Engineering and Technology Journal e-ISSN: 2456-3358

Volume 10 Issue 08 August-2025, Page No.-6624-6629

DOI: 10.47191/etj/v10i08.53, I.F. – 8.482

Steel Structure Design with Concentric Brace Frame System Sukawati Market Building Block C

Ni Wayan Ratna Kirani[1], I Nengah Sinarta[1,2], Putu Aryastana[1,2*]

[1] Department of Civil Engineering, Universitas Warmadewa, Denpasar, Bali, Indonesia

[2] Master Program of Infrastructure and Environmental Engineering, Universitas Warmadewa, Denpasar, Bali, Indonesia

ABSTRACT: The Ring of Fire district is a leader in setting out a framework that has to be efficient and effective from a planning perspective. The objectives of this study are to find out how the behavior of steel structure in case of X-type concentric braced system in the Sukawati Market Block C building. The Super Structure design is based on the following cross sections: column, HB. 350. 350. 12. 19 for K1, HB. 300. 300. 10. 15 for K2, and HB. 200. 200. 8. 12 for K3, and one may notice the economic efficiency ratio of the cross-section is 90%. The used beams are beam 1 IWF 250.250.6.9, beam 2 IWF 350.175.7.11, beam 3 IWF 450.200.9.14 and the maximum cost ratio value of the cross section is 98%. Profile IWF is utilized as a bracing element. 200. 100. 5,5.8 with an economic index of 64%.

KEYWORDS: Earthquake, Steel Structure, Bracing

I. INTRODUCTION

Indonesia with its high volcanic and seismic activities stimulates the evolution of planning for a building which is strong, effective and efficient. High-rise buildings need strong structural elements to support the buildings from the lateral forces, so they would not have lateral displacement from their foundation (Fitriyati & Trimurtiningrum, 2022). In order to increase the resistance to shear forces, the building's structure requires further supporting members, such as braces (Haryono et al., n.d.).

There are 2 types of braced frame systems, which are Concentric Braced Frame System (CBF) and Eccentric Braced Frame System (CBF) has X type, X 2 story type, V type, inverted V type, K type, Z type and diagonal type (Badan Standardisasi Nasional Kepada Yth Sekretaris Badan Penelltian dan Pengembangan, 1034). Of these types of CBF it is not clear which bracing type has the very good potential in resisting the earthquake force in multi-story building structures (Ayu et al., 2021). According to (Fitriyati & Trimurtiningrum, 2022), it is required to have the best structure of tipe X-1 and tipe X-2 type braces to ensure the unbalanced forces and over limit deflection, when the beams are deflected, which will cause to fail.

High-rise structures need to add stiffness in terms of member sizes for the ability to withstand loads. The CBFS can better carry force, especially transverse force compared with the MRFS, though structural sectional dimensions adopted are smaller, thus mass amount difference of buildings is appeared. This can be seen from the inter floor displacements where the Moment-Resisting Frame System (MRFS) has a higher ductility over the Concentric Braced Frame System (CBFS); For X direction, the displacement for MRFS is 12.9 cm and that for CBFS is 9.4 cm. For the Y-direction, W MRFS = 11 cm, whereas W CBFS = 8 cm (Septian Y., 2023).

The application of the concentric bracing type X in the multi-storey reinforced concrete structures can also improve the strength, stiffness and capacity of columns in resisting shear and axial forces in structural buildings than those of the displacements of in open frame buildings which the shear forces are concentrated within the buildings that had a bracing than those of the open frame (Gede et al., 2024).

Corresponding to the facts and advantages of this structural system, the author has the purpose of the analysis of the structure of Sukawati Market Block C, are to know (1) magnitudes of displacements of courses building without lateral bracing and with lateral bracing, and (2) economical index figure of the section used the building in lateral bracing.

II. LITERATURE

According to (Dwi Kurniati, 2022) stated in the results of his research that the average decrease without bracing was 43.28 mm in the X direction and 26.53 mm in the Y direction. After being given Λ type bracing to 39.27 in the X direction and 24.23 in the Y direction. In the comparison before and after reinforcement of Λ type bracing there is a difference in value of 4.01 mm in the X direction and by 2.31 mm in the Y direction. The addition of Λ type bracing to the building structure can reduce the deviation (drift) when compared to without using bracing.

Stated in the results of his research, performance-based earthquake-resistant building planning will produce information on the extent to which a reduced earthquake force will affect the structure and can be used as a guideline by civil engineers in planning buildings or evaluating existing buildings (Indri Dwi Nurhayati, 2021.).

According to (Rizki & Pamungkas, 2021.) according to the results of the analysis, the probability of collapse of the steel structure SRPM building structure when exposed to a fling earthquake is obtained. The centerline collapse value at 10% collapse is obtained at 0.667. For collapse conditions (IDR = 5%), the number is 1.319.

A. *Bracing Structure*

From the table above, it can be seen that the Inter-Floor Deviation that occurs in the structure due to earthquakes x and y has met the requirements, so the structure is declared safe against horizontal deformation that occurs due to earthquake loads acting on the structure.

1) Tensile Structure Components

$$\mathbf{r} = \sqrt{\frac{\mathbf{I}}{\mathbf{A}}} \quad (1)$$

$$Pn = Fy \times Ag \quad (2)$$

$$Pn = Fu \times Ag \quad (3)$$

2) Compression Structure Components

$$Fcr = \left[0.658^{\frac{Fy}{Fe}}\right] Fy \quad (4)$$

$$Fe = \frac{\pi^2 E}{(\frac{Lc}{r})^2} \quad (5)$$

$$Pn = Fcr \times Ag \quad (6)$$

3) Sliding Components

$$\frac{h}{tw} \leq 1,10 \sqrt{Kv\, x \frac{E}{Fy}} \quad (7)$$

$$Aw = ht \times tw \quad (8)$$

$$Vn = 0.6\, xFy \times Aw \times Cv \quad (9)$$

With:

I = Inertia of the cross section
A = Area cross section
Pn = Nominal Axial
Fy = Yield stress of steel
Fu = Breaking stress of steel
E = Steel elasticity
Vn = Slide nominal
CV= 1

B. *Breasing Connection*

1) Bracing flange connection to gusset plate

$$Poof = \frac{P_u x\, (b_{fx} t_f)}{A} \quad (10)$$

$$ØRn = Øfu \times Ae \quad (11)$$

Control:

$$ØRn > Poof \quad (12)$$

$$ØRn = Ø[0.6.\ Fu.Anv + Ubs.fu.Ant]$$

$$ØRn \leq Ø\ [0.6.\ Fy.Agv + Ubs.fu.Agt] \quad (13)$$

Control:

$$ØRn > Vu \quad (14)$$

2) Bracing body connection to gusset plate

$$ØRnv = ØFn \times Ae \quad (15)$$

Control::

$$ØRnv > Fuw \quad (16)$$

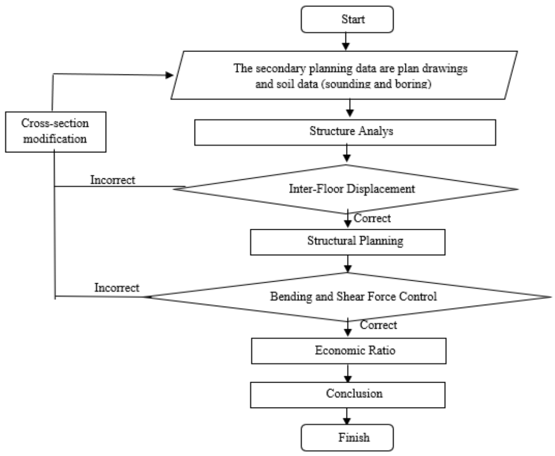
With:

Pu = Ultimate axial force
Vu = Ultimate shear force
Rn = Nominal strength

III. METHODOLOGY

A. *Structural Modeling*

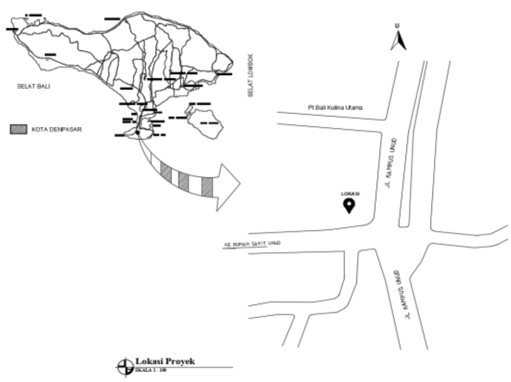
The flow of the implementation process for the case study is shown in Figure 1 below. The research method used is the literature study method. The literature review is a data collection method in which the information is collected through documents, such as written documents, visuals or electronic documents. The data collected is processed using the ETABS V.22 software, which generates moments (Mu), shear (Vu), tension, and tension or compression forces (Pu). Such forces are then calculated in order to find the inter-story drift. Then calculations of elements structures (columns, beams, braces), bending force and shear force control force to get the economic efficiency ratio.



Picture 1. Flowchart of Analysis Method

B. *Planning Location*

The planned location is Jalan Raya Sukawati No. 96X, Batuan Village, Sukawati District, Gianyar Regency, Bali Province. The Sukawati Market Block C building is located there.



Picture 2. Location of Sukawati Market Building Development Plan

C. *Planning Data*

The structure planning of Sukawati Market Building a block C consists of: Existing building data, covering building specifications, project working drawings and soil data.

D. Planning Standards

In the planning of the structure of the Sukawati market building, the references are used as a reference among other:

1) SNI 1729-2022 Indonesian National Standard for structural steel buildings.
2) SNI 2847-2019 Indonesian National Standard for structural concrete requirements of building structures.
3) SNI 1727-2020 Indonesian National Standards that regulate the minimum load for design of buildings structure.
4) SNI 1726-2019 Indonesian National Standard for guidelines for earthquake resistance planning for building and non-building structures.

E. Load Calculation

1) Dead Load

The dead loads acting on the structure are as follows:

a. Burdenthe dead weight that occurred in the roof frame was 56.89 kg/m^2
b. Burdenthe dead weight that occurs on the plate is 118.35 kg/m^2 and on floors 2,3,4 it is 164.24 kg/m^2
c. Burdendead on lift 142.45 kg/m^2

2) Burden of Life

The live loads acting on the structure are as follows:

a. Burdenthe life force that occurs on the roof frame is 135.62 kg.
b. Burdenthe life that occurs on the floor plate is 195.78 kg/m^2
c. Burdenthe life that occurs in the elevator is 62.88 kg/m^2

3) Rain Load

The rain load that occurs on the roof frame is 19.99 kg/m^2

4) Wind Load

The wind load based on the average wind speed in the Renon area is 5.79 kg/m2 for incoming winds and -11.57 kg/m^2 for outgoing winds.

5) Earthquake Load Calculation

Based on the building risk category for this building, namely: IV, the earthquake priority factor is 1.5. Then, at the building location, the Ss value is 0.95 and S1 is 0.35. Based on the soil data classification obtained, the soil is categorized assoftand the SDS value was 0.72 and SD1 was 0.61.

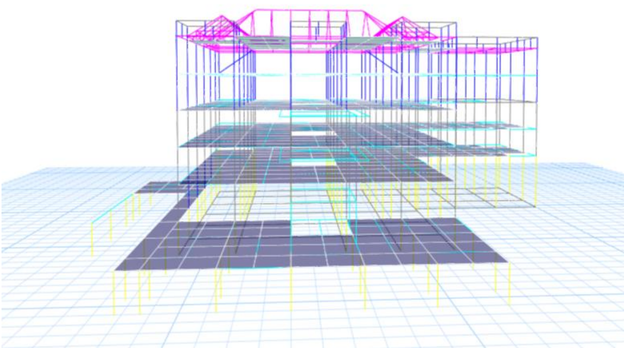
From the data above, the earthquake load acting on the structure is as follows:

R = 7 (Table 2.8 SNI 1726:2019)
Wt = 3657571.46 Kg
Ct = 0.0724
Hn = 14.4 m
x = 0.8
Cu = 1.4
T = 0.612 seconds
Cs = 0.213
V = 907098.4 Kg

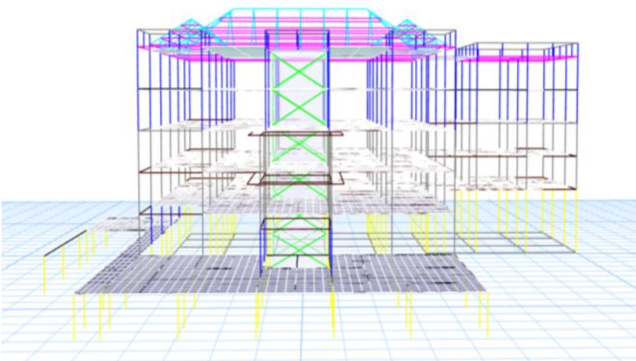
IV. RESULTS

A. Modeling Structure

To model the Sukawati Market Building structure can be simulated by ETABS 2000 V 22 software. This structure is consisted of 4^{th} floor with steel construction. The unbraced structure modeled is given in Ficture 3 and the braced structure modeled in Ficture 4.



Picture 3. 3D Model of the Unbraced Structure



Picture 4. 3D Model of the Structure With Bracing

B. Deviation Analysis

1) Unbraced Structure

Table 1. Interfloor Deviation Results of Earthquake X

Location	h (mm)	H (mm)	Direction X δmax	Direction X Δmax •Cd/Ie	Δijin	Control
RB	1500	19600	15,22	5,5	23	OK
LT. 5	3900	18600	14,22	12,10	60	OK
LT. 4	3900	14700	12,02	10,29	60	OK
LT. 3	3900	10800	10,15	12,38	60	OK
LT. 2	3900	6900	7,9	24,75	60	OK
LT.1	3000	3000	3,4	18,70	46.15	OK
BS	0	0	0	0	0	OK

According to Table 1, it's concluded that the amount of lateral displacement of upper level away from base is in the range of 0 mm to 15.22 mm, in the X direction, the maximum value of this displacement is at RB that is 15.22 mm and the minimum of this displacement is at LT. 1 which is 3.4 mm. By the way, 12,10 mm is the maximum inter-story drift it can produce on LT. 2 and the minimum acceptable inter-story drift level is 5,5 mm at RB. Therefore, the inter-storey drift is permissible as per the above table.

Table 2. Interfloor Deviation Results of Earthquake Y

Location	h (mm)	H (mm)	Direction Y δmax	Direction Y Δmax •Cd/Ie	Δijin	Control
RB	1500	19600	20,82	8,08	23	OK
LT. 5	3900	18600	19,35	3,14	60,5	OK
LT. 4	3900	14700	18,78	12,76	60	OK
LT. 3	3900	10800	16,46	22,00	60	OK
LT. 2	3900	6900	12,46	23,16	60	OK
LT.1	3000	3000	8,25	45,38	46,15	OK
BS	0	0	0	0	0	OK

From Table 2, the deflection from base to upper storey can be noted here that the maximum value of this value of this parameter on X direction is at RB of 20,82 mm where, as minimum value of this parameter is at LT. 1 which is 8,25 mm. At the same line, the highest inter-storey drift is 45,38 mm at LT. 2 and the smallest allowable inter-storey drift is 8,08 mm at RB. Thus, referring to the above table, the inter-story drift is permissible.

2) Structure with Bracing

Table 3. Inter-floor Deviation Results of Earthquake X

Location	h (mm)	H (mm)	Direction X δmax	Direction X Δmax •Cd/Ie	Δijin	Control
RB	1500	19600	8,39	1,21	10	OK
LT. 5	3900	18600	7,99	3,96	33,5	OK
LT. 4	3900	14700	6,67	4,28	35	OK
LT. 3	3900	10800	5,24	5,49	35	OK
LT. 2	3900	6900	3,41	5,91	35	OK
LT.1	3000	3000	1,44	4,32	40	OK
DASAR	0	0	0	0	0	OK

According to Table 4, lateral displacement from base to the upper storey is known that the maximum value of the displacement in the X-direction is 8,39 mm at RB and the minimum value is 1,44 mm at LT. 1. In addition, LT. 2 sustains the highest inter-story drift of 5,91 mm whereas the lowermost acceptable inter-story drift is 1,21 mm at RB. Hence, according to the given table, the inter-storey drift is acceptable.

Table 4. Interfloor Deviation Results of Earthquake Y

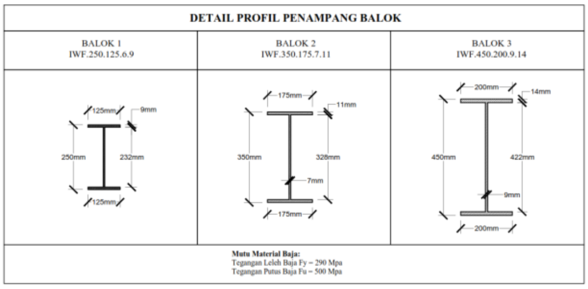
Location	h (mm)	H (mm)	Direction Y δmax	Direction Y Δmax •Cd/Ie	Δijin	Control
RB	1500	19600	15,48	1.62	10	OK
LT. 5	3900	18600	14,92	6,27	33,5	OK
LT. 4	3900	14700	12,85	7,77	35	OK
LT. 3	3900	10800	10,26	10,38	35	OK
LT. 2	3900	6900	6,8	11,61	35	OK
LT.1	3000	3000	2,93	8,79	40	OK
DASAR	0	0	0	0	0	OK

Based on Table 4, the lateral displacement from the base to the upper level can be observed that the maximum value of this parameter in the X direction is at RB of 15,48 mm and the minimum value of this parameter is at LT. 1, which is 1,44 mm. Meanwhile, the maximum inter-story drift of 11,61 mm is found on LT. 2 and the minimum permissible inter-story drift is 1,62 mm at RB. Therefore, based on the table above, the inter-story drift is allowable.

C. *Super Structure Planning*

1) Beam Structure

Cross sections of the beams employed, namely Beam 1 IWF 250.250.6.9, Beam 2 IWF 350.175.7.11, and Beam 3 IWF 450.200.9.14, are depicted in Figure 5.



Picture 5. Beam Cross Section

Table 5. Beam Planning Recapitulation

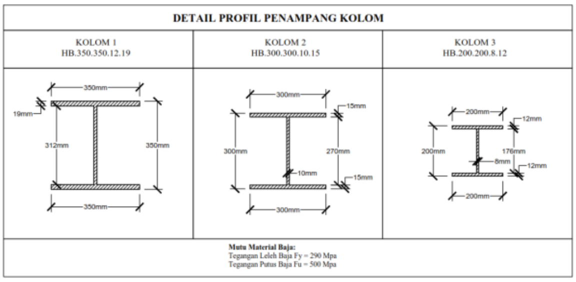
Location	Name	L (mm)	Flex Control	Slide Control	Shear and Flexural Interaction	Economic ratio
Leheran	Balok 1922	7200	OK	OK	OK	43%
Talang floor	Balok 1222	4050	OK	OK	OK	72%
	Balok 1955	7200	OK	OK	OK	97%
	Balok 1943	7200	OK	OK	OK	76%
4th floor	Balok 2090	5820	OK	OK	OK	70%
	Balok 2209	7200	OK	OK	OK	70%
	Balok 529	7200	OK	OK	OK	85%
3r floor	Balok 1716	5820	OK	OK	OK	71%
	Balok 1661	7200	OK	OK	OK	74%
	Balok 521	7200	OK	OK	OK	98%
2n floor	Balok 1858	6000	OK	OK	OK	72%
	Balok 1871	7200	OK	OK	OK	72%

Balok 1861	7200	OK	OK	OK	87%

According to Table 5, analysis indicates that all the control performed in the tensile structural analysis, flexural structural analysis and compressive structural analysis satisfy the conditions. The maximum achieved economic ratio is 98% corresponding to Beam 3 on 3rd floor and the minimum thus obtained is that of a 1 neck beam being 43%. Furthermore, the economic ratio is also equal to 70% for the gutter child beam and Beam 2 on the 4th floor, and to 72% for the neck child beam, child beam on the 3rd floor and Beam 2 on the 2nd floor.

2) Column Structure

Cross-section profiles of the columns used are given in Figure 6 for Column 1 HB 350.350.12.19, Column 2 HB 300.300.10.15 and Column 3 HB 200.200.8.12.



Picture 6. Column Cross Section

Table 6. Column Planning Recapitulation

Location	Name	L (mm)	Press Control	Drag Control	Flex Control	Economic ratio
Leheran	Kolom 554	1500	OK	OK	OK	0,48
5th floor	Kolom 487	3900	OK	OK	OK	0,44
4th floor	Kolom 878	3900	OK	OK	OK	0,3
3rd floor	Kolom 859	3900	OK	OK	OK	0,28
2nd loor	Kolom 873	3900	OK	OK	OK	0.9
1st floor	Kolom 888	3000	OK	OK	OK	0.06

The analysis results of table 3 indicate that all the controls carried out in the tension structural analysis, bending structural analysis and compressive structural analysis are satisfied. The maximum economical ratio achieved is 0.90 in a column 873 of the 2nd floor and the minimum thus obtained is that of a column 888 of the 1st floor being 0.06.

3) Bracing Structure

Cross-section profiles of the brace used are IWF. 200. 100. 5. 5. 8.

Table 7. Bracing Planning Recapitulation

Location	Name	L (mm)	Press Control	Drag Control	Economic ratio
4th floor	Braced	7963	OK	OK	0,15
3rd floor	Braced	8006	OK	OK	0,44
2nd loor	Braced	8006	OK	OK	0,58
1st floor	Braced	8237	OK	OK	0,64

From table 7, the analysis results show that each of the criteria for the controls implemented in the analysis of tensile and compressive structures have been met. The highest economic ratio obtained is 0.64 on the 1st floor bracing and the lowest economic ratio is 15% on the 4th floor.

V. CONCLUSIONS

The comparison of the results of the model to the loads applied to the building structure, the system of steel structures with and without a concentric bracing system in both the X and Y directions exhibits a number of significant dissimilarities not only the values of permitted deformation and inter-storey displacement. Where the deformation value produced in the steel structure provided with both the bracing reinforcement and without the bracing reinforcement in the excess reinforcement is smaller. During difference earthquakes, for no bracing reinforcement, the inter-floor displacement in X direction is larger than that with bracing reinforcement. On the other hand, the inter-storey displacement along the Y-direction on the level 5 demonstrates a different result, in which the permissible displacement under the bracing reinforcement is larger than that of the un-reinforced condition. Indeed, in the building without reinforcement along the Y axis, the inter-floor displacement is practically equal to what is allowed.

The steel stiffness evaluation with bracings on beams and columns also comprises tensile structures, flexural structures and compressive structures, with the testing criteria to be acceptable (OK). The maximum economic ratio achieved is 0.98 for beam 3 on the 3-level and the maximum economic ratio for column is 0.9 for column 873 on the 2-level.

REFERENCES

1. Fitriyati and Trimurtiningrum. 2022. “Studi Perbandingan Perilaku Sistem Rangka Bresing Tipe X-1 dan Tipe X-2 Pada Gedung Perkuliahan 10 Lantai”. Jurnal Online Skripsi Manajemen Rekayasa Konstruksi Polinema 3(2): 222-228.
2. Haryono, Sri. 2015. “Penggunaan Struktur Bresing Konsentrik Tipe X Untur Perbaiakan Kinerja Struktur Gedung Bertingkat Terhadap Beban Lateral Akibat Gempa”. Jurnal Teknik Sipil dan Arsitektur, Universitas Tunas Pembangunan Surakarta.

3. Badan Standarisasi Nasional. 2020. *SNI 1729 – 2020 Spesifikasi Untuk Bangunan Gedung dan Baja Struktural*. Jakarta: BSN.
4. Mahadewi, D. Ayu Utari and Khatulistiani, Utari. 2021. "Pengaruh Penempatan Bresing Inverted V dan X-One Strory Terhadap Simpangan Horizpntal Pada Gedung Bertingkat Struktur Baja". Seminar Ketekniksipilan, Infrastruktur dan Industri Jasa Konstruksi (KIIJK) 1(1):25-34.
5. Yoganata, Y. Septian. 2023. "Analisis Pengaruh Penggunaan Bresing Pada Struktur Bangunan Baja 20 Lantai". Jurnal Online Skripsi Manajemen Rekayasa Konstruksi Polinema 4(4):366-371.
6. Wiryadi, Tubuh, and Wirawan. 2024. "Perilaku Dinamis dari Penggunaan *Bracing X* Tingkat pada Gedung Bertingkat Dengan Analisis Time History". Reinforcement Review in Civil Engineering Studies and Management 3(1):41-55.
7. Kurniati, Dwi. 2022. "Rekayasa Bracing Tipe V Dan Tipe Λ Pada Gedung Kampus". Jurnal Teknik Sipil Universitas Warmadewa Paduraksa 11(1):103-111.
8. Indri Dwi Nurhayati. 2020. "Pengaruh Sistem Rangka Penahan Beban Gravitasi Terhadap Perilaku Keruntuhan Struktur Srpm Baja Dengan Bracing Konsentrik Akibat Getaran Gempa". Jurnal Ekonomi 18(1) 41–49.
9. Rizki, Fatkur and Pamungkas, Pujo. 2021. "Analisis Kinerja Struktur Pada Konstruksi Baja dan Konstruksi Beton Bertulang Dengan Analisa *Pushover* Statik Non-Linear Menggunakan *Software* ETABS (Studi Kasus: Hotel Santika, Batam)". Journal of Civil Engineering and Planning 1(2):64-76.