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COMPARISON BETWEEN CONCENTRIC BRACING FRAME AND ECCENTRIC BRACING FRAME IN EARTHQUAKE-RESISTANT HIGH-RISE BUILDINGS

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ABSTRACT

Earthquake is a natural disaster that often occurs in Indonesia, so buildings must be designed according to earthquake regulations SNI 1726:2019 Seismic. The height of the building is based on the maximum limit according to SNI 1726:2012 table 9 and article 7.2.5.4. Based on these limitations, a size of 12 floors (48 meters) and eight floors (45.9 meters) in this study. Previous research has shown that ground motions were evaluated using the response-based damage model proposed by (Karsaz & Razavi Tosee, 2018). Then, the structures were rehabilitated with different bracing systems (eccentric and concentric inverted-V) and, again, their damage under earthquakes was evaluated and compared with those of moment resisting frames. The pushover analysis results while mid and high-rise buildings with Lateral shear force CBF is 0.91 %, whereas EBF is 2.77 %, compared to MRF. Therefore, CBF has a higher elastic stiffness than EBF. The bracing increases displacements for CBF by 70 % and EBF by 77% compared to MRF because EBF bracing decreases the displacements of the structural floors considerably; therefore, it can be said that the EBF bracings provide more lateral hardness for steel structures in comparison to the CBF bracings. The maximum inter-story drift CBF is 85%, while EBF is 86% for e = 0.50 m. Therefore, EBF is more malleable than CBF; the weight difference is 1.530%for CBF and 3.20 %for EBF compared to MRF. Therefore, EBF has a higher weight than CBF, the weight of the intended frames. There is little difference in the importance of the planned structures but the difference between their seismic performances under nonlinear static and dynamic. Using response-based damage models could be suitable for estimating the vulnerability of steel structures rehabilitated with a bracing system.

***Keywords**: Comparison, (CBF)Concentric Bracing Frame, (EBF) Eccentric Bracing Frames, Earthquake Resistant*

1. INTRODUCTION

Indonesia is in an area prone to natural disasters, namely earthquakes [1]. An earthquake occurs when a movement is caused by the earth's plates, which appear at the base of the earth's crust, which collides side rubs together to produce energy intensity that causes vibrations on the earth's surface. The vibrations cause buildings above the ground to collapse; as a ret, the vibrations generated by the earthquake cannot be held by the structure [2], [3].

On Saturday, 10th April 2021, had devastating earthquake occurred at 07:00:02 UTC with a moment magnitude (Mw) updated 6.1; the earthquake epicentre was located at 8.83 °S - 112.50 °E at the southern part of Java Island at a depth of 80 km. Meteorological Climatological and Geophysics Agency have committed to developing earthquake ground motions accelerometer sensors in Indonesia since 2004. This report presents characteristics of ground motion records of East Java related to the potential damage area close to the epicentre using ground motion records that the Indonesia National Strong Motion Network has detected. Over 50 accelerometer sensors had seen during that earthquake at the epicentre distance of less than 1000 km. GEJI accelerometer station is located closest to the earthquake source, with an epicentre distance of 64.4 km to the epicentre. As an early report following SNI 1710-2019 GEJI accelerometer station, as classified soil class D, showed the maximum peak ground acceleration of the GEJI accelerometer station is 223.08 gals and a full spectral acceleration of 642.5 gals at 0.2 seconds. It has estimated impact ground shaking V-VI MMI. Three accelerometers with a large motion with a PGA of more than 100gals have been identified; they showed that the horizontal shaking is larger than the vertical at the PGA, short-period Ss and long-period spectra S1. It is associated with the directional wave that led to the most dominant peak direction, horizontal E-W. While we compared the spectra from the GEJI site to SNI (Indonesia National Standard) design, it showed well proportion between them, which means that the spectral accelerometer at a short period Ss still has a width range from SNI 1726-2019 design. All strong motion records data attenuate with distance at a rate generally consistent with modified next-generation attenuation (NGA) from the Zhao equation[4].

Damage to buildings from earthquakes is because the building has a quality and very low seismic resistance, so it is done by a collision between the Indian-Australian plate and susceptibility to earthquake and hazard mitigation due to earthquakes of all kinds of buildings in that area have a high seismic distribution zone. The building materials must be good and quality; people Must understand the basics of testing building materials; the hound sees that they are resistant to earthquakes and tsunamis. Houses stat built as one unified whole foundation, columns, and walls so that the parts of the building cannot be separated when earthquakes and tsunamis occur [5], [6].

Research conducted by Khan et al. (2015) entitled "Effect Of Concentric And Eccentric Type Of Bracings On " shows that 1) multilevel drift compared to the X bracing model was found to provide better results for the direction linear static analysis when compared to other models, 2) support is better for both linear and nonlinear static analysis, 4) concentric inverted V amplifier model better value for graded drift when compared to other models rendering to be better than the rest of the models [7].

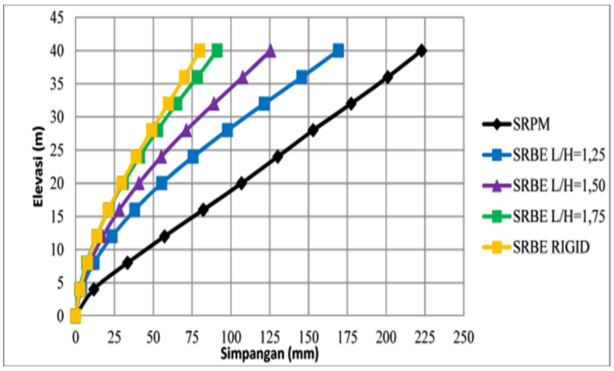

Figure 1. Deviation Between Floors

Source:[8]

Based on SNI 1726:2019 article 7.3.3, there are various kinds of earthquake-resisting systems, including the building frame system (single system). One of the developments in earthquake-resistant structural technology is stiffeners or bracing [9]. This stiffener aims to reduce the impact of lateral forces caused by earthquake forces. Currently, there are 3 (three) earthquake-resistant steel structure systems known, namely the Moment Resisting Frame System (SRPM), the Concentric Bracing Frame System (SRBC), and the Eccentric Bracing Frame System (SRBE) [10], [11].

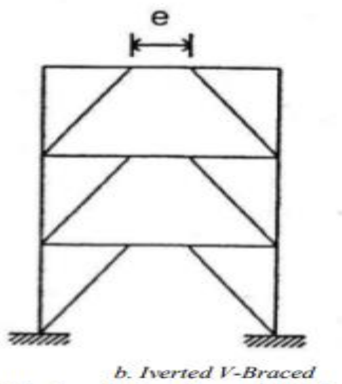

Figure 2. Eccentric bracing Frame Structures Linke 50cm

Source: [12]

The concentric bracing frame system (SRBC) has quite good rigidity with the presence of stiffeners. This system is lacking in energy absorption because the inelastic capacity of the bracing elements is considered to be lacking. The deficiency in the SRBK system in receiving lateral loads was overcome by the advent of the eccentrically bracing frame system (SRBE).

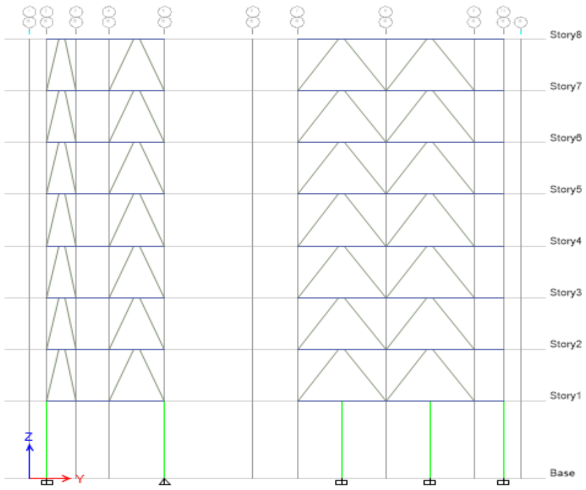

Figure 3. Ecconcentric bracing frame (50cm)

Furthermore, while bracing reduces bending moment and shear forces in columns, bracing increases axial compression in columns connected to them. The eccentric reinforcement reduces the lateral stiffness of the system and increases the energy dissipation capacity. Due to the abnormal connection of the braces to the beam, the plan's lateral stiffness depends on the shaft's bending stiffness. The vertical component of the earthquake-induced bracing forces causes the load to be concentrated laterally on the beam at the eccentric brace connection point [13].

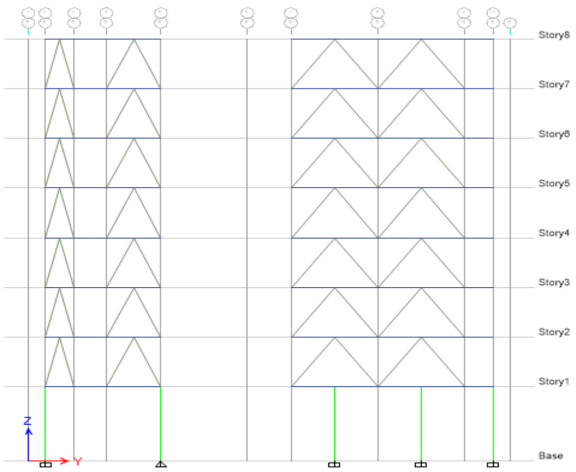

Figure 4. Concentric bracing frame

Brewing is a technology that can reduce eccentricity and increase building stability. This shows that eccentric-type bracing is better used in buildings that experience more dominant seismic forces, while concentric bracing is better used in wind loads [14].

This then prompted the researcher to analyze the position of the two braces in the earthquake-loaded building. The difference is in the working force; in previous research, the working load was wind load, but in this study, the working load was earthquake force. The study also stated that eccentric bracing is more suitable for use in areas where earthquake loads dominate rather than wind loads. Eccentric braces are more flexible than concentric braces [15].

Based on the formulation of the problem above, the objectives of this study are as follows:

1. We analyze the lateral forces in every story concentric and eccentric bracing frames.
2. We are analyzing the displacements for every story for the concentric and eccentric bracing frames.
3. Analyzing the many stories drift of concentric bracing frame eccentric bracing frame.
4. Describe the comparison between the concentric bracing frame and the eccentric bracing frame.

In carrying out structural analysis, this thesis research refers to regulations recognized in Indonesia.

2. METODE

Modelling and Analysis of Unrestricted Structures To determine the number of internal forces that arise in structural elements using the ETABS Structural Analysis Professional 2020 auxiliary program. These internal forces include shear forces, axial forces, bending moments, and twisting moments. In addition, it is also used to determine the shift between levels (story displacement).

3. RESULTS AND DISCUSSION

Earthquake Parameters According to SNI1726- 2019.

1. Building Structure Risk Category

The type of utilization of the building strongly influences the category of building risk. And the AC Polinema building is intended for educational building facilities, so the structure is included in risk category IV. And from the earthquake risk category IV, we get an earthquake priority factor (Ie) of 1.5

2. Site Class Classification

From the data, the land in the building site in the Malang area shows that the site classification for the land includes medium soil (SD).

Table 1. Site Class Classification

Site Class Classification = SD

Variable	Mark	Variable	Mark	Variable	Mark
PGA (g)	0.3997	FPGA	1.104	PSA	0.441
SS(g)	0.865	FA	1.154	SDS	0.67
S1(g)	0.4044	FV	1.8956	SD1(g)	0.51
CRS	0.96	SMS	0.9982 1	T0	0.15
CR1	0.93	SM1	0.581	Ts	0.76

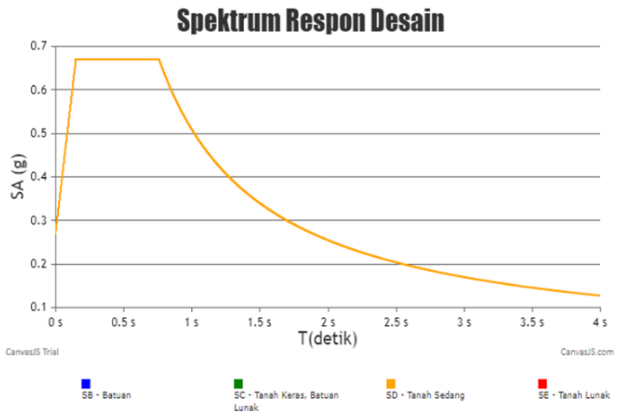

Figure 5. Design response spectrum

3. Site coefficient factor (Fa, Fv).

Table about Site Coefficient Fv Maximum earthquake acceleration spectral response parameter considered risk-targeted (MCER) mapped on short periods, T = 1 second, S1 . which also corresponds to found that the site coefficient Fa = 1.12 and Fv = 1.895.

4. Earthquake Design Category, KDS

The earthquake design category depends on the short-period design spectral acceleration (SDS) as well as on the 1-second period (SD1), which are presented in the following table: earthquake Design Categories Based on Acceleration Response Parameters in Short Periods With SDS =0.63433 and for SD1 = 0.511, it can be concluded that the design category used is earthquake design category D. So, from the earthquake design category D, the level of earthquake risk is in the high class, so special earthquake-resistant structures must be planned.

5. Central Period (T):

The structural form of the AC Polinema building has eight floors and a semi-basement; according to SNI 1726-2019, T < 3.5 Ts and uses the equation Due to the high risk of seismicity (in the earthquake design category D), the earthquake-resistant structure uses a Steel Frame and Composite Concrete System with Moment resisting steel frame. So, we get the factor R = 8, Ωo = 3 and Cd = 5.5

a. Comparison Story Forces between MRF, CBF and EBF

Comparison Story Forces between MRF, CBF and EBF:

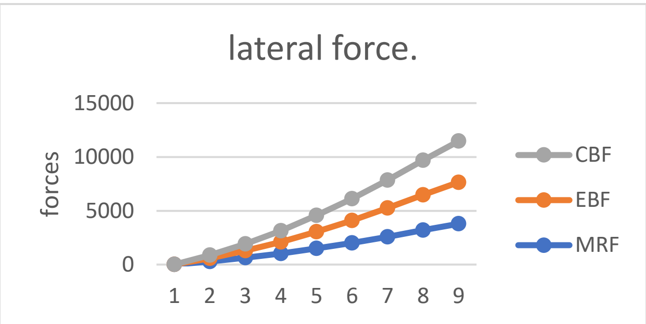

Figure 6. Story Forces between MRF, CBF and EBF

The Figure shows that CBF has greater strength to resist seismic forces than other models (EBF and MRF). The ultimate shear power for CBF is 195672 kg. The percentage of shear energy increased by about 94.0% for CBF compared to MRF. While EBF with link length e = 0.4 m can resist the shear pressure 195597 kg greater than the other link length. It is about 55.0%% for EBF with e = 0.4 m compared to MRF. It can be concluded that the shear force is increasing with the increase of link length. The CBF's increase in shear force resistance is 92%, whereas EBF is 91%, compared to MRF. Therefore, CBF has a higher elastic stiffness than EBF, with the same result for Tanijaya. CBF has greater strength to resist seismic forces than other models (EBF and MRF). The ultimate shear power for CBF is 234210.48 kg. The percentage of shear energy increased by about 74.0% for CBF compared to MRF. While EBF with link length e = 1.0 m can resist the shear pressure 126438.58 kg greater than the other link length. It is higher at about 52.0% for EBF with e = 1.0 m than MRF. It can be concluded that the shear force is increasing with the increase of link length.[16].

b. Comparison Maximum Story Displacement between MRF, CBF and EBF

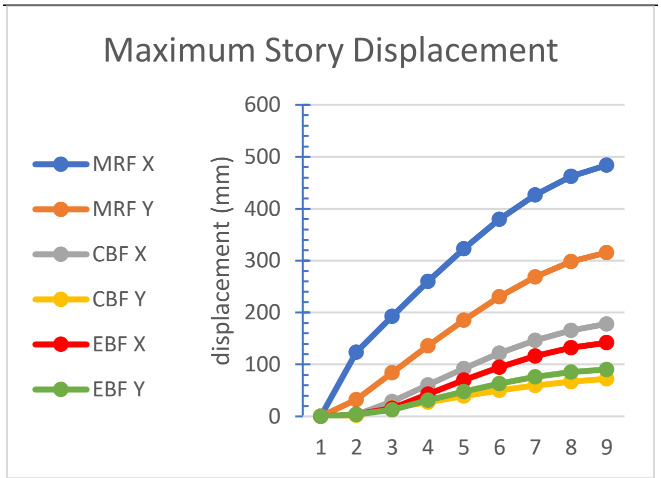

Figure 7. Comparison Maximum Displacement between MRF, CBF and EBF

It's important to note that the actual maximum story displacement MRF relies on the bending capacity of columns and beams and can exhibit higher story drifts than bracing frames. However, MRF may experience larger story displacements in severe earthquakes than bracing structures due to the potential for beam plastic hinges and post-yield deformations. CBF may experience significant deformation during strong earthquakes, leading to damage and the potential need for repair or replacement of the brace.

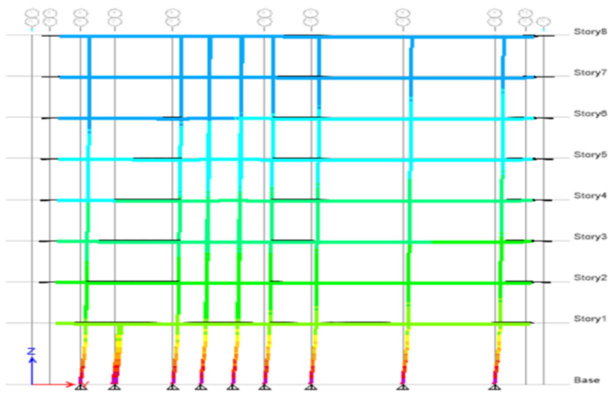

Figure 8. Maximum Story Displacement CBF

MRF Proper design practices can provide sufficient stiffness and strength to limit story drifts within acceptable limits. The eccentricity of the braces allows controlled yielding and energy dissipation. The diagonal braces in CBF provide stiffness and strength to resist lateral forces, limiting the overall building drift. EBF This characteristic helps determine the maximum story displacement by absorbing and dissipating seismic energy. Due to their efficient load path, CBF can effectively distribute forces and reduce story displacements. EBF is designed to provide enhanced flexibility and energy dissipation compared to CBF. and EBF generally has lower maximum story displacements compared to MRF and CBF. This aligns with Karsaz & Razavi Tose's (2018) research. on average, inverted-V bracing systems showed the highest effect on the seismic behaviour of the rehabilitated 15-storey structure, where the improvement rate was 96%. The next top-ranking systems were concentric V and concentric inverted-V, which improved the seismic behaviour of 15-storey structures by 92% and 88%, respectively.

c. Comparison Maximum Story Drift between MRF, CBF and EBF:

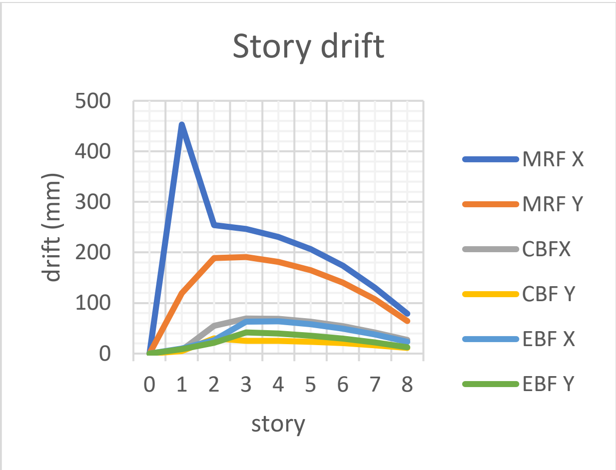

Figure 4.18 Comparison Maximum Drift between MRF, CBF and EBF

Based on the graph above, it can be concluded that the deviation between floors in MRF (without bracing) exceeds the permitted limit. It is observed that this research building must be given a stiffener structure so that the deviation between floors does not exceed the permissible limit so that this building is shown a stiffener structure, as in CBF or bracing. Models CBF and EBF are eligible for the deviation between floors because they do not exceed the permissible limit. The inter story drift in Model CBF is smaller than in EBF drift CBF 85% while for EBF is 86% for e = 0.50 m Therefore, EBF is more ductile than CBF. This result proves that Model CBF is more robust and stiffer than EBF the maximum relative deformations between stories are one of the parameters to distinguish the creation of

d. Calculation of Building Weight

Below is a table about building weight:

Table 2. Building Weight

Bracing	Weight kN	Weight Kg	weight %
MRF	174179.8	17762859	100 %
CBF	176845.3137	18034685.09	101.5 %
EBF	179752.60	18331170.23	103.20 %

This study compares the results of the analysis and design of multi-story steel frames with different bracing systems in terms of their steel weights ETABS software allows the member grouping and selects the required steel sections for beams, columns and bracing members from a set of standard steel sections in consequence of the structure. The difference in weight and the effect of considering P-Delta noniterative based on mass is so small that it can be ignored. Therefore, the P-Delta effect is not considered in this study's analysis of the frames.

When different bracing sections are used, the building weights are approximately the same (Table 4.32), changing. The weights of bracings are generally the controlling factor for the total weight of structures. The percentage difference in weight between the maximum differences between CBF and EBF bracing weights the percentage difference between 101.5 and 103.20 per cent. At the same time, the weight of steel profiles for bracings is changing[18]. The weights of bracings are generally the controlling factor for the total weight of structures. The percentage difference between the CBF and EBF overall total weights is 101.5, 103.2 and per cent, respectively. It is also worth mentioning the differences between CBF and EBF brace weights of all four steel profiles in the percentage difference in brace weights—unfortunately, some of the steel frames with stress. The biggest change in weight in both cases is for the 8th-story building.

4. CONCLUSION

The following are the conclusions that can be drawn from alternative structural planning.

1. Shear Lateral force for CBF is 0.91 %, whereas EBF is 2.77 %, compared to MRF. Therefore, CBF has a higher elastic stiffness than EBF.
2. Maximum displacements the bracing increases displacements for CBF by 70 % and EBF by 77% compared to MRF because EBF bracing decreases the displacements of the structural floors considerably. Therefore, the EBF bracings provide more lateral hardness for steel structures than the CBF bracings.
3. Drift should meet the limit requirements based on the used lateral resisting element. MRF's inter-the maximum story drift results are 453.035 mm, CBF is 69.416mm, and EBF is 63.803mm. The ultimate inter-story implication CBF is 85%, while EBF is 86% for e = 0.50 m. Therefore, EBF is more pliable than CBF.
4. The weight difference is 1.530%for CBF and 3.20 %for EBF compared to MRF. Therefore, EBF has a higher weight than CBF. The weights of the intended frames There is little difference in the weight of the planned structures but the difference between their seismic performances under nonlinear static and dynamic.

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