

OPTIMIZATION OF LINK LENGTH AND PLACEMENT OF ECCENTRICALLY BRACED FRAME (EBF) TO ENHANCE STRUCTURAL RESPONSE IN A 12-STORY STEEL BUILDING

Muhammad Indra Setiadi ⁽¹⁾, Ade Yuniati Pratiwi ⁽²⁾

⁽¹⁾ Mahasiswa Program Studi Teknik Sipil Universitas Lambung Mangkurat

⁽²⁾ Dosen Pengajar, Program Studi Teknik Sipil Universitas Lambung Mangkurat

Komp. Benawa Raya, Jl. Madinah blok 0 Rt 46 Rw 03 Banjarbaru, Kalimantan Selatan – 70721

Email: indrasetiadi778@gmail.com ⁽¹⁾; ade.pratiwi@ulm.ac.id ⁽²⁾

ABSTRACT

Seismic-resistant building design is essential in regions like South Kalimantan, which are prone to earthquakes and dominated by soft soil conditions. The Eccentrically Braced Frame (EBF) system offers an effective structural solution due to its high stiffness and ductility through controlled plastic deformation in the link element. However, the performance of this system is highly influenced by the link length and the placement of the bracing. This study aims to optimize the link length and the placement of eccentric bracing to improve the structural performance of a 12-story steel building under seismic loading. Numerical simulations were conducted using SAP2000 software by applying several EBF configurations to evaluate structural responses such as drift ratio, base shear, and element capacity checks based on SNI 1726:2019 and AISC 341-16 standards. The results show that variations in link length and bracing placement significantly affect structural behavior. Models utilizing short links and strategically placed bracing demonstrated lower drift and higher base shear values compared to structures without EBF. Therefore, optimizing EBF components proves to enhance both the resilience and efficiency of high-rise steel building design in seismic zones.

Keywords: *Eccentrically Braced Frame, Link Optimization, Structural Response, Steel Building.*

1. INTRODUCTION

The increase in the construction of multi-storey buildings in earthquake-prone areas such as South Kalimantan requires the design of structures that are efficient and resistant to lateral loads. Steel structures are the main choice due to their strength and flexibility, but require a lateral retaining system that is able to effectively dissipate earthquake energy. One of the widely used systems is the Eccentrically Braced Frame (EBF), which combines the rigidity of the Concentrically Braced Frame (CBF) and the ductility of the Moment Resisting Frame. In this system, plastic deformation is concentrated in the link element, so that earthquake energy can be absorbed without causing major damage to the main element (Kaffah, 2021).

Previous research has shown that variations in link length and bracing position have a significant effect on the performance of the structure. Short links are more efficient in energy dissipation, while strategic bracing placement can increase rigidity and decrease the deviation between floors (Deng et al., 2015; Nurkhaliza et al., 2021). Based on this, this study aims to analyze the influence of link length and eccentric bracing position on the structural response of a 12-storey steel building using SAP2000 software, with the aim of obtaining an optimal and efficient EBF configuration for buildings in seismic areas.

2. THEORITICAL STUDY

Eccentrically Braced Frame (EBF)

The *Eccentrically Braced Frame* (EBF) system is an effective solution to increase the resistance of buildings to lateral loads, especially in seismic conditions. With eccentrically mounted bracing elements, EBF allows plastic deformation of the *links* to efficiently distribute earthquake energy and reduce structural damage. Designs with *replaceable links* can minimize permanent damage (Lettieri, 2023), while the addition of eccentric *bracing* increases energy dissipation and rigidity, making them ideal for high-rise buildings (Kamanli & Ünal, 2017). Its application is also effective in reducing lateral displacement and shear forces between floors in earthquake-prone areas.

Link Beam

The behavior of the *link beam* in the EBF system is greatly influenced by the length of the element, which is generally differentiated into short links (dominating the shear force) and long links (dominating the bending moment). The boundaries on the link element are determined by the following equation:

$$M_p = Z_x \cdot f_y$$

$$V_p = 0.6 (h - 2f_y t_f) t_w$$

Where:

M_p = Cross-sectional plastic moment	h = Cross-sectional height
Z_x = Cross-sectional plastic modulus	t_f = Tebal flens
f_y = Cross-sectional melting stress	t_w = Web thickness
V_p = Cross-sectional plastic shear force	ϕ = bending reduction factor 0.9

Base Shear

The shear force of the seismic base, in the set direction should be determined according to the following equation: V

$$V = C_s W$$

Where: C_s = Seismic response coefficient

W = Effective seismic weight

Story Drift

To control the deviation between floors, SNI 1726:2019 provides a formula used in the calculation. The deviation of the center of mass at the level () (mm) corresponds to the following equation. δ_x

$$\delta_x = \frac{C_d \delta_{xe}}{I_e}$$

Where:

C_d = deflection implication factor

δ_{xe} = deviation at x-level in this article

I_e = determined earthquake priority factor

3. METHOD

General Data

Material data includes data from reinforced concrete for slabs and steel for column, beam, *bracing*, and *link* structures described as follows:

Concrete	$f_c' = 30$ MPa (for floor plates)
Steel Quality	BJ 41 (for beams, columns, joints and <i>bracing</i>)
Building Categories	Hospital
Soil Type	Soft Soil

Building Structure Modeling

The models analyzed include:

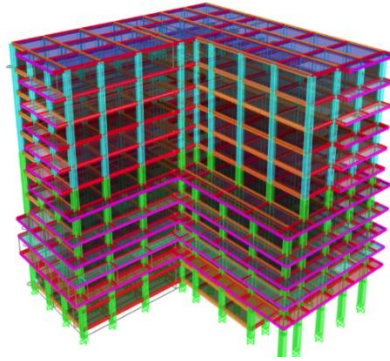


Figure 1. 3D Visible Building Structure

Capacity Check

Inspection of the cross-sectional capacity of the steel profile is a crucial aspect in structural engineering to ensure that structural elements are able to withstand loads without experiencing failure. This emphasizes the importance of selecting the right cross-sectional profile in the initial design process.

Link Length

Short links provide a better structural response than longer *links*. However, *intermediate links* are still used as a comparison to the performance of *short links*. *Links* that are too long tend to behave like blocks so that the mechanism of shear collapse is difficult to achieve, so *long links* were not used in this study.

Determination of Bracing Placement Position and Link Position Variation

Model Variation I

In this variation, it is focused on determining the response of the structure to the use of short and medium links to the building structure

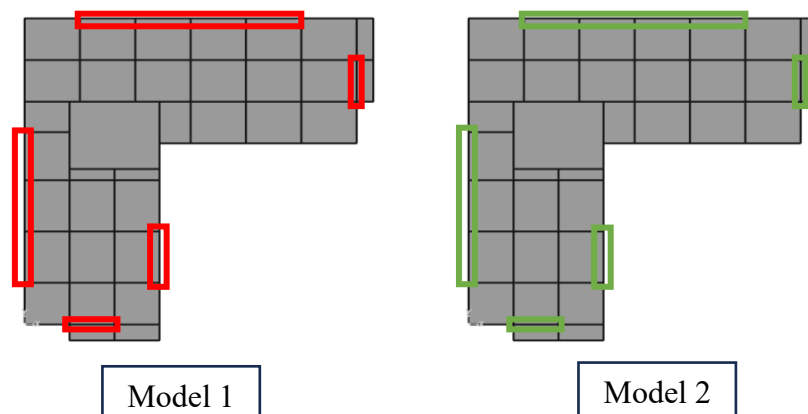


Figure 2. Placement of Position Variations

Where:

1. — short link
2. — intermediate link

Model Variasi II

In this variation, the purpose is to determine the response of the structure to the placement of bracing where the placement will be placed in the middle of the structural elements, edges, and a combination between the two.

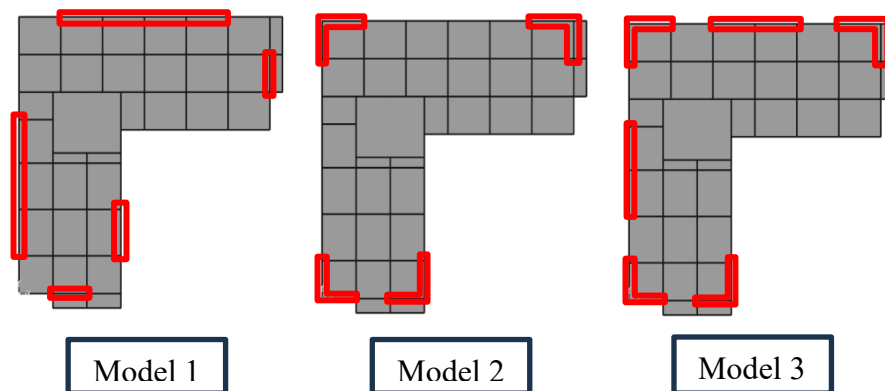


Figure 3. Placement of *Bracing Position Variations*

Where:

- 1) — short link

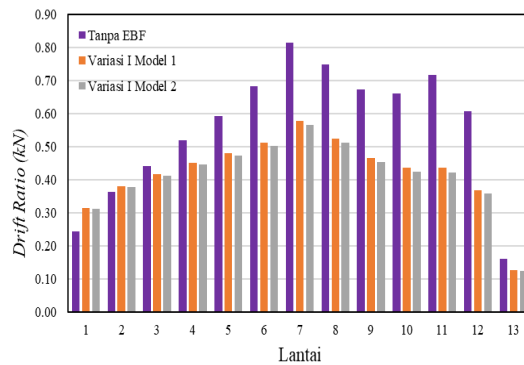
4. RESULT AND DISCUSSION

Story Drift Comparison Results

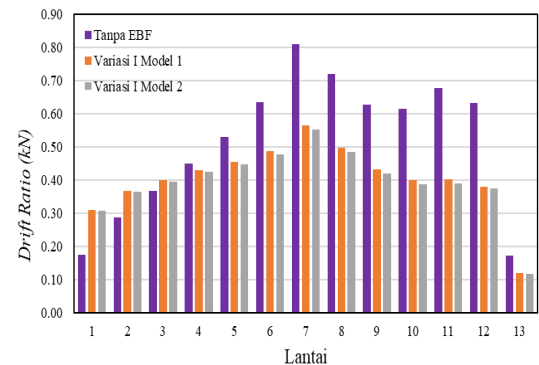
The analysis is carried out to obtain *story drift* due to the combination of loading that will be taken for maximum results. Based on structure models with variation I and variation II configurations.

Table 2. Results of *Drift Comparison Variation Ratio I*

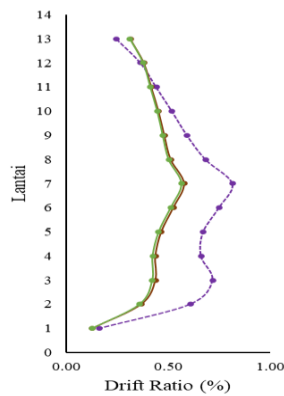
Without EBF		Variation I model 1		Variation I model 2		Variation Decrease I model 1		Variation Decrease I model 2	
Δ_x	Δ_y	Δ_x	Δ_y	Δ_x	Δ_y	Δ_x	Δ_y	Δ_x	Δ_y
%	%	%	%	%	%	%	%	%	%
0.24	0.17	0.31	0.31	0.31	0.31	-28.28	-78.25	-27.70	-77.06
0.36	0.29	0.38	0.37	0.38	0.37	-4.48	-1.27	-3.75	-27.39
0.44	0.37	0.42	0.40	0.41	0.39	5.51	9.38	6.44	-7.67
0.52	0.45	0.45	0.43	0.45	0.43	12.80	16.78	13.88	5.60
0.59	0.53	0.48	0.46	0.47	0.45	18.89	23.03	20.08	15.57
0.68	0.63	0.51	0.49	0.50	0.48	25.10	28.75	26.49	24.73
0.81	0.81	0.58	0.56	0.57	0.55	29.21	30.67	30.67	31.79
0.75	0.72	0.52	0.50	0.51	0.49	30.08	33.50	31.67	32.51
0.67	0.63	0.46	0.43	0.45	0.42	30.76	35.65	32.55	32.94
0.66	0.61	0.44	0.40	0.42	0.39	33.99	39.33	35.98	36.80
0.72	0.68	0.44	0.40	0.42	0.39	39.23	43.82	41.26	42.72
0.61	0.63	0.37	0.38	0.36	0.37	39.58	37.26	41.00	40.82
0.16	0.17	0.13	0.12	0.12	0.12	21.89	25.43	22.58	31.73



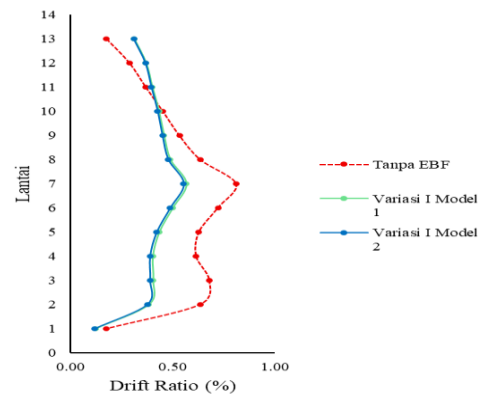
Drift Ratio Variation I Direction X



Drift Ratio Variation I Direction Y

Figure 5. Results of *Drift Ratio* Variation I Comparison

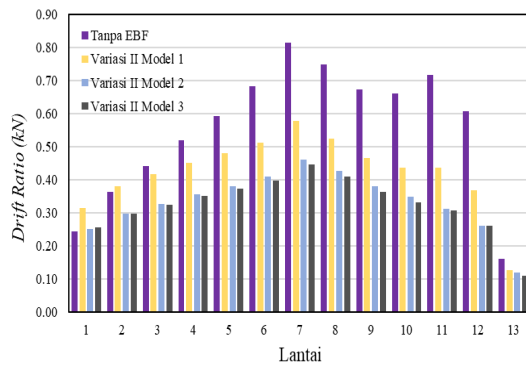
Drift Ratio Variation I Direction X



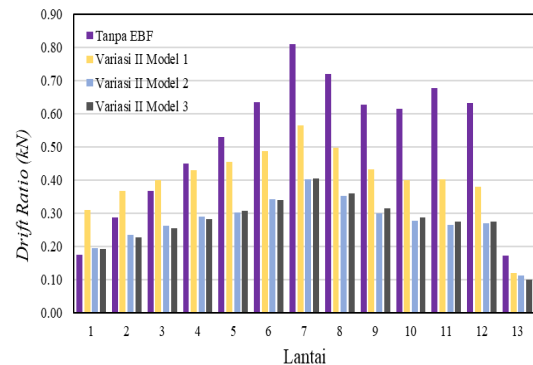
Drift Ratio Variation I Direction Y

Figure 6. Results of *Drift Ratio* Variation I ComparisonTable 3. Results of *Variation Drift Ratio II* Comparison

Tanpa EBF		Variasi II model 1		Variasi II model 2		Variasi II model 3		Penurunan Variasi II model 1		Penurunan Variasi II model 2		Penurunan Variasi II model 3	
Δx	Δy	Δx	Δy	Δx	Δy	Δx	Δy	Δx	Δy	Δx	Δy	Δx	Δy
%	%	%	%	%	%	%	%	%	%	%	%	%	%
0.24	0.17	0.31	0.31	0.25	0.20	0.25	0.19	-28.28	-78.25	-2.47	-12.29	-4.54	-10.82
0.36	0.29	0.38	0.37	0.30	0.23	0.30	0.23	-4.48	-28.26	18.37	18.20	18.26	20.34
0.44	0.37	0.42	0.40	0.33	0.26	0.32	0.25	5.51	-8.69	25.96	28.46	26.43	30.50
0.52	0.45	0.45	0.43	0.36	0.29	0.35	0.28	12.80	4.41	31.38	35.70	32.28	37.18
0.59	0.53	0.48	0.46	0.38	0.30	0.37	0.31	18.89	14.26	35.95	43.18	37.18	42.33
0.68	0.63	0.51	0.49	0.41	0.34	0.40	0.34	25.10	23.27	40.23	46.00	41.79	46.53
0.81	0.81	0.58	0.56	0.46	0.40	0.45	0.41	29.21	30.26	43.39	50.36	45.22	49.99
0.75	0.72	0.52	0.50	0.43	0.35	0.41	0.36	30.08	30.87	43.05	51.22	45.38	49.92
0.67	0.63	0.46	0.43	0.38	0.30	0.36	0.31	30.76	31.14	43.61	52.05	46.17	49.84
0.66	0.61	0.44	0.40	0.35	0.28	0.33	0.29	33.99	34.77	47.17	54.81	49.86	53.06
0.72	0.68	0.44	0.40	0.31	0.26	0.31	0.28	39.23	40.66	56.63	61.07	57.23	59.35
0.61	0.63	0.37	0.38	0.26	0.27	0.26	0.27	39.58	39.77	57.33	57.50	57.01	56.59
0.16	0.17	0.13	0.12	0.12	0.11	0.11	0.10	21.89	30.67	26.72	35.49	32.57	42.11

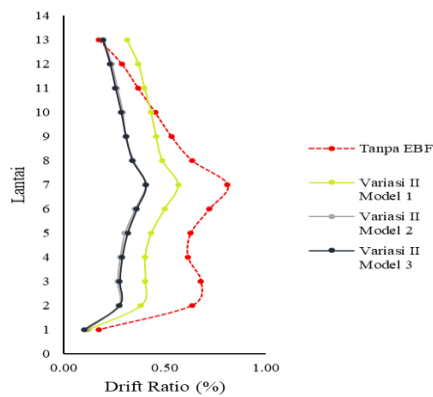


Drift Ratio Variation II Direction X

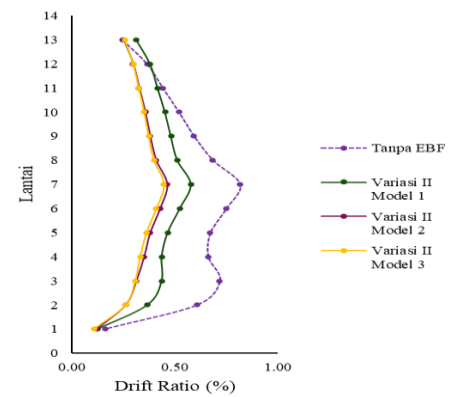


Drift Ratio Variation II Direction Y

Figure 7. Results of Variation Drift Ratio II Comparison



Drift Ratio Variation II direction X



Drift Ratio Variation II direction Y

Figure 8. Results of Variation Drift Ratio II Comparison

Result of Base Shear

The value of the base shear or base shear force in the analysis will be checked by the results of running SAP 2000 to obtain the elastic base shear results produced by the equivalent static.

Table 4. Base Shear Comparison Results

Direction	Without EBF	Variation I		Variation II		
		Model 1	Model 2	Model 1	Model 2	Model 3
	kN	kN	kN	kN	kN	kN
X	1678.476	2268.874	2205.445	2268.874	3310.909	2562.792
Y	1670.519	2399.472	2340.18	2399.472	3022.448	2528.644

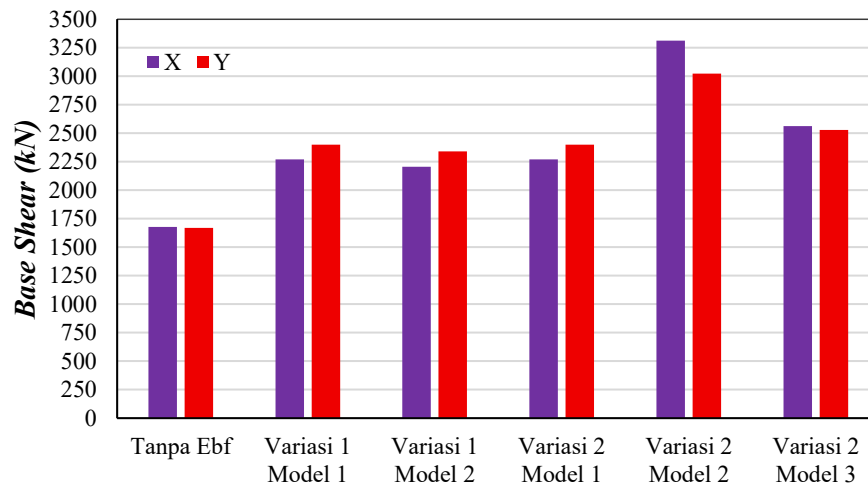


Figure 7. Base Shear Comparison Results

Structural Capacity Check

The selection of capacity checks is taken from the largest internal force data from the use of variations where capacity checks will be carried out on column structural elements, beams, *links*, and *bracing*.

Table 5. Cross-sectional Capacity Check Results

Structural Elements	Output (SAP2000)	Nominal Capacity (ϕP_n atau ϕV_n)	Information	Note
Column	$P_u = 7438.339$ kN	$\phi P_n = 874.711$ kN	Not Ok	Replanning is needed; WF profile 400.400.13.21 does not sufficiently withstand pressure.
Beam (early)	$V_u = 374.112$ kN, $M_u = 385.5358$ kNm	ϕM_n (awal) < M_u (tidak memenuhi momen)	Not Ok for the moment	WF's initial profile 400.200.8.13 does not meet the capacity of the moment against M_u .
Beam (repeat)	$V_u = 374.112$ kN, $M_u = 385.5358$ kNm	$\phi V_n = 529.92$ kN (setelah ulang)	Ok	Replanning to WF profile 400.300.10.16 meets sliding requirements; Moment improvements are made.
Link Beam	$V_u = 114.489$ kN, $M_u = 83.3228$ kNm	$\phi V_n = 255.053$ kN	Ok	The link is compact and works as an earthquake energy dissipater.
Bracing (early)	$P_u = 358.469$ kN	$\phi P_n = 52.582$ kN	Not Ok	The WF profile of 200.100.5.5.8 is not strong enough, it needs to be enlarged.
Bracing (repeat)	$P_u \approx 451.017$ kN	$\phi P_n = 1230.047$ kN	Ok	The new profile of WF 350.250.9.14 meets the pressure requirements.

5. CONCLUSION

1. In this study, the effect of link length was evaluated through two models, namely short links and intermediate links, and compared with structures without EBF. The results of the analysis showed that the difference between the two was not significant, with a drift ratio of 19.56% and 20.86%, respectively, and a base shear of 43.64% and 40.09%.
2. The effect of bracing placement was tested through three variations: in the middle, at the edges, and in combination. The results showed that the placement of bracing at the edge produced the highest base shear with an increase of 97.26% compared to without EBF, while the difference in drift ratio between variations was relatively small. This shows that the bracing position has a significant effect on the response of the structure.
3. The best model is obtained in the II variation of model 3 because it provides the greatest decrease in drift ratio and the most even stiffness distribution. Based on the results of the capacity check, the profiles of WF 400.300.10.16 (beam), WF 346.174.6.9 (link), and WF 350.250.9.14 (bracing) were declared to meet, while the columns needed to be replaced with composite columns due to high axial values (7438.34 kN).

REFERENCES

- Alvandi, B., Safitri, A. R., Purwanto, D., 2019. Perencanaan *High Rise Building* atau Bangunan Bertingkat dengan Permodelan Kolom dan Balok Transfer. *Jurnal Sipil: Universitas Muhammadiyah Tangerang*, 1(2), 163.
- Al-Koiy, & In, K. J. O., 2019. *Evaluasi of Stiffness of Reinforced Concrete Shear Wall eith Different Sizes of Opening Against Lateral Loading*. *Sustainability*, Switzerland: Near East University, 11(1), 1-14.
- Badan Standarisasi Nasional., 2020. *Beban Minimum untuk Perancangan Bangunan Gedung ddan Struktur Lain*. SNI 1727:2020. BSN, Jakarta.
- Badan Standarisasi Nasional. (2012). *SNI 1726-2012 Tata Cara Perencanaan Ketahanan Gempa Untuk Struktur Bangunan Gedung dan Non Gedung*.
- Badan Standarisasi Nasional., 2019. *Tata Cara Perencanaan Ketahanan Gempa untuk Struktur Bangunan Gedung dan non Gedung*. SNI 1726-2019. BSN, Jakarta.
- Brush, R.C., Shirkol, A., & Sruthi, J. S., 2022. *Seismic Analysis of RCC Building with Different Shape of Shear Wall and Without Shear Wall*. *ASPS Conference Proceedings: Malaviya National Institute of Technology*, 1(1), 983-989.
- Lesmana, Y., 2020. *Handbook Analisa dan Desain Shear Wall Beton Bertulang dual System Berdasarkan SNI 2847-2019 & 1726-2019* (Y. Lesman (ed)). Nas Media Pustaka. Makassar.
- Pribadi, A., Herbudiman, B., & Sudrajat, R., 2022. Analisis Perbandingan Variasi Tata Letak dinding Geser dengan Metode *Pushover*. *Teknik Sipil*, 08(02), 125-135.
- Saputro, D. N., Rahayu, T. F., 2021. Analisis Gaya Geser Seismik Terintegrasi Building Information Modeling (BIM) 3D. *KIIJK: Universitas Jendral Soedirman*, 1(1), 85-95
- Pratiwi, A. Y., Afriyono, H., Chairunnisa, N., W. A., Nurwidayati, R., & Fahreza, A., 2025. *Experimental Assessment of Flexural Performance in Concrete Beams Reinforced with Angle Steel Profiles: A comparative Study Against Typical Reinforcement System*. *Journal of Applied Enineering Science*, 23(1), 90-98.
- Deded Eka Sahputra, & Aniendhita Rizki Amalia. (2022). Modifikasi Struktur Gedung Menara Parkson Menggunakan Struktur Baja dengan Sistim Rangka Bresing Eksentrik. *Civil Engineering Collaboration*, 7, 14–21.
<https://doi.org/10.35134/jcivil.v7i1.35>