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EVALUATION OF THE STRUCTURE OF CAMPUS II OF MUHAMMADIYAH UNIVERSITY, WEST SUMATERA WITH NON-LINEAR STATIC PUSHOVER

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Abstract

The campus building II of the Muhammadiyah University of West Sumatra is one of the facilities used for the Faculty of Engineering lectures that must be considered both in terms of safety and comfort in the planning process. Being in an earthquake-prone location, the campus II building of the Muhammadiyah University of West Sumatra became the object of this research. All forms of regulations related to building safety have been issued by the government, this is to ensure the quality, both quality and quantity of the building. The purpose of this study was to evaluate the performance of the campus II building of the Muhammadiyah University of West Sumatra from the influence of earthquake forces both from the x direction and from the y direction, then how the collapse pattern occurred. This research was conducted using ETABS V.16.2.1 software to model the building under study and to calculate the performance based design based on the regulations of the Applied Technology Council (ATC-40), FEMA 356 and FEMA 440. The results showed that the shear force obtained from the thrust given in the X-direction was 43.561.8104 kN at Step 8 the displacement value was 317.320 mm and the thrust given in the Y-direction was 39274.5448 kN at Step 11 the value displacement is 289,851 mm. Displacement in the building does not exceed the allowable displacement, so that the building is safe against the design earthquake. The maximum total drift is 0.013 and the maximum In-elastic drift is 0.011, so the building is included in the Damage Control (DO) performance level.

Keyword : Applied Technology Council, Non-Linear Static Pushover

Abstrak

Gedung kampus II Universitas Muhammadiyah Sumatera Barat merupakan salah satu fasilitas yang digunakan untuk perkuliahan Fakultas Teknik yang harus diperhatikan baik dari segi keamanan maupun kenyamanan dalam proses perencanaannya. Berada di lokasi rawan gempa, gedung kampus II Universitas Muhammadiyah Sumatera Barat menjadi obyek penelitian ini. Segala bentuk regulasi terkait keselamatan bangunan telah dikeluarkan oleh pemerintah, hal ini untuk menjamin kualitas, baik kualitas maupun kuantitas bangunan. Tujuan penelitian ini untuk mengevaluasi kinerja gedung kampus II Universitas Muhammadiyah Sumatera Barat dari pengaruh gaya gempa baik dari arah x maupun dari arah y, kemudian bagaimana pola keruntuhan yang terjadi. Penelitian ini dilakukan dengan menggunakan software ETABS V.16.2.1 untuk memodelkan bangunan yang diteliti dan menghitung performance based design berdasarkan regulasi Applied Technology Council (ATC-40), FEMA 356 dan FEMA 440. Hasil penelitian menunjukkan bahwa diperoleh gaya geser dari gaya dorong yang diberikan pada arah X sebesar 43.561.8104 kN pada Langkah 8 nilai perpindahan sebesar 317.320 mm dan gaya dorong yang diberikan pada arah Y sebesar 39274.5448 kN pada Langkah 11 nilai perpindahan sebesar 289.851 mm. Perpindahan dalam gedung tidak melebihi

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perpindahan yang diijinkan, sehingga gedung aman terhadap gempa rencana. Total drift maksimum adalah 0,013 dan In-elastic drift maksimum adalah 0,011, sehingga bangunan tersebut termasuk dalam tingkat kinerja Damage Control (DO).

Kata Kunci : *Dewan Teknologi Terapan, Pushover Statis Non Linier*

INTRODUCTION

In civil engineering, we are required to be able to innovate in planning a building and also to be able to analyze the planned building in order to create a building that is safe, strong, and economical. Evaluation of earthquake-resistant buildings based on seismic performance in Indonesia is very important because most parts of Indonesia are in earthquake areas with moderate to high intensity, so Indonesia is said to be prone to earthquakes. In the process of designing building structures in earthquake-prone areas, standards and building design regulations are needed to ensure the safety of occupants against major earthquakes that may occur and to avoid and minimize damage to building structures and casualties due to earthquakes (Wibowo, 2020).

In planning the structure of earthquake-resistant buildings, the performance-based seismic design method is often used, where this method utilizes computer-based non-linear analysis to determine the inelastic behavior of the structure from various ground vibration intensities, so that the performance of the building structure in critical conditions can be known. Pushover analysis is an analytical procedure to determine the collapse behavior of a building against an earthquake by providing a pattern of static lateral loads on the structure, which is then gradually increased by a multiplier until a lateral displacement target from a reference point is reached (Sandhi, 2018; Utomo, 2012).

This study aims to evaluate the performance of the Campus II Building Structure of Muhammadiyah University of West Sumatra against earthquakes from the x direction and from the y direction, to determine the maximum displacement and maximum shear force that the structure can withstand (Prasetya, 2020; Rahmat, 2020). Evaluating the performance of the structure with reference to ATC-40, FEMA 356 and FEMA 440. This research was carried out using the ETABS V.16.2.1 software to create a model of the building under study. This study evaluates the performance of the structure of the campus II of the Muhammadiyah University of West Sumatra, which is located on Jl. Diponegoro, Aur Kuning, Bukittinggi city (Fema, 2005).

RESEARCH METHOD

A. Building Data

The structure of the campus II University of Muhammadiyah Sumatra Barat uses concrete quality f'c 30 MPa for the elements of columns, beams, floor plates and roof plates. For reinforcing steel material using screw reinforcement steel (BJTD) quality fy 400 MPa and for plain reinforcing steel using plain reinforcing steel (BJTP) quality fy 240 MPa.

For analysis in this study using ETABS V.16.2.1 software to get the Performance Point which is shown based on the capacity curve. The structure of the Campus II University of Muhammadiyah Sumatra Barat has a number of floors 6 and 1 ground floor, with a description of the building can be seen in Table 1 below.

Table 1. Building Description

UMSB Bukiitnggi Faculty of Engineering Building	
Structural System	SRPMK Beton Bertulang
Building function	Lecture Building
Jumlah Lantai	6
Number of Floors	One floor (as vehicle parking)
Floor area 1	847,69 m²
Floor area 1	712,09 m²
Typical floor area (3-5 floors)	765,29 m²
Typical floor area (6th floor/Roof)	1141,29 m²
Typical number of floors	6 Lantai
Typical floor height	4,00 m
basement depth	4,00 m
Maximum building height	24,00 m
The total area of the building including the basement	4241,16 m²

(Source: As-built drawing of Campus II Building, Muhammadiyah University of West Sumatra)

The structural elements used in the Campus II building of the Muhammadiyah University of West Sumatra are typical from the ground floor to the 6th floor. In Table 2, Table 3 and Table. 4 below is a list of descriptions of concrete and structural elements, steel quality and description of reinforcement in the structural elements of the Campus II Building, Muhammadiyah University, West Sumatra. For modeling using ETABS V.16.2.1 software can be seen in Figure 2.

Table 2. Description of Concrete and Structural Elements

Function	Concrete Quality f'c (MPa)	Density of concrete λc (kg./ m3)	Modulus Ec 4700 √fc' (MPa)	Poisson ratio νs	Dimension (mm)	Thick (mm)

Column K1	30	2400	25743	0,2	700 x 700	
Column K2	30	2400	25743	0,2	500 x 500	
Beam B1	30	2400	25743	0,2	700 x 400	
Beam B2	30	2400	25743	0,2	600 x 400	
Beam B3	30	2400	25743	0,2	400 x 300	
Floor Plate	30	2400	25743	0,2		120
Roof Plate	30	2400	25743	0,2		120

(Source: As-built drawing of Campus II Building, Muhammadiyah University of West Sumatra)

Table 3. Steel Quality

Function	Steel Type	Steel Quality f'c (MPa)	Density of Steel Λc $^{(kg/m^3)}$	Ec (MPa)	Poisson ratio νs
Logitudinal reinforcement	BJTD 40	400	7850	200.000	0,3
Tranversal reinforcement	BJTP 24	240	7850	200.000	0,3
floor and roof slab reinforcement	BJTP 24	240	7850	200.000	0,3

(Source: As-built drawing of Campus II Building, Muhammadiyah University of West Sumatra)

Table 4. Description of Reinforcement in Structural Elements

Element Name	Logitudinal reinforcement	Confinemet Reinforcement	Blanket Concrete
Column K1	26 – D. 25mm	focus Ø 10 mm – 100 mm Field Ø 10 mm – 150 mm	40 mm
Column K2	20 – D. 25mm	focus Ø 10 mm – 100 mm Field Ø 10 mm – 150 mm	40 mm
Beam B1	Top 11 – D. 25 mm Medium 4 – D. 16 mm Bottom 7 – D. 25 mm	T focus Ø 10 mm – 100 mm Field Ø 10 mm – 150 mm	Top 50 mm Bottom 50 mm
Beam B2	Top 7 – D. 25 mm Medium 2 – D. 16 mm Bottom 5 – D. 25 mm	focus Ø 10 mm – 100 mm Field Ø 10 mm – 150 mm	Top 50 mm Battom 50 mm

Beam B3	Top 6 – D. 25 mm	focus Ø 10 mm – 100 mm	Top 40 mm
	Medium 2 – D. 13 mm	Field Ø 10 mm – 150 mm	Battom 40 mm
	Bottom 3 – D. 25 mm		
Floor Plate	Top Ø 10 – 150 mm		Top 25 mm
	Bottom Ø 10 – 150 mm		Battom 25 mm
Roof Plate	Top Ø 10 – 150 mm		Top 25 mm
	Bottom Ø 10 – 150 mm		Battom 25 mm

(Source: As-built drawing of Campus II Building, Muhammadiyah University of West Sumatra)

Figure 3. Geometric and Plan of Existing Building : Ground Floor Plan

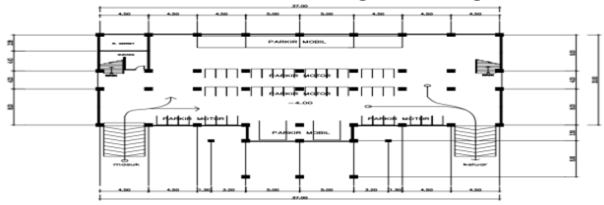


Figure 4. Front View

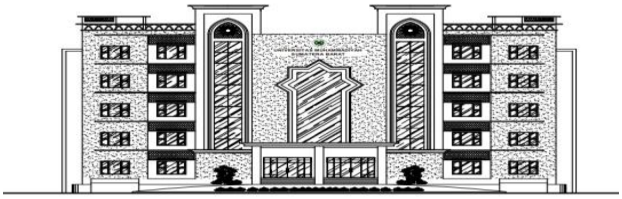


Figure 5. Side view

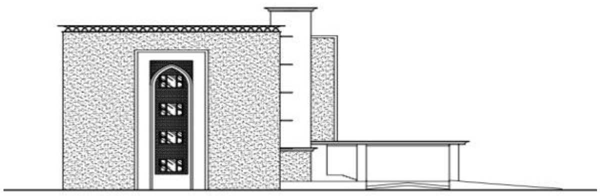
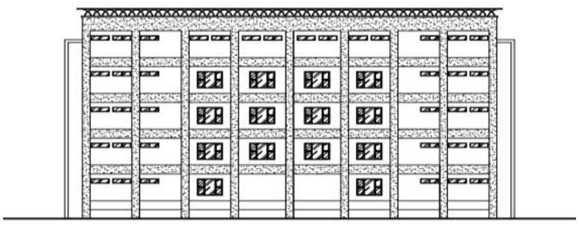


Figure 6. Rear View

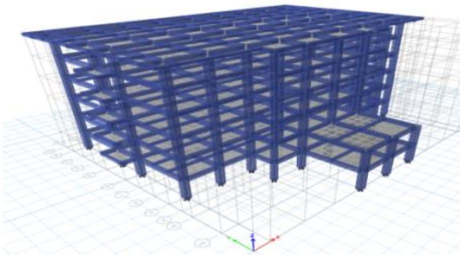


B. Building Structure Modeling

The types of structural loading used in the ETABS V.16.2.1 software are many and varied, but not all types of loading must be used in a loading, but enough to be used as needed. For this analysis using the load, namely:

1	Dead load	=	Self-weight of structural elements such as beams, plates and columns.
2	Live load	=	Reduced live load
3	SIDL	=	Additional dead load.
4	RL	=	Additional live load on the roof floor
5	GRAFITY	=	Gravity load
6	PUSH X	=	Lateral load for x direction pushover analysis
7	PUSH Y	=	Lateral load for y direction pushover analysis

Figure 7. 3D modeling with ETABS V.16.2.1 software (Capture: ETABS)



In this case the structure is modeled from the existing data structure using the Etabs v16.2.1 program with the following steps:

a. Create a grid line for modeling.
b. Defines structural materials.
c. Make structural elements in the form of beams, columns, floor plates and define cross sections.
d. Applying structural elements to the grid of beams, columns and plates according to the geometry of the structure.
e. Define and input the load on the structure in the form of live & dead loads, as well as other calculated loads.
f. Perform modeling assumptions:
   1) Mesh Area on the floor plate
   2) Floor plate diaphragm
   3) Rigid Zone Factor / End Length Offsets, For Beam & Column Stiffness
   4) Definition of clamping level
   5) Define Mass Source
   6) Model Check

a. Defines a pushover load case in the form of a Gravity load, a Push-X load, and a Push-Y load.
b. Determine the pushover loading reference point
c. Defining Plastic Joints (Hinges)
d. Running Non-Linear Pushover Analysis
e. Discussion result

RESULT AND DISCUSSION

Pushover analysis was carried out using the Capacity Spectrum Method in accordance with ATC-40, FEMA 356 and FEMA 440. For pushover analysis, it was very appropriate to do it with the help of ETABS V.16.2.1 software.

The joint properties in this modeling for column elements use the P-N2-M3 hinge type, while for beam elements the default-M3 hinge type is used, because the beam effectively resists the moment force in the direction of the strong axis (axis-3), so that plastic hinges are expected to occur at beam element. Plastic hinges are assumed to be located at each end of the column and beam elements.

At the time of pushover analysis using ETABS V.16.2.1 software the running process is carried out by entering two kinds of running processes, namely as follows:

GRAVITY	:	the push-gravity process is carried out with 100% dead load (Dead Load) & 100% additional dead load (SIDL), then 25% live load (Live Load) and 25% roof live load (RL)
PUSH-X	:	the push-X process is carried out with acceleration in the direction of X, UX, U1 which is based on gravity loads with a displacement control of 2% of the total building height. (480mm)
PUSH-Y	:	the push-Y process is carried out with acceleration in the direction of Y, UY, U2 which is based on the gravity load with a displacement control of 2% of the total building height. (480mm)

The pushover method is a non-linear static analysis where the influence of the design earthquake on the building structure is considered as static loads that exist at the center of mass of each floor, whose value is gradually increased until it exceeds the loading that causes yielding (plastic joints). First, in the building structure with a further increase in load, it undergoes a large post-elastic deformation until it reaches a plastic condition. The results of the pushover analysis carried out with the non-linear ETABS V.16.2.1 software are the capacity curve (Capacity Cruve) of the melting scheme in the form of the distribution of plastic joints that occur and the Performance Point.

The capacity curve shows the relationship between earthquake forces and displacements that occur until the structure collapses. The displacements reviewed are the displacement of the roof and the base shear. The capacity curve and the plastic hinge yielding scheme can be seen in Figure 8 and Figure 9 below.

Figure 8. Push – X Capacity Curve

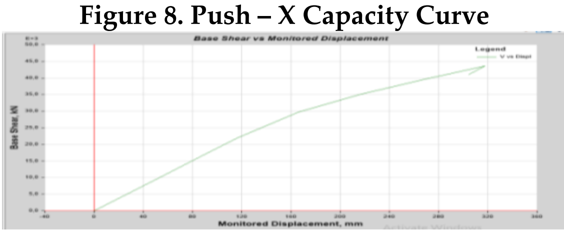
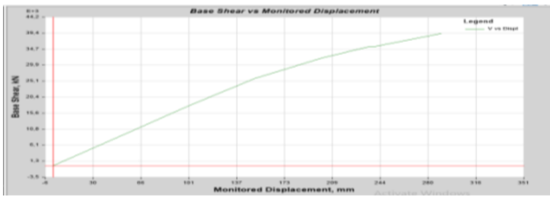


Figure 9. Push – Y Capacity Curve



The calculation results from the X-direction pushover analysis in step 4 have occurred the first yielding of the structure with a lateral force of 29808.9336 kN and a displacement of 166.771 mm, then from the Y-direction pushover analysis also the first yielding occurred at step 4 with a lateral force of 25869,7006 kN and produces a displacement of 150,288mm. Meanwhile, from the X-direction pushover analysis at step 8, the lateral force resisted by the structure is 43561.8104 kN and produces a displacement of 317.32 mm, then the structure experiences a decrease in the base shear force and collapses, as well as the Y-direction pushover analysis. able to be resisted by the structure, which is 39274.5448 kN and produces a displacement of 289.851 mm, then the structure experiences a decrease in the base shear force and collapses.

Defining plastic hinges aims to conform to the Beam Sway Mechanism (Strong Column Weak Beam) mechanism, so that plastic hinges for structures are planned to occur in the basic beam and column elements of the building. From the results of the analysis that has been carried out, it can be seen the location of the plastic hinges formed in the beams and columns. In Tables 5 and 6, it can be seen the distribution of plastic hinges for push-X and push-Y.

Table 5. Base Shear vs. Monitored Displacement (Push-X)

Step	Monitored Displ (mm)	Base Force kN	>CP
0	-0,011	0	0
1	47,989	9045,3124	0
2	95,989	18090,6603	0
3	116,368	21930,9579	0
4	166,771	29808,9336	0
5	214,809	34889,9622	2
6	267,523	39529,1069	2
7	315,748	43432,2180	4
8	**317,32**	**43561,8104**	**4**
9	304,741	41019,5807	4

(Source: ETABS, Pushover Cruve)

Push-X . Drift Ratio Value

Maximum Total Drift $= \frac{Dt}{H}$

$= \frac{317{,}320\ mn}{24000\ mm}$

$= 0{,}013\ mm$

Maximum Inelastic Drift $= \frac{Dt\ - D1}{H}$

$= \frac{317{,}320\ mm\ - 47{,}989\ mm}{24000\ mm}$

$= 0{,}011\ mm$

Table 6. Base Shear vs. Monitored Displacement (Push-Y)

Step	Monitored Displ (mm)	Base Force kN	>CP
0	0,069	0	0
1	48,069	8407,8566	0
2	96,069	16816,5722	0
3	101,986	17853,3111	0
4	150,288	25869,7006	4
5	199,812	31940,1316	6
6	236,500	35454,6816	12
7	236,516	35457,0452	12
8	240,435	35446,1251	26
9	289,839	39274,0806	32
10	289,851	39274,5282	34
11	**289,851**	**39274,5448**	**34**

(Source: ETABS, Pushover Cruve)

Push-Y . Drift Ratio Value

Maximum Total Drift $= \frac{Dt}{H}$

$$= \frac{289{,}851\ mn}{24000\ mm}$$

$$= 0{,}012\ mm$$

Maximum Inelastic Drift

$$= \frac{Dt - D1}{H}$$

$$= \frac{289{,}851\ mm - 48{,}069\ mm}{24000\ mm}$$

$$= 0{,}010\ mm$$

According to the ATC-40 drift ratio limit, the results of the above calculation show that the Campus II Building of the Muhammadiyah University of West Sumatra is included in the Damage Control (DO) performance level, this means that in the event of an earthquake the structure is able to withstand an earthquake with little structural damage, the people who live / are the building is safe.

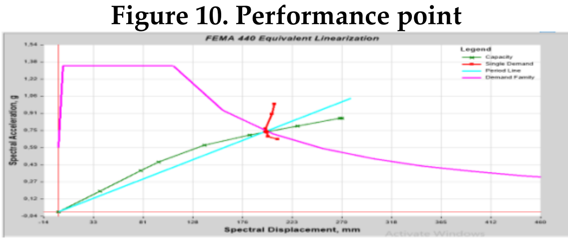
Table 7. Limitation of Drift Ratio

Interstory Drift Limit	Performance Level			
	Immediate Occupancy	Damage Control	Life Safety	Structural Stability
Maximum Total Drift	0,01	0.01 - 0.02	0,02	0.33 Vi/Pi
Maximum Inelastic Drift	0,005	0.005 - 0.015	no limit	no limit

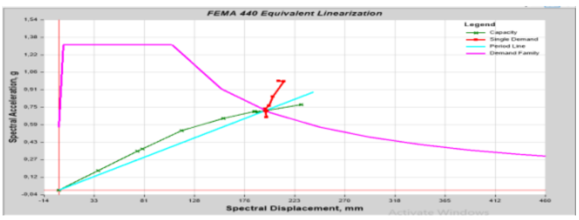
(Source: ATC-40)

Based on the design spectrum response curve from the 2011 earthquake map for values of Ss = 1.6 and S1 = 0.6 as input for pushover analysis in the Acceleration-Displacement Response Spectrum format, it is shown in Figure 10 below.

Figure 10. Performance point



(a) x direction



(b) y direction

The following is the data obtained from the Push-X and Push-Y performance points.

Push-X . performance point value

Push-Y . performance point value

V (kN)	=	36296,398	V (kN)	=	35890,284
D (mm)	=	230,790	D (mm)	=	246,167
Sa (g)	=	0,732	Sa (g)	=	0,715
Sd (mm)	=	195,830	Sd (mm)	=	193,121
T eff (sec)	=	1,002	Teff (sec)	=	0,987
B eff	=	0,073	Beff	=	0,067

From the analysis carried out using the ETABS V.16.2.1 software, the shear forces for Push-X and Push-Y are obtained, which can be seen in Table 8 and Table 9 below.

Table 8. Evaluation of the performance of the Push-X . structure

Gaya geser dasar (kN)	Performance Point			
	Vt (kN)	Dt	B eff (%)	T eff (detik)
34889,962	36296,398	230,790	7,32	1,002

(Source: ETABS, Pushover Cruve)

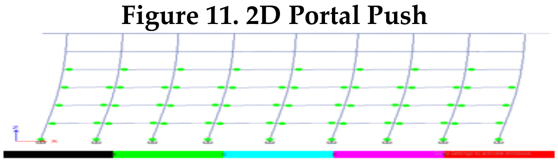
Table 9. Evaluation of the performance of the Push-Y . structure

Gaya geser dasar (kN)	Performance Point			
	Vt (kN)	Dt	B eff (%)	T eff (detik)
17853,311	35890,284	246,167	7,15	0,987

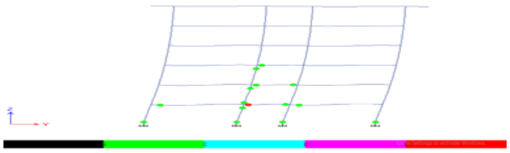
(Source: ETABS, Pushover Cruve)

It can be seen that the value of the basic shear force Vt Push-X = 36296.398 > Vx = 34889,962 kN and Vt Push-Y = 35890,284 kN > Vy = 17853,311 kN. The effective attenuation value (β eff) of Push-X is 7.32% and the value of the effective attenuation (β eff) of Push-Y is 7.15%, this value is smaller than the maximum allowable effective attenuation limit of 40%. So based on the capacity spectrum method the behavior of the structure in the x and y directions in the design earthquake has experienced inelasticity due to melting at the plastic hinges. The maximum displacement limit is 2%.H (480 cm), the displacement target from the push-X analysis is 230.790 mm < 480 mm and push-Y is 246.167 mm < 480 mm so that the building meets safety requirements. Picture. 7 and Fig. The following is a display of the occurrence of plastic joints from the push-X and push-Y analysis.

Figure 11. 2D Portal Push



(a) x direction



(b) y direction

In Figure 12 Push–X the displacement value is 304.741 mm at step 9 and in Figure 13 Push–Y the displacement value is 289.851 mm at step 11. At this stage the behavior of the Campus II Building of the University of Muhammadiyah Sumatra, West Sumatra, still behaves linearly. The occurrence of plastic hinges at level E indicates a linear boundary in the beam structure, which is then followed by the first yielding of the beam and column structures. Thus at this stage the building structure has also behaved non-linearly. The plastic hinge mechanism in the study shows that the analysis of the capacity of the building structure and the characteristics of the damage to the building structure when an earthquake occurs in the review building fulfills the concept of a strong column weak beam, which can be seen from Figures 12 and 13, namely the beam has yielded and collapsed while the column is still in good condition. linear.

From the results of this analysis, it can be determined the performance level of the structure based on ATC-40, FEMA 356 and FEMA 440, from the calculations with the three methods above, it can be tabled the value of the displacement target or performance point to determine the level of performance of the structure based on each method:

Table 10. Recapitulation of performance levels based on each method

Kriteria	Arah	Gaya geser (kN)	Dispalcement (mm)	Maximum Total Drift (mm)	Level Kinerja
ATC – 40	X	43561,8104	317,320	0,013	*Damage Control* (DO)
	Y	39274,5448	289,851	0,012	*Damage Control* (DO)
FEMA 356	X	36296,3983	230,790	0,010	Immediate Occupancy (IO)
	Y	35890,2837	246,167	0,011	*Damage Control* (DO)
FEMA 440	X	36296,3983	230,790	0,010	Immediate Occupancy (IO)
	Y	35890,2837	246,167	0,011	*Damage Control* (DO)

From the results of the evaluation of the performance level of the structure, the overall performance level of the Campus II University of Muhammadiyah Sumatra Barat is at the Damage Control (DO) level, this result explains that in the event of an earthquake the level of structural damage that occurs is between IO and LS. The Damage Control (DO) performance level indicates a building condition where the damage caused by the earthquake caused structural elements to begin to damage lightly but still in a condition that is easily repaired.

CONCLUSION

From the results of the analysis and evaluation of the structure of the Campus II Building, Muhammadiyah University, West Sumatra based on non-linear static analysis using the pushover analysis method with the help of ETABS V.16.2.1 software, the following conclusions are obtained:

1. Analysis with ETABS V.16.2.1 software obtained that the maximum shear force that can be accepted by the structure due to Pushover in the X Direction is 43561,8104 kN with the displacement that occurs due to the maximum shear force is 317.32 mm or 31.73 cm. And due to the Y direction pushover, the maximum shear force that occurs is 39274.5448 kN with a displacement value of 289.851 mm or 29.00 cm.
2. The Performance Point on the structure due to Push-X that occurred in the fifth and sixth steps resulted in a basic shear force of 36296.398 kN, displacement (Dt) 230.790 mm, effective damping (β eff) 7.32% and effective time (T eff) 1.002 seconds. And due to the Push–Y that occurs in the eighth and ninth steps, it produces a basic shear force of 35890.284 kN, displacement (Dt) 246.167 mm, effective damping (β eff) 7.15% and effective time (T eff) 0.987 seconds.
3. From the results of calculations with the help of ETABS V.16.2.1 software, it shows that the building reviewed as a whole is included in the performance level based on ATC-40, FEMA 356 and FEMA 440 namely Damage Control (DO), this means that if an earthquake occurs at The Campus II building of the Muhammadiyah University of West Sumatra suffered minor structural and non-structural damage, but this building is still safe to use and is still in a condition that is easily repaired.

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