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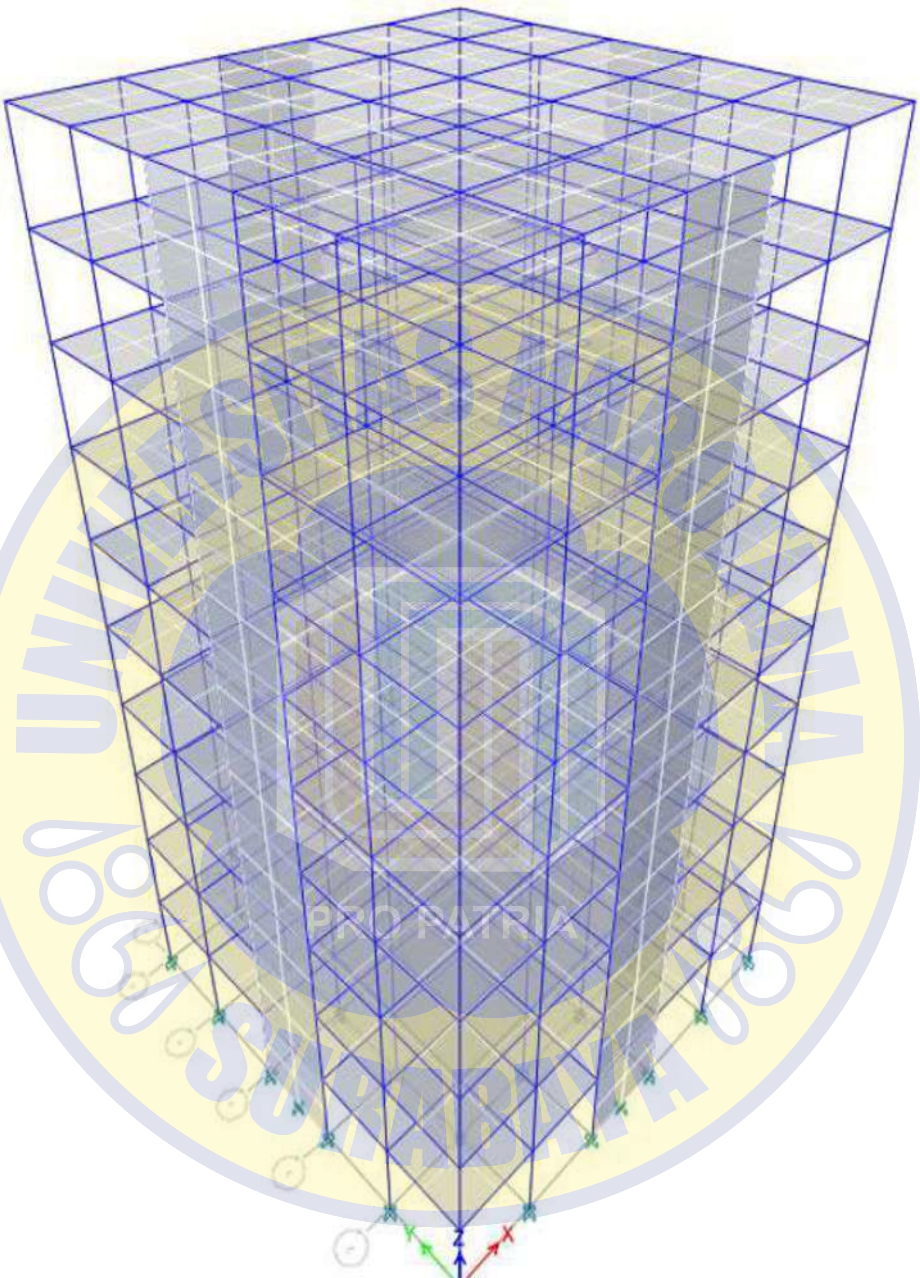

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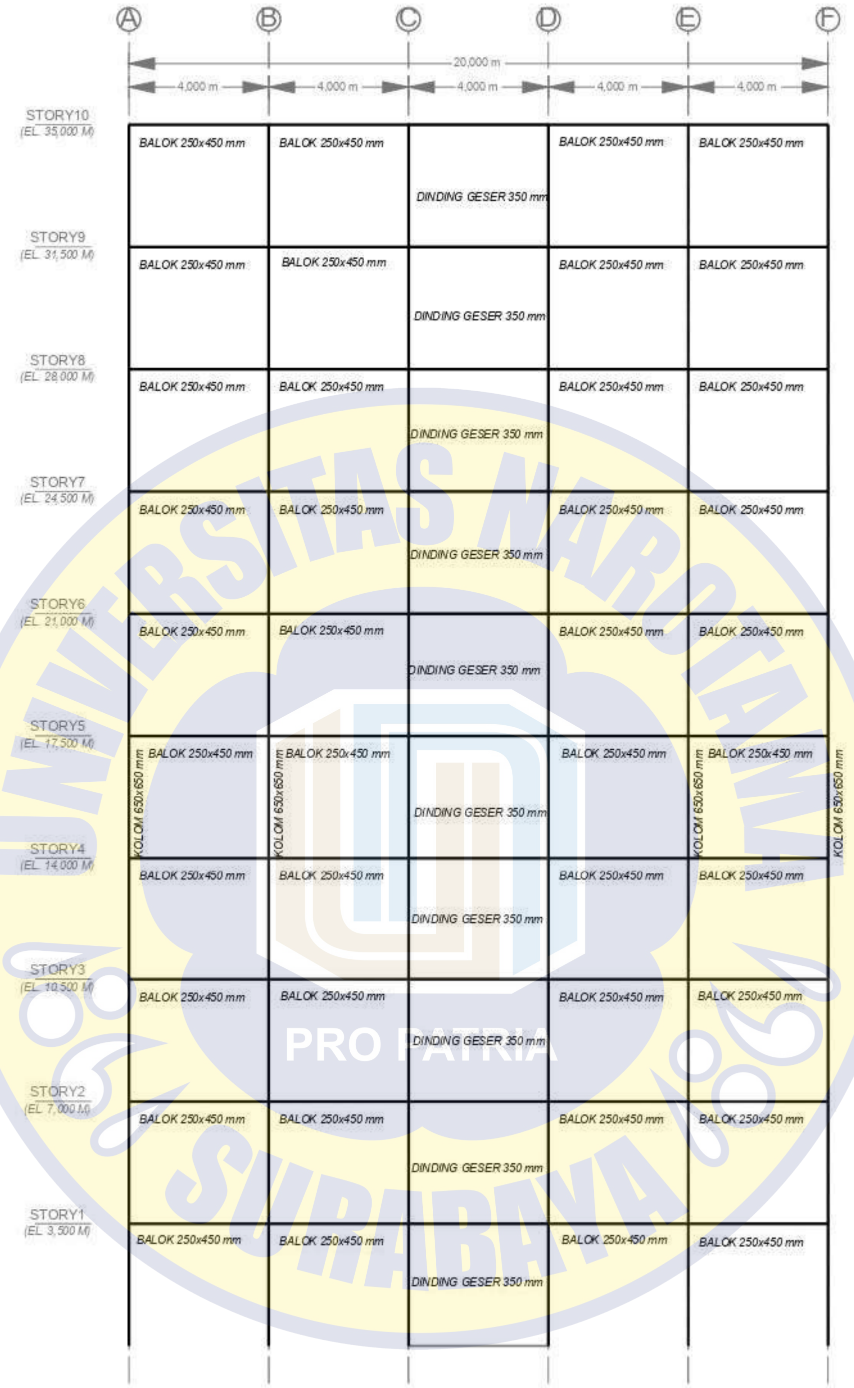

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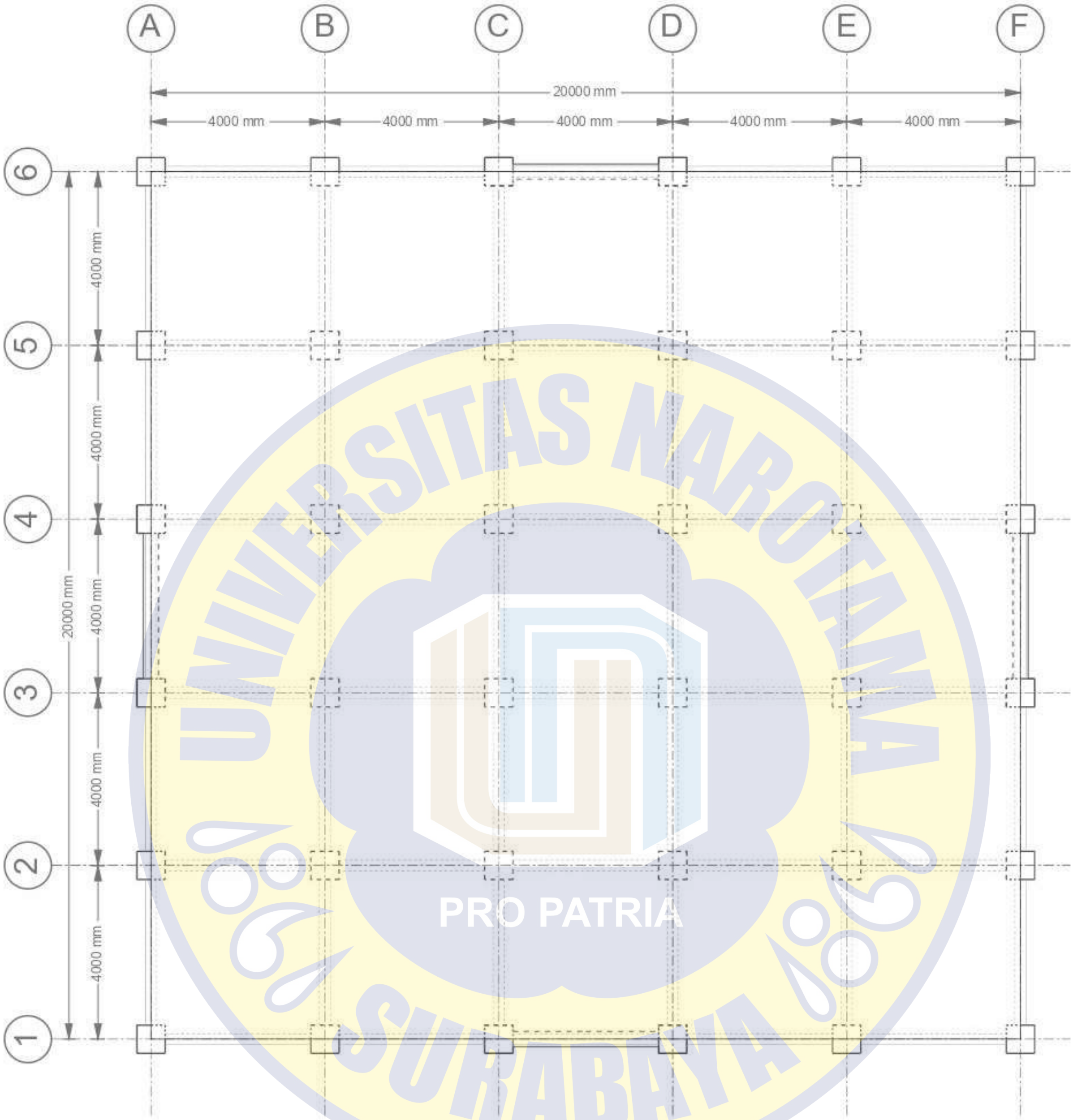

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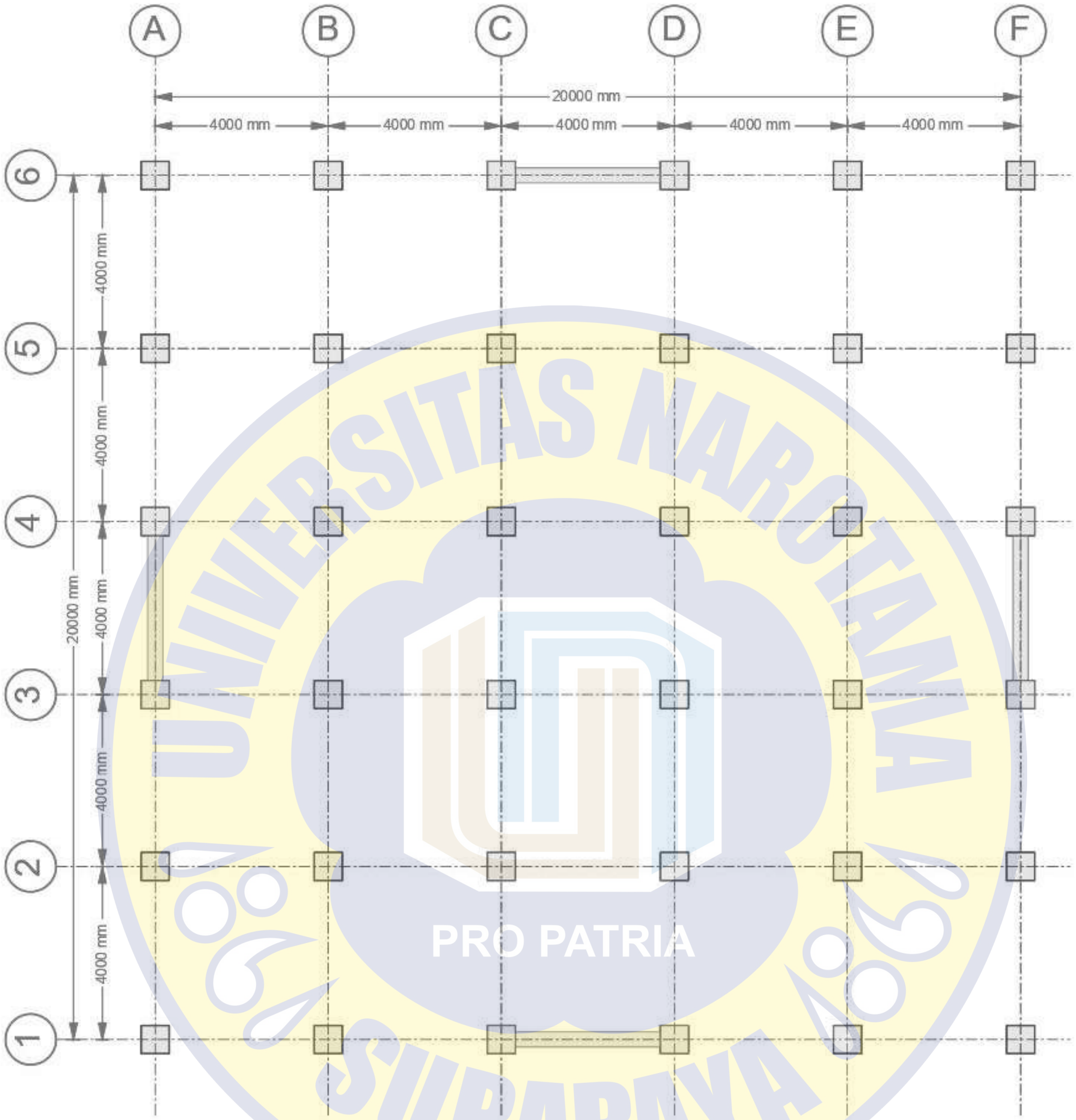

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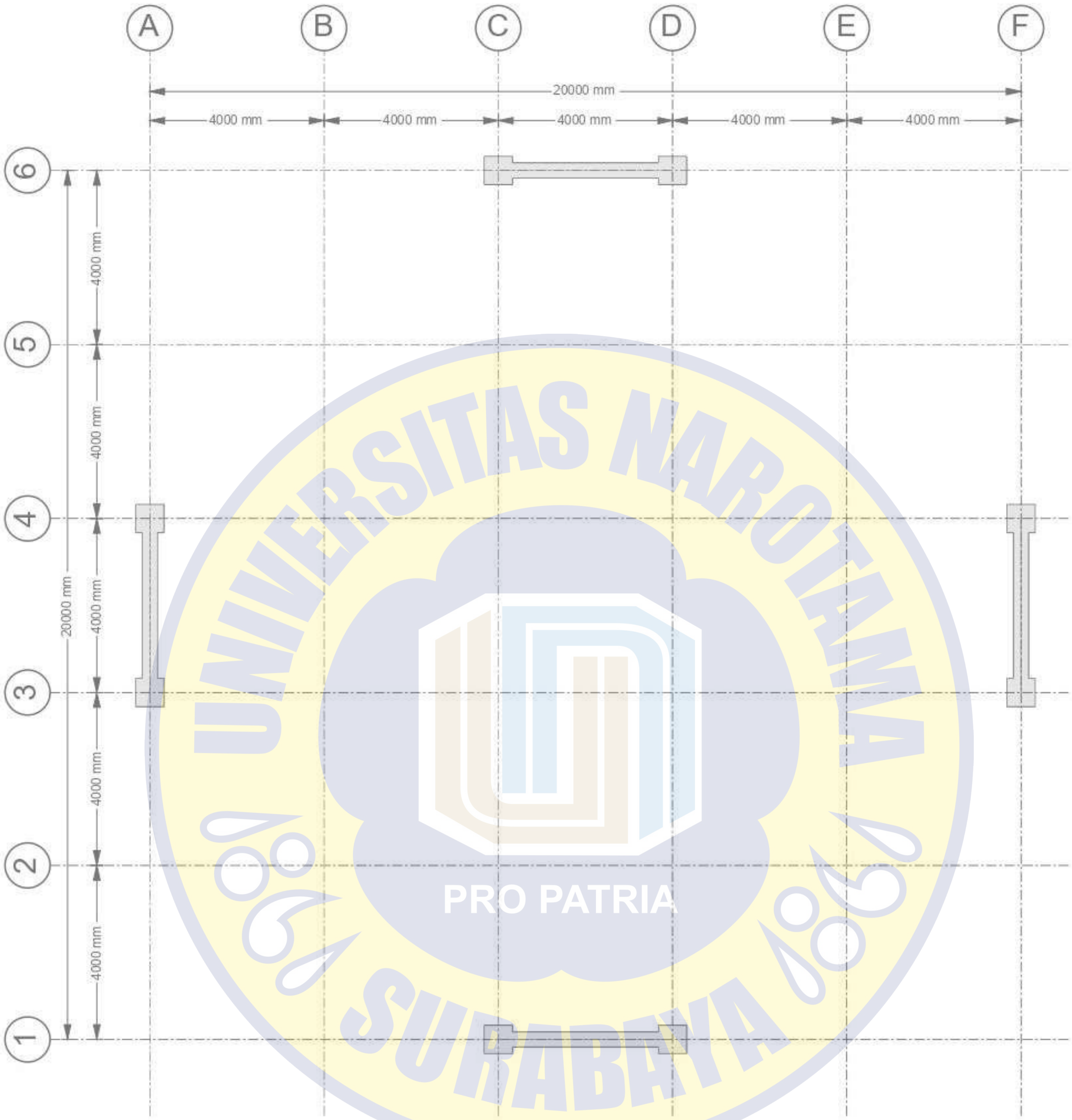

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PUSHOVER ANALYSIS OF THE STRUCTURE A 10 FLOOR BUILDING WITH ATC-40

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Abstract

The concept of earthquake-resistant buildings is very meaningful to try on buildings located in certain earthquake areas, especially in Indonesia considering the situation which is located in a shock area with a fairly high intensity of events.
The purpose of this research is to determine the seismic performance criteria of the planned structure using the SMRF (Special Moment Resisting Frame) structural system from the results of the displacement values using the ATC-40 code, showing the yielding scheme (plastic joint distribution) that occurs from the calculation results of the software program, knowing the pattern of building collapse so that it can be known joint- joint that is damaged and damaged from the pushover analysis.
From the results of the research, the building structure is able to provide nonlinear behavior which is indicated by the initial phase and the majority of the occurrence of plastic joints occurs in new beam elements and then column elements and has fulfilled the earthquake-resistant building concept, namely strong column - weak beam.
The results of the structural performance evaluation according to the ATC-40 rule that the Performance Level of the SMRF building in the x and y directions is at a Performance Level of 0.011 in the Immediate Occupancy (IO) category where the building is safe during an earthquake, the risk of loss of life and structural failure is not too significant, the building does not experience significant damage, and can be reused and not disturbed by repair problems, where the strength and stiffness are approximately the same as the conditions before the earthquake.

Keywords
Earthquake; Nonlinear; Plastic Joints; Pushover; Reinforced Concrete;

1. Introduction

The concept of earthquake-resistant buildings is very meaningful to try on buildings located in certain earthquake areas, especially in Indonesia considering the situation which is located in a shock area with a fairly high intensity of events. Based on the SNI Earthquake SNI1726-2019, earthquake-resistant buildings must be designed to withstand shock forces with waves of 500, 1000 and 2500 years. Therefore, the building that is built must be planned in such a way that when a shock occurs on a certain scale it does not endanger the occupants who live in the building. Based on these conditions, it is hoped that the construction to be built in earthquake-prone areas can follow applicable national standards and the building can still operate and be safe when affected by an earthquake. (Zebua et al., 2020).

In the construction world, there are several earthquake-resistant structural systems that can be used, namely the special moment resisting frame system. In a special moment resisting frame system, there are beams and columns as important structures to withstand earthquakes, while in a double system, shear walls / structural walls are involved in resisting the lateral forces that occur. (Wibowo & Zebua, 2021).

Shear walls are frame walls that function to increase the strength and stiffness of the building structure against lateral loads due to earthquakes. Shear walls are considered to be stiffer than ordinary frame elements so that they can withstand greater lateral loads due to earthquakes and at the same time limit the drift between floors (Nawy, n.d.). According to Moehle, the use of reinforced concrete shear walls is more cost effective than reinforced concrete truss systems (Moehle et al., 2012). Shear walls using boundary elements can increase the deformation capacity effectively (Cheng et al., 2020).

Earthquake engineering is a very broad knowledge and is related to the effects of earthquakes that can be caused to humans and the environment. To reduce the impact of the earthquake, it is necessary to conduct a seismic evaluation and analysis in earthquake-prone areas. The method used is Pushover Analysis (Pranata, 2006).

The pushover analysis method is one of the components of performance-based design which is a means to determine the capacity of a structure. Pushover analysis is a nonlinear static analysis where the influence of the design earthquake on the building structure is considered as static loads that capture the center of mass of each floor, whose value is gradually increased until it exceeds the load that causes the first joint (plastic joint) yielding. inside the building structure, then with a further increase in load undergoes a large post-elastic deformation until

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it reaches the expected transition target or until it reaches a plastic condition. In the pushover process, the structure is pushed until it yields at one or more locations in the structure. The capacity curve will show a linear condition before reaching the melting state and then behave nonlinearly.

This analytical procedure aims to determine the behavior of the collapse of a building with a moment resisting frame system against an earthquake, by providing a static lateral pattern on the structure gradually increasing with a lateral displacement target from a reference point. In this analysis using the Pushover Analysis method with the ATC-40 method.

2. Methodology

2.1. Research Flow

The research process is shown in a methodology flow chart which can be seen in the Figure 1:

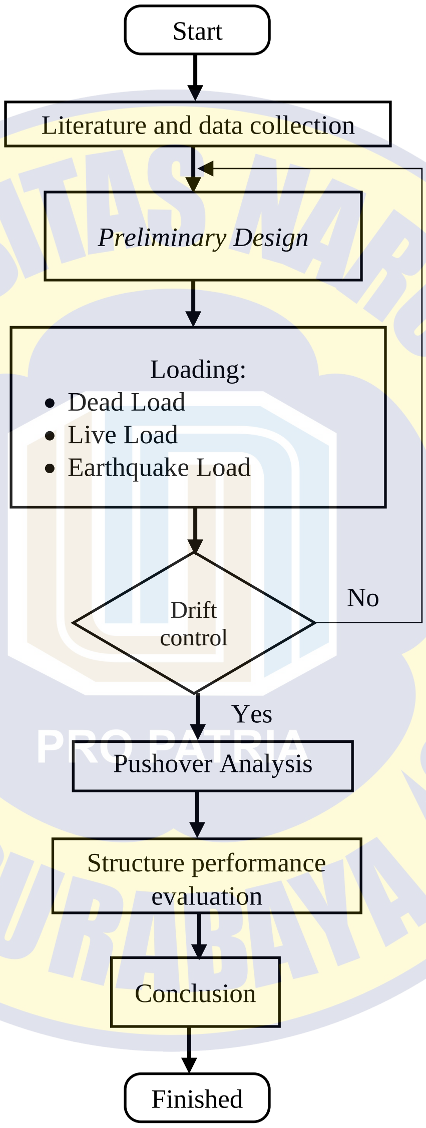

Figure 1. Flow Chart

2.2. Research types and concepts

This study carried out building planning according to SNI 2847-2019 regulations for a 10-storey building located on Nias Island to find out how the behavior of the building structure against the regulations made. The method used to determine the level of security of this building uses the ATC-40 Pushover analysis method.

2.3. Load

This research uses live load, dead load, earthquake load (static linear) and earthquake load (static nonlinear) pushover. For earthquake loads using the equivalent static method according to the regulations of SNI 1726-2019 and SNI 1727-2020 as building loads.

3. Result and Discussion

3.1. Structure Data

(f_c')	=	35 MPa
(f_y)	=	400 MPa
Beam	=	20x40 cm
Coloum	=	65x65 cm
Shearwall	=	35 mm
Structure Type	=	SMRF
Function of building	=	Office

The top view of the building analyzed in this study is shown in Figure 2.

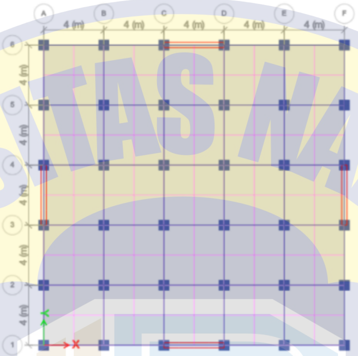

Figure 2. Top View of the Building

Table 1. Displacement in the x and y directions

Floor	H (m)	δ (x)	δ σ (y)
Rooftop	3.5	102.543	102.543
10	3.5	91.511	91.511
9	3.5	79.724	79.724
8	3.5	67.445	67.445
7	3.5	54.881	54.881
6	3.5	42.377	42.377
5	3.5	30.381	30.381
4	3.5	19.436	19.436
3	3.5	10.174	10.174
2	3.5	3.291	3.291
Base 1	0	0	0

From the results of the displacement values in the x and y directions, it can be seen that they have the same value, because the building being analyzed is symmetrical. The highest displacement value is 102.543 cm and the lowest is 3.291 cm.

3.2. Drift Analysis

From the results of running there is a deviation between floors, according to SNI 1726-2019 in planning for earthquake loading it is necessary to control the performance of the structure limits of the building from the analysis building. The deviation control is carried out in 2 directions, namely the x and y directions according to the formula below.

$$\delta_S = \frac{C_d \, x \, \delta_{se}}{I} \qquad (1)$$

Description:

δ_{se} = displacement on the xth floor
C_d = displacement magnification factor (5.5)
I = building priority factor (1)

$\Delta_1 = \delta_{S2} - \delta_{S1}$
$\Delta_a = 0.020hx$

Table 2. Performance Control of Structural Limits Due to Equivalent Static Earthquake Load in X and y directions

Floor	H (m)	δ_e (xy)	δ (xy)	Δ (xy)	Δ a (0.02Hxy)	Ket
Atap	3.5	102.543	563.987	60.676	70	Yes
10	3.5	91.511	503.311	64.829	70	Yes
9	3.5	79.724	438.482	67.535	70	Yes
8	3.5	67.445	370.948	69.102	70	Yes
7	3.5	54.881	301.846	68.772	70	Yes
6	3.5	42.377	233.074	69.987	70	Yes
5	3.5	30.381	167.096	69.092	70	Yes
4	3.5	19.436	106.898	50.941	70	Yes
3	3.5	10.174	55.957	37.857	70	Yes
2	3.5	3.291	18.101	18.101	70	Yes
Base	0	0	0	0	0	Yes

from the table above, it can be seen that the values in the calculations according to the regulations of SNI 1726: 2019 contained in the x and y direction tables above, it is concluded that all floors meet the specified structural performance limits. The highest value of Δxy=69,987 mm based on SNI 1726:2019 Article 7.12.1 does not exceed the control threshold with a value of Δa = 70 mm.

3.3. Pushover Analysis

The results of the pushover analysis on the structure are in the form of a structure capacity curve as shown in **Figure 3** below:

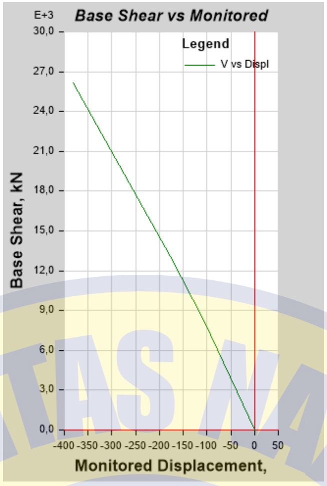

Figure 3. Capacity curve in x and y directions

Table 3. Monitored displacement x and y

Step	Displ (mm)	Base Force (kN)	A-B	B-C	A-IO	IO-LS	LS-CP	>CP	Total
0	0	0	1236	0	1236	0	0	0	1236
1	-36.8	2891.2	1234	2	1236	0	0	0	1236
2	-107.1	8284.0	1086	150	1236	0	0	0	1236
3	-177.9	13092.3	758	478	1234	0	0	2	1236
4	-303.8	21167.7	626	610	1234	0	0	2	1236
5	-381.7	26123.3	582	654	1230	4	0	2	1236
6	-381.7	26126.3	582	654	1228	4	0	4	1236

From the results of running pushover with the ETABS v19 program for the x and y directions, it is found that 6 steps of the thrust load pattern are applied to the structure until it collapses. From the table above, it can be seen that the collapse occurred from step 3 to 6 with the CP position.

In calculating the ATC-40 capacity spectrum method, a performance point is needed. Then, from the performance point obtained by the 10-story building, it can be evaluated against the damage that will occur during an earthquake in the area. The performance level of the building against earthquakes refers to the deviation limit at the ATC-40 Structure Performance Level, namely; IO (Immediate Occupancy), LS (Life Safety), CP (Collapse Prevention) and SS (Structural Stability).

After getting the displacement target, then the displacement target obtained from the x and y directions is 102.543 mm calculations are carried out according to the regulations for the ATC-40 capacity spectrum method as shown in table 4 below:

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Table 4. Results of Structure Performance Level according to ATC-40

Arah	Parameter	Hasil Analysis Pushover ATC-40
Arah x-x	Monitored displ. Δ (mm)	381.729
	Drift actual $(\Delta/Ttot)$	0.011
	Performance level	Immediate Occupancy (IO)
Arah y-y	Monitored displ. Δ (mm)	381.729
	Drift actual $(\Delta m/Ttot)$	0.011
	Performance level	Immediate Occupancy (IO)

From the table above, according to the ATC-40 rules, the performance level of the building in the direction of xx and yy is at Immediate Occupancy (IO) where the building is safe during an earthquake, the risk of casualties and structural failure is not too significant, the building does not experience significant damage, and can be re-used. and not bothered by repair problems, where the strength and stiffness are approximately the same as the conditions before the earthquake. With these results, the analyzed building is very safe because in ATC-40 the function of office buildings should be allowed up to the LF (Life Safety) performance level, but the analyzed building only reaches the IO (Immediate Ocupancy) performance level before the LS (Life Safety) performance level (ATC 40, 1996).

3.4. Plastic Joint Mechanism

The analyzed building has the same plastic hinge between the x-x direction and the y-y direction because the analyzed building is symmetrical. The distribution scheme of the plastic hinges in the pushover analysis can be seen in Figures 4 to 5 showing the structural behavior of the planned earthquake-resistant building concept, namely strong column - weak beam.

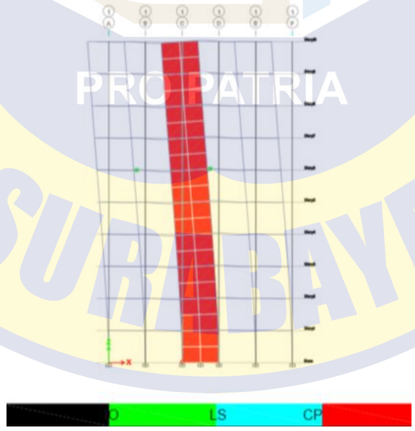

Figure 4. Distribution Scheme of SMRF Building Structure Plastic Joints in the x-x. direction

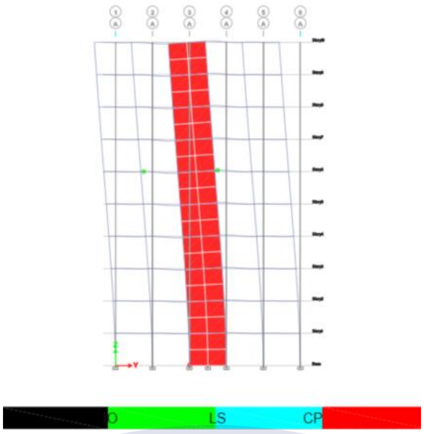

Figure 5. Distribution Scheme of SMRF Building Structure Plastic Joints in the y-y. direction

In Figures 4 and 5 above, it can be seen that the collapse of the x-y direction occurs at steps 3-6 where some beams have been included in the IO-CP category.

3.4. Conclusion

The analyzed building has met the allowable limit for the displacement between floors according to the provisions of SNI 1726:2019 where the largest value Δxy = 69,772 mm has not crossed the threshold a = 70 mm.

The results in the analyzed building have the same plastic hinge between the x-x direction and the y-y direction because the building being analyzed is symmetrical. The plastic hinge distribution scheme in the pushover analysis is in accordance with the plan which shows the behavior of the structure planned for the earthquake resistant building concept, namely strong column - weak beam.

The results of the evaluation of the performance of the structure according to the ATC-40 rule that the Performance Level of the building in the direction of x-x and y-y is at a Performance Level of 0.011 in the Immediate Occupancy (IO) category where the building is safe during an earthquake, the risk of casualties and structural failure is not too significant, the building is not experienced significant damage, and can be used again and not disturbed by repair problems, where the strength and stiffness are approximately the same as the conditions before the earthquake.

The designed building is very safe because in ATC-40 the function of an office building should be allowed to the LF (Life Safety) performance level, but the analyzed building only reaches the IO (Immediate Ocupancy) performance level before the LS (Life Safety) performance level.

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DERMAWAN ZEBUA, Dilahirkan di Kabupaten Nias tepatnya di Desa Oladano Kecamatan Idanogawo pada hari minggu tanggal 28 Desember 1997. Anak kedua dari lima bersaudara pasangan dari Sabarani Zebua dan Meriwati Zai. Penulis menyelesaikan pendidikan sekolah dasar di SD Negeri 84 Tetehosi di Kecamatan Idanogawo Kabupaten Nias pada tahun 2010. Pada tahun itu juga penulis melanjutkan Pendidikan di SMP Negeri 2 Sipora Kecamatan Sipora Utara Kabupaten Kepulauan Mentawai dan tamat pada tahun 2013 kemudian melanjutkan Sekolah Menengah Atas di SMA Negeri 2 Sipora pada tahun 2013 dan selesai pada tahun 2016. Pada tahun 2016 penulis melanjutkan pendidikan di perguruan tinggi swasta, tepatnya di Universitas Widya Kartika Surabaya di Fakultas Teknik pada Program Studi S-1 Teknik Sipil dan selessai ttahun 2020. Lalu pada tahun yang sama penulis melanjutkan Pendidikan S-2 di Magister Teknik Sipil Universitas Narotama Surabaya sampai penulisan Tesis ini Penulis masih terdaftar sebagai mahasiswa Magister Teknik Sipil Universitas Narotama Surabaya.

Penulis,

DERMAWAN ZEBUA