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Evaluasi Displacement Horizontal Pasar Raya Padang Blok IV Berdasarkan Gaya Gempa Pada SNI-03-1732-2019

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Abstract

Pasar Raya Padang Market blok IV was built in 2016 as an resisting earthquake building based on SNI-1726-2012. The building has a building dilatation with a distance of 1 cm. The purpose of this study was to evaluate the dilatation distance of the Raya Padang Blok IV market building based on the seismic forces required in SNI-1726-2019.The evaluation method used in this research is numerical analysis method by using non-linier pushover over analysis. The numerical model used 3D model with the input material and the earthquake loading according to the proposed design and the response spctrum from SNI-1726-2019. This research evaluate overall structural performance of the buildings based on ATC-40. The results of the pushover analysis of the Raya Padang Blok IV Market building are the maximum displacement of the building of 9.936 mm, the allowable displacement is 320 mm, and the shear force to occur is 1409.094 KN, while the design shear force is 1508.3265. The results of this analysis conclude that the existing dilatation distance in the existing building meet the minimum requirement need based on this study. Building performance level reachs Immidiate Occupancy Level which means the building can be functioned immideately as the eartquake ends.

Keywords : Displacement, Pushover, dilatation, Earthquake

1. Introduction

Earthquake-resistant building is important criteria for building's safety in Indonesia, because there are many earthquake areas with low to high intensity[1]. Indonesia nasional standard require that standard earthquake resistant builing must have a regular, simple and symmetrical lay out. Buildings that are irregular in shape and located in earthquake areas should be provided with dilatation. Dilatation is necessary to reduce fatal damage such as torsion in buildings and pounding. Dilatation is obtained from the analysis of building displacement or shear forces that occur in the building structure.

Pasar raya market is an economic and activity center for Padang's citizen. As the main market, it is always full and packed with visitor to fullfill their needs. The building is located in a coastal area so that the Pasar Raya Padang building must be able to be used as a *shelter* in the event of a tsunami disaster. As a shelter, this building must not be damaged either in the structure or non-structural or structural performance level.

Seismic regulations in Indonesia continue to change, namely with the renewal of SNI-03-1726-2012 to SNI-03-1726-2019. The Pasar Raya Padang Block IV building is planned to withstand the earthquake load based on SNI 03-1726-2012. If the Padang Raya market building is analyzed using the SNI-03-1726-2019 earthquake force, it will change the earthquake force factor and may affect the horizontal *displacement* which is the basis for determining building dilation. The purpose of this study is to evaluate the dilatation of the Pasar Raya Padang Block IV building (Figure 1) which in its actual condition is 1 centimeter.

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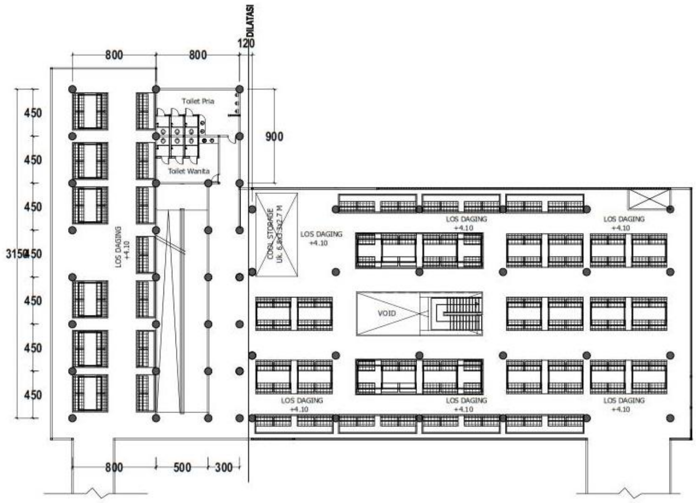

Figure 1 2nd Floor Plan of Pasar Raya Market

1.1 Earthquakes

An earthquake is a natural event in which there is a vibration on the earth's surface due to the sudden release of energy from the epicenter of the earthquake in the earth (*Hypocenter*). The released energy propagates through the ground in the form of vibration waves. The vibrations felt in the surface are called earthquakes[2].

Earthquakes are caused by collisions or friction between tectonic plates or the descent of the sea floor. Plates in larger oceans will collide with continental plates and sink downwards. The movement is slowing down due to friction from the earth's crust. The movement will produce a pile of energy in the friction zone and fault zone. When the elastic limit of the plate is exceeded, a fault occurs which produces sudden energy. This causes vibrations in all directions which is called an earthquake[3].

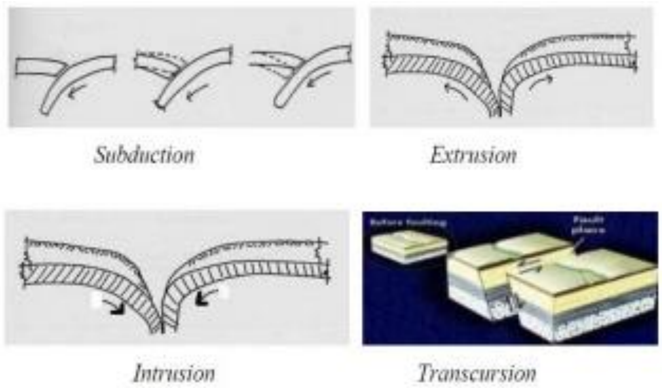

Figure 2 Schematic of shift/collision between plates

a. The mechanism of shift or collision between tectonic plates is as follows.*Subduction.* One tectonic plate is pointing downwards and the other tectonic plate is pointing up
b. *In extrusion,* tectonic plates approach each other and move up and away from each other.
c. *intrusion.* The two tectonic plates approach each other and move downwards.
d. *Transcursion,* one tectonic plate moves vertically/horizontally to the other plate.

1.2 Criteria for Earthquake Safe Buildings Earthquake-

Resistant buildings must be resistant to minor earthquakes without being damaged, resistant to moderate earthquakes even though damage occurs only to non-structural parts, resistant to large earthquakes without collapsing even though there is damage to buildings Earthquake-resistant buildings should have a simple regular floor plan that does not have excessive vertical protrusions, irregular buildings in earthquake-prone areas are feared to have fatal damage in certain parts [2][4].

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Buildings that are in order according to SNI-1726-2019 are as follows

a. The height of the building structure is not more than 40 m or 10 stories.
b. Plans of rectangular structures or not more than 25% of the largest building length.
c. The shape at the corner of the building does not exceed 15% of the size of the building plan in the direction of the side of the

1.3 Building

Dilation Dilatation is the separation of the building plan because the building does not belong to a symmetrical or regular building. Dilation is generally applied to the connection or meeting of a low building with a high one or with the main building and wing buildings and buildings whose plans are not symmetrical.

The design of earthquake-resistant buildings is to ensure that all general masses in the building from the bottom floor to the top floor have a symmetrical location with each other, an asymmetrical location will cause torsional moments to the building which can eventually collapse other parts of the building[5]. The desired building forms as an earthquake-safe building design are simple circular, square, L, T, or H-shaped plans, usually the form of a floor plan that is difficult to use in earthquake-safe buildings.

Desain pada bangunan tahan gempa adalah memastikan semua massa umum pada gedung dari lantai bawah sampai lantai paling atas memiliki lokasi yang simetris satu sama lainya, lokasi yang tidak simetris akan menimbulkan momen torsi terhadap bangunan yang pada akhirnya dapat meruntuhkan bangunan bagian lain [5]. Bentuk-bentuk gedung yang dikehendaki sebagai desain bangunan aman gempa adalah bangunan denah sederhana berbentuk lingkaran, bujur sangkar, bentuk bentuk L, T, atau H biasanya bentuk denah yang sulit digunakan dalam bangunan aman gempa.

Tujuan penggunaan dilatasi adalah antisipasi benturan yang terjadi pada bangunan dan menyebabkan kerusakan pada bangunan saat terjadi gaya vertikal maupun horizontal. Kerusakan biasanya terjadi pada pojok-pojok bangunan, akibat terjadinya beban lateral maka beban bergetar sendiri-sendiri. Perlunya pemisah bangunan dengan jarak yang telah diperhitugkan agar tidak bertumbukan. Dilatasi memiliki beberapa jenis yaitu dilatasi balok kantilever, dilatasi menggunakan 2 kolom, dilatasi balok gerber, dilatasi balok gerber.

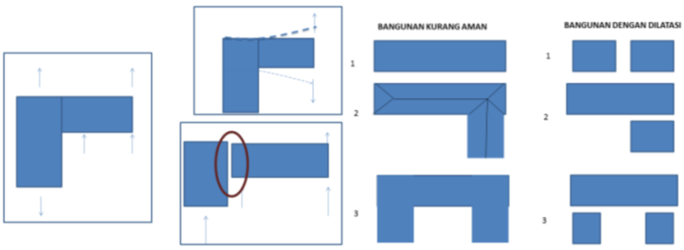

Figure 3 Various Forms of Dilation in Asymmetrical Buildings

1.4 ATC-40 Building Performance Criteria

The design of earthquake-safe buildings requires regulations to ensure the safety of building users against earthquakes and also minimize damage to building elements [6]. The criteria for earthquake-resistant buildings according to the *Applied Technology Council* (ATC) 40 of 1996 are 3, namely.

a. *Immediate Occupancy*

When an earthquake occurs, the structure is able to withstand the earthquake so that there is no damage to the building, both structural and non-structural elements, so that buildings in this category can be used immediately.

b. *Life Safety*

In the event of an earthquake the structure is able to withstand earthquakes, causing damage to non-structural elements. This building can be used if it gets a moderate repair.

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c. *Collaps Prevention*

The structure was damaged during the earthquake but the building did not collapse. This building cannot be used if it is not repaired

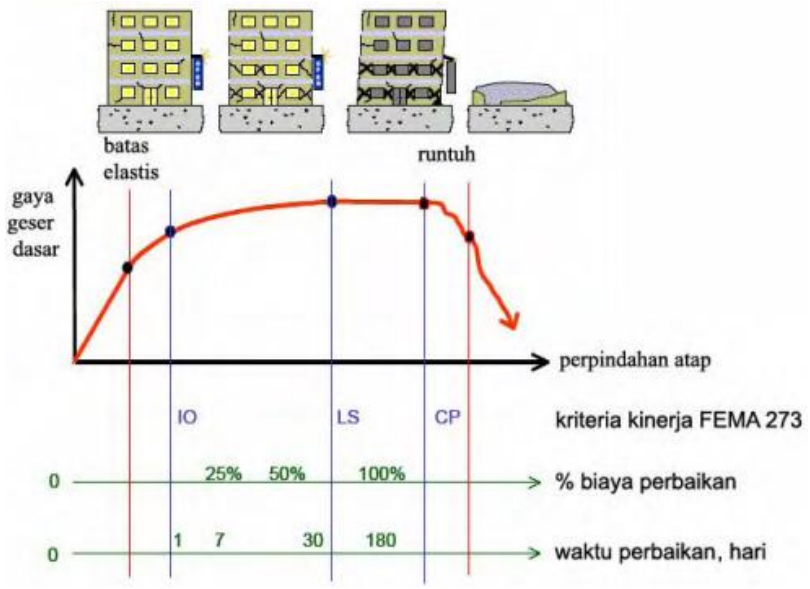

Figure 4 Illustration ofbuilding collapse

The Applied Technology Council (ATC) 40 of 1996 recommends displacement limits for building structures due to earthquake loads. The basic concept of performance refers to non-linear static structure analysis.

Table 1 Drift Ratio Constraints

	Derajat Performace			
Interstorey Drift Limit	IO	DC	LS	SS
Max Total drift	0.01	0.01-0.02	0.02	0.33 Vi/ Pi
Max Inelastic Drift	0.005	0.005-0.015	-	-

Max Total Drift

$$\text{Dmax} = \frac{\text{Dt}}{\text{Htot}}$$

Max Total In-elastic

$$\text{Dimax} = \frac{(\text{Dt} - \text{D1})}{\text{Htot}}$$

Dt = Total roof displacement
D1 = displacement at the first plastic hinge condition
Htot = total structure height

1.5 Linear Pushover

Analysis Static analysis of thrust load is a non-linear analysis that analyzes the influence of earthquakes in the lateral direction on the building structure which is considered as a static load at the center of mass of each floor and is increased gradually (incrementally) proportionally until it reaches the target or is on the threshold collapse or plastic hinge[7], .linear analysis *Pushover* requires a computer to draw on real buildings. Some computer programs that can be used are SAP2000, ETABS, GTStrudl and Adina.

Analysis *Pushover* can be used as a tool for planning earthquake resistant buildings if it meets the following requirements:

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a. The results of the pushover analysis are still in the form of methods, but the actual seismic behavior changes over a certain period of time, while the load characteristics of the pushover analysis are monotonous and static.
b. It is important to select the lateral load in the analysis.
c. The non-linear analysis model will be more complicated than the linear model, because it will take into account the deformation load of the structural elements.

1.6 Hinge

Plastic joints are an incapable form of the building structure in the strong column weak beam design design or the concept of strong column and weak beam [8]. Plastic hinges are modeled on column and beam elements, the designed beam is the moment M3, and the plastic hinge column used is the axial force (P), the local axis moment 2 (M2), and the moment in the direction of the 3 axis (M3).

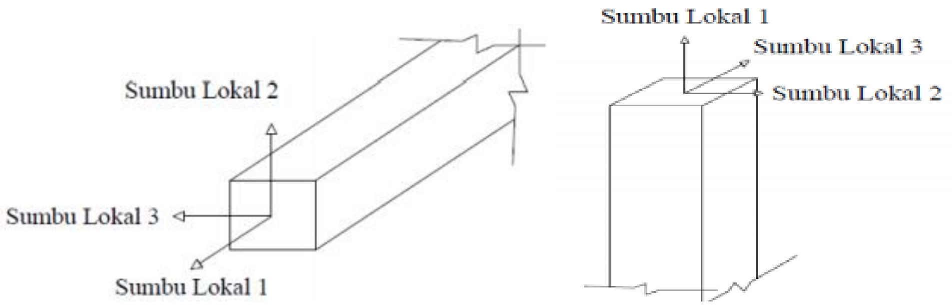

Figure 5 Position of Local Axis Beam (right) position of local axis of column (left) in SAP2000 Program

Determination of the plastic hinge position is desired to occur at position 0 meaning that the plastic hinge is at the beginning of the element length, and expressed by 1 is the end of the element length.

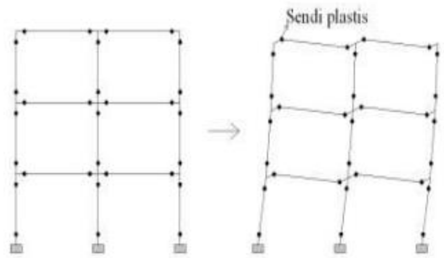

Figure 7 Plastic Joint Position in Building Structure

The building structure when receiving earthquake loads at levels or conditions certain plastic hingeswill occur *(hinge)* in the beams in the building [9]. Plastic hinge is a form of inability of beam and column structural elements to withstand internal forces. If there is a collapse, it is the first beam that collapses as the principle of aearthquake resistant building *strong column weak beam*, where if the column is destroyed first the building will be destroyed.
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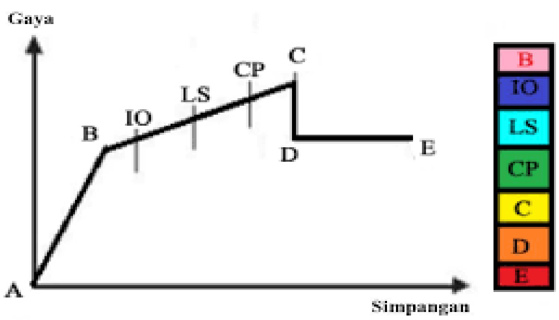

Figure 8 Curves of Plastic Joints

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Table 2 Properties of Plastic Joints

B	Menujukan batas linear yang diikuti terjadinya pelelehan awal pada struktur.
IO	Terjadinya kerusakan kecil atau tidak berarti pada struktur, kekakuan struktur sedikit berkurang atau sama saat sebelum gempa terjadi.
LS	Terjadi kerusakan berawal dari kerusakan kecil sampai dengan kerusakan sedang, kekakuan berkurang, tetapi masih aman terhadap keruntuhan.
CP	kerusakan serius pada struktur, kekuatan dan kekakuannya sangat berkurang, yang disebabkan oleh kecelakaan yang disebabkan oleh jatuhnya *material*.
C	Gaya geser paling besar masih di tahan oleh bangunan.
D	Gaya geser yang cukup besar, bangunan tidak stabil dan akan rubuh.
E	Bangunan rubuh, tidak dapat menahan beban

2. Methods

In order to carry out research on theEvaluation of Displacement Horizontalthe Padang Raya market Block IV, several stages of activities were carried out as follows Pemodelan Tiga Dimensi (3D)

2.1. Three Dimension Modeling (3D)

modeling is carried out by adjusting the analysis model withdrawings *As Built Drawing* , adjusted for all models of building structural elements.

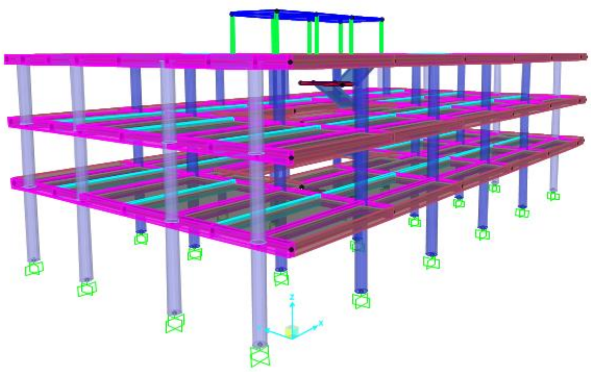

Figure 9 Three-Dimensional (3D) Modeling

2.2. Calculation of load

Calculation of the load acting on the structure in the form of dead load, additional dead load and live load. The dead load is calculated from the existing modeling where the building's own load is calculated by SAP2000 and entered into the *DEAD load case*, the additional dead load is a dead load that is not calculated by SAP200 such as architectural loads, and wall loads. The load shown below is the SIDL load in the form of additional dead loads in the form of floor covering loads, selling table loads, and ceramic specific loads. Load L is the live load whose value is sourced from SNI-1727-2020, the live load for functional market buildings is 6 kN. Load R is the rain load calculated using the design rain load equation in SNI-1727-2020.

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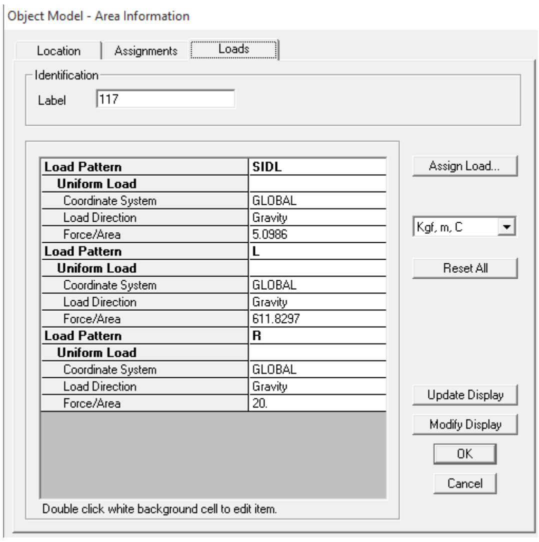

Figure 10 Load information inputted in SAP2000.

2.3. Determination of Plastic

Joints Plastic hinges are designed to occur in the main beam and column, because the beam exposed to the load will affect the moment in the direction of the 3 axis (M3), while in the column subjected to the load it will affect the axial force (P) and the local axis moment 2 and the local axis 3 (PM2M3). Analisis Pembebanan Non-Linear.

In case of *pushover* static, two types of loading will be carried out, the first is gravity loading. In this analysis the gravity load used is a constant load with a factor of 1 and live loads with a factor of 1 (considering that the analysis is not influenced by any factors). After the first condition is completed, the load on the building will continue to the second condition, which is due to side loading. The lateral load pattern that represents the inertial force due to the earthquake on each floor is obtained from the load pattern according to the first pattern of the structure. The direction of the lateral load is the same as the direction of the main axis of the building. In the case of a static pushover with a gravity load, choose to push to the load level specified by the mode, since the effective gravity load has already been calculated. In this analysis the pushover condition of the gravity load is called GRAV.

2.4. Structural Performance Analysis From Pushover Analysis Results

In the SAP2000 program, the results of the analysis obtained acurve *pushover* capacitythat will show the behavior of the structure when given a shear force from the *response spectrum* according to the earthquake acceleration in the building area. The discussion of the results of the pushover analysis is concluded from the *displacement* of the given force and will get a conclusion in the form of building performance and how much dilatation distance is needed for the building to avoid collisions between other buildings. Building performance is stated based on the ATC-40 regulations.

2.5. Comparing the Maximum Displacement with the existing Dilatation in the Existing Building

The results of the pushover analysis in the form of the displacement value are compared with the dilatation distance in the Pasar Raya Padang Block IV building. From the comparison, it can be assessed whether the building is safe against earthquake forces according to SNI-03-1726-2019.

2.6. Flowchart

The research method can be seen in Figure 11.

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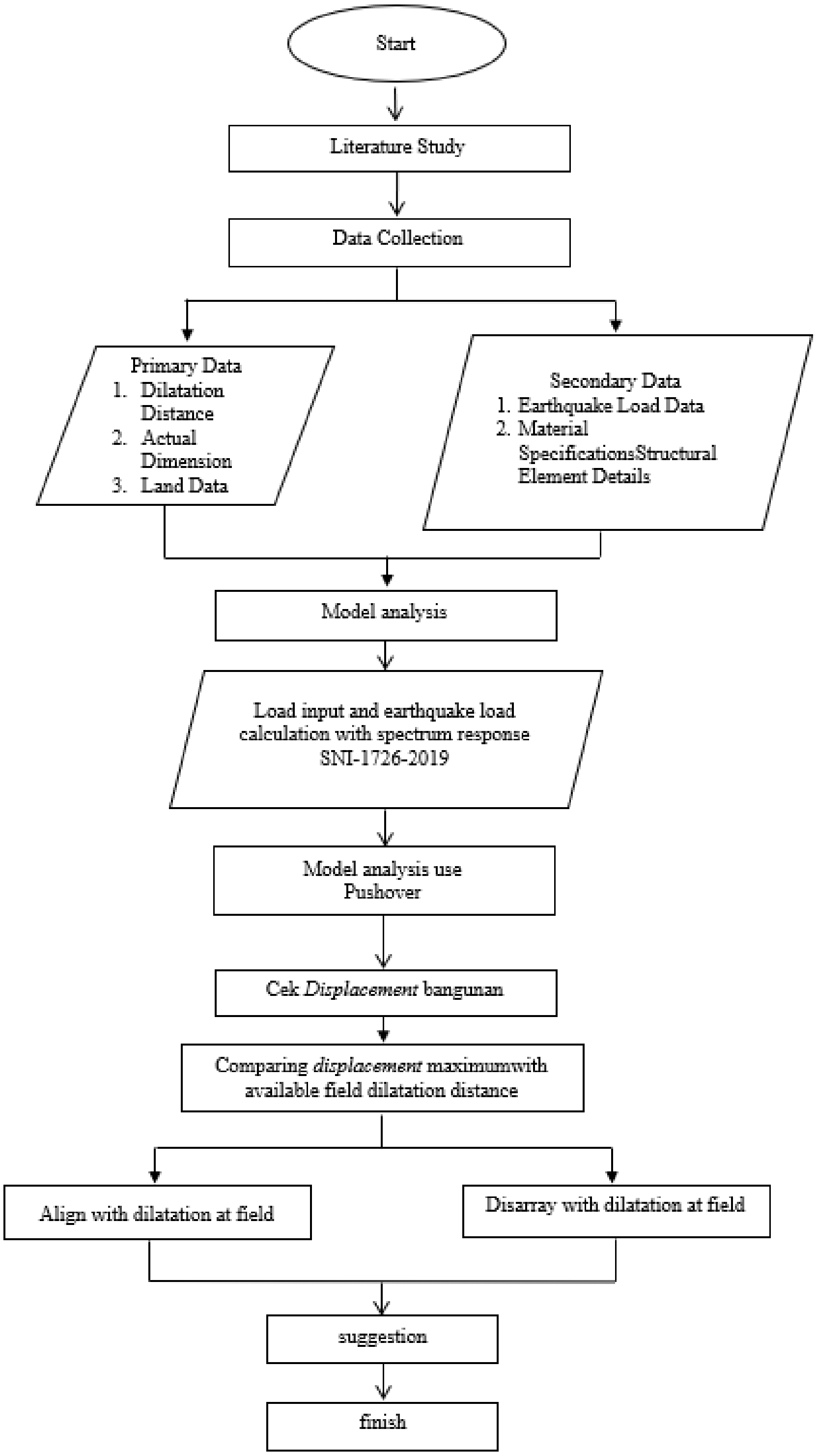

Gambar 11 Flowchart

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3. Result and Discussion

3.1. Displacement

Based on the results of pushover analysis using the SAP2000 program, the results are in the form of graphs and data in the form of shear force, *displacement*, effective period, effective damping.

Table 3 Recap of SNI-1726-2019 Pushover

Performance point			
Base Shear (V) (KN)	*Displacement* (D) (mm)	Effective Period (Teff) (dt)	Effective Damping (Beef) (%)
1409,094	9,396	0,549	5,1

Table 4 Recap of Pushover Results Using SNI 1726-2012

Performance point			
Base shear (V) (KN)	*Displacement* (D) (mm)	Effective Period (Teff) (dt)	Effective Damping (Beef) (%)
1519,516	10,094	0.55	5,1

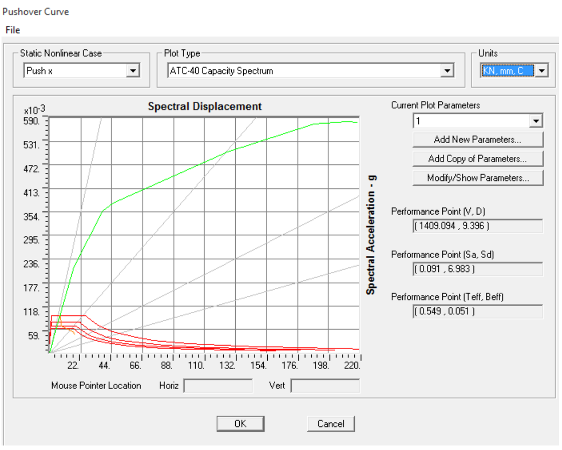

Figure 12 Pushover Results With SNI-1726-2019 Earthquake Load

3.2. Planned

Shear Force Approach shear force of 1774,4963 kN multiplied by 0.85 then the result is 1508,3236 kN smaller than the shear force that occurs in the building in the first analysis 1409.094 kN and the second analysis 1519,619kN then these results are in accordance with shear force contro

3.3. Permission Deviation Control

The permit deviation according to SNI 1726-2019 is 25% of the building height, the building height is 12.8 m, then them. The *displacementdisplacement* permitis 0.32that occurs in the building is smaller than the permit displacement. This proves that the working force of the building is still safe for the building structure.

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3.4. Structure Ductility and Structure Performance

Calculation SNi-1726-2019

$$\mu = \frac{\Delta \max}{\Delta 1}$$

$$\mu = \frac{0{,}0094}{0{,}003798} = 2{,}475$$

Based on the ductility requirements, the ductility value is not less than 1.0 and not more than 5.0, then the ductility is qualified.

Maksimum Total Drift

$$Dmax = \frac{Dt}{Htot}$$

$$Dmax = \frac{0{,}0094}{12{,}8} = 0{,}00734 < 0{,}01$$

3.5. Actual Dilation Analysis

Distance dilatation that exist in the actual building is 0,01 m while the *dispacament* building is 0.0094 mthen there is a safe distance so dilated that secure buildings against seismic forces.

3.6. Session

From the results of the pushover analysis carried out on the Pasar Raya Padang Block IV, the *displacement of the* buildingbuilding according to the SNI-1726-2019 earthquake force according to the 2021 RSA was obtained at 9.396 mm, while the displacement based on the SNI 1726-2012 earthquake force was 10.094 mm, then the dilatation distance existing in the Pasar Raya Padang Block IV building meets the requirements for dilatation. The shear force in the pushover analysis with SNI-1726-2019 is 1409.094 KN and the shear force that occurs with the SNI-1726-2012 analysis is 1519,516 KN, this value meets the requirements for the design shear force of 0.85V is 1508 ,3265 KN.

Table 5 Data Recap of Analysis Results

NO	Review	SNI 1726-2012	SNI 1726-2019
1	Base Shear (V) (kN)	1519.516	1409.094
2	Displacement(mm)	10.094	9.396
3	Effective Period (Te_{ef}) (s)	0.55	0.594
4	Effective Attenuation (%)	5.1	5.1
5	Ductility	2,8804	2,475
6	Maksimum Drif Total	0.00085 <0,01	0.000734<0,005
7	Maksimum Inelastis Drift	0,0005579< 0,01	0,0004376<0,005

4. Conclusion

Displacement of the building resulting from the pushover analysis is 9,396 mm, this will be the dilatation distance that should exist in the building so that the building does not collide with other buildings, where the existing dilatation is 1 cm, Pasar Raya Padang Blok IV has a performance level, namely *Immediate Occupancy*. So the building can be used as a temporary evacuation site in the event of a tsunami.

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