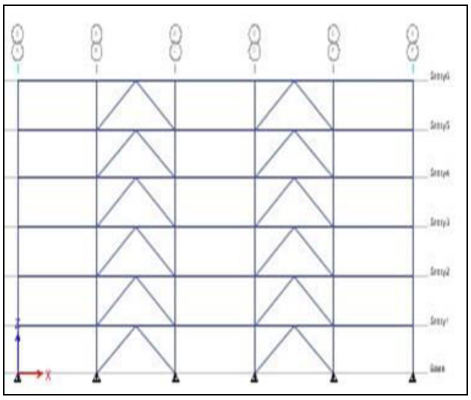

Figure 3 *6 storey concentric braced frame*

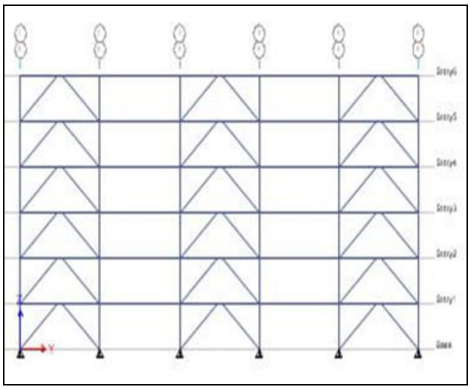

Figure 4 *6 storey eccentric braced frame*

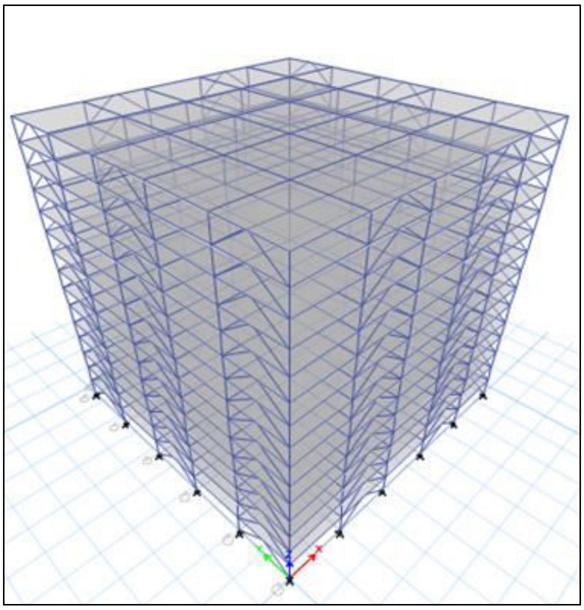

***Figure 5** 3D view of the building*

***Table 1:** 6 storey lateral load distribution as per IS1893-2002*

Storey Level	Height in mm	Plane frame	Concentric braced frame	Eccentric braced frame
6	2100	2240.90	2489.88	2240.897
5	1750	1913.12	2125.69	1913.118
4	1400	1255.30	1361.44	1225.299
3	1050	689.11	765.678	689.109
2	750	306.48	340.540	306.486
1	350	76.13	84.59	76.137
Total		6481.04	7167.818	6451.046

***Table 2**-9 storey lateral load distribution as per IS 1893-2002*

Storey Level	Height in mm	Plane frame	Concentric braced frame	Eccentric braced frame
9	3150	4710.08	4186.745	3766.778
8	2800	3917.33	3482.076	3132.794
7	2450	2999.05	2665.821	2398.416
6	2100	2202.85	1958.094	1761.681
5	1750	1528.76	1358.896	1222.587
4	1400	978.47	869.754	782.511
3	1050	550.28	489.141	440.076
2	750	244.19	217.056	195.283
1	350	61.21	54.407	48.9502
Total		17192.22	15281.99	13749.08

***Table 3**-15 storey lateral load distribution as per IS 1893-2002*

Storey Level	Height in mm	Plane frame	Concentric braced frame	Eccentric braced frame
15	5250	4771.16	4236.182	3810.380
14	4900	4383.64	3892.114	3500.896
13	4550	3779.00	3355.271	3018.014
12	4200	3221.09	2859.911	2572.445
11	3850	2707.14	2403.593	2161.99
10	3500	2237.17	1986.320	1786.664
9	3150	1811.17	1608.089	1446.451
8	2800	1431.89	1271.342	1143.553
7	2450	1093.85	971.198	873.577
6	2100	805.27	714.977	643.111
5	1750	557.92	495.359	445.568
4	1400	357.29	317.225	285.339
3	1050	201.34	178.768	160.799
2	750	89.51	79.477	71.4885
1	350	22.38	19.868	17.871
Total		27469.82	24389.69	21398.15

Tables 1 to 3 gives the lateral loads due to earthquake as computed using IS 1893-2002 for the three structures considered. The addition of bracing is likely to make the structure stiffer and hence the period is likely to come down from the values computed from the code given expression. In case of six and nine storey structures S_a/g value is the maximum and hence the lateral force is not likely to change for the lower period. But in case of fifteen storey structure the S_a/g value is found to be 1.458 which is likely to go up if the natural period from dynamic analysis is used. However in this paper the time period is computed as per IS 1893-2002 and the results are compared.

4. Conclusions

The seismic performance of 6 storey, 9 storey and 15 storey structure incorporated with specially concentrated braced frame (SCBF) and eccentric braced frame (EBF) are evaluated by linear analyses. The seismic performance is evaluated in terms of maximum storey displacement. This paper plans to assess the performance level of structure without bracing, with incorporating brace SCBF and EBF in alternative bays respectively. Mainly bracing which governs the seismic load (i.e. lateral action), so that the beam column connections were assumed to be pinned connection. The results of this study can be summarized as follows

(1) It has been observed that the performances of building 6 storeys, 9 storeys and 15 storeys without bracing system were subjected to lateral load results in higher maximum storey displacement.

(2) To control the effect of such maximum storey displacement, specially concentrated braced frames are incorporated in alternative bays to achieve the functional requirement under the seismic loads which results in the better than the structure without bracing system.

(3) Further to enhance the structural integrity and resistance with respect to lateral loads, eccentric braced frames were incorporated to target the lesser maximum storey displacement compared to the conventional braced system.

(4) From the study it has been observed that the number of bracing bays and height of building have greater effect on the performance.

The following graphs are plotted storey height with displacement results of this study are enlisted below

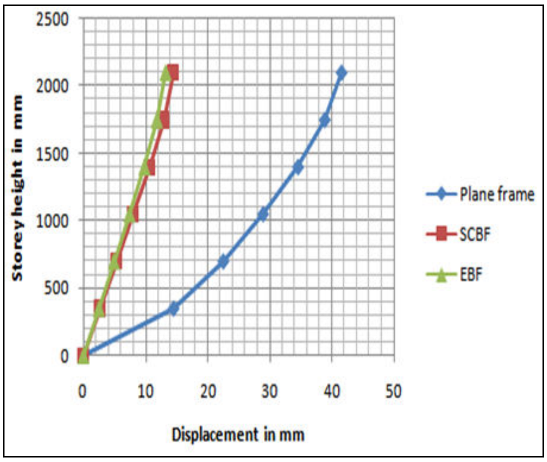

Figure 6 *6 storey maximum displacement*

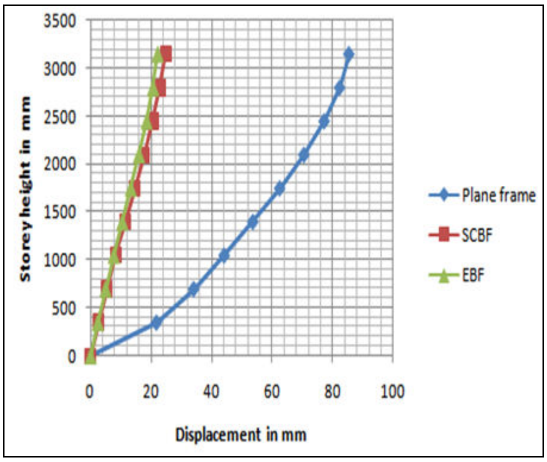

Figure 7 *9 storey maximum displacement*

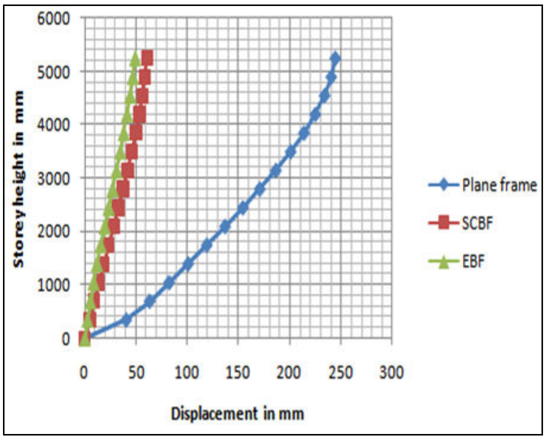

Figure 8 *15 storey maximum displacement*

References

[1] Gul Yigitsoy, Cem Topkaya, Taichiro Okazaki., "Stability of beams in steel eccentrically braced frames", Journal of Constructional Steel Research., vol (96)-May2014, CD01 pp14-25.

[2] Chen C-H, Mahin SA., "Performance Based Seismic Demand Assessment of concentrically Braced Steel Frame Buildings", PEER Report 2012/103, University of California, Berkeley, Dec2012.

[3] S.U. Maniyar, D.K. Paul., "Enhancement of seismic performance using shear link braces in a building designed only for gravity loads", Journal of Institute of Engineering., Ser. A (Feburary-April2012) 93(1):27-43.

[4] Mussa Mahmoudi, Mahdi zaree, "Evaluating response modification factors of concentrically braced frames", Journal of Constructional Steel Research 66 (2010) 1196-1204.

[5] Moghaddam H, Hajirasouliha I, Doostan A. "Optimum seismic design of concentrically braced steel frames", concepts and design procedures. Journal of Constructional Steel Research 2005; 61(2):151-66.

[6] Sabelli R., "Research on improving the design and analysis of earthquake resistant steel braced frames". Final report NEHRP Fellowship in Earthquake Hazard Reduction; 2000.

[7] Federal Emergency Management Agency. FEMA. "Next-generation performance-based seismic design guidelines program plan for new and existing buildings", FEMA-445. Washington (DC); 2006.

[8] Housner G., "Limit design of structures to resist earthquakes", In: Proceedings of the first world conference on earthquake engineering. 1956.

[9] Lee SS, Goel SC., "Performance-based design of steel moment frames using target drift and yield mechanism", Report no. UMCEE 01-17; MI: University of Michigan at Ann Arbor; 2001.

[10] Chao SH, Goel SC., "Performance-based design of eccentrically braced frames using target drift and yield mechanism", AISC Eng J 2006; 173_200. 3rd Quarter.

[11] Chao SH, Goel SC., "Performance-based plastic design of special truss moment frames", AISC Eng J 2008; 127_50. 2nd Quarter.

[12] Goel SC, Chao SH., "Performance-based plastic design earthquake resistant steel structures", International Code Council; 2008. p. 261.

[13] Chao SH, Goel SC, Lee SS., "A seismic design lateral force distribution based on inelastic state of structures", Earth Spectra 2007; 23(5):547_69.

[14] AISC, ANSI/AISC 341-05. "Seismic provisions for structural steel buildings".

[15] Gupta A, Krawinkler H., "Prediction of seismic demands for SMRFs with ductile connections and elements", Report no. SAC/BD-99/06. Sacramento (CA): SAC Joint Venture; 1999.

[16] Building Seismic Safety Council. BSSC, “National earthquake hazard reduction program (NEHRP) recommended provisions for seismic regulations for new buildings and other structures part 2: commentary”, FEMA 450-1.
[17] Richards PW., “Seismic column demand in ductile braced frames”, Journal of Structural Engineering 2009; 135(1):33_41.
[18] Thornton W, Muir LS. Design of vertical bracing connections for high-seismic drift. Modern Steel Construction; March 2009.
[19] Malley JO, Popov EP, Shear links in eccentrically braced frames. Journal of structural Engineering 1984; 110(9):2275-95.
[20] Engelhardt MD, Tsai KC, Popov EP, “Stability of beams in eccentrically braced frames”, In: Fukumoto, Lee, editors. Stability and ductility of steel structures; 1992.p.99-112.
[21] ASCE 7-05. Minimum Design loads for buildings and other structures, ASCE 7-05. Viriginia: American society of civil Engineers; 2005.