Seismic Evaluation of Existing Building Structures in the City of Madiun using Pushover Analysis

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Abstract. This paper presented the seismic evaluation of the existing building structure in Madiun city. The selected building analysis is Parkir Building of Pasar Besar Madiun city that located at Panglima Sudirman street Madiun city Indonesia. The structural system of this building is Moment Resisting Frame (MRF). The building structure is reinforced concrete. Seismic load calculation use equivalent static load analysis base on Seismic Resistance Design Standart for Building Structures (SNI 1726:2012). Pushover analysis of this building use software ETABS version 9.00. Aim of this research to know the performance level of this building. The pushover analysis is a relatively simple tool for Performance Based Seismic Evaluation (PBSE).

1. Introduction
Several zone of Indonesian country is located in ring of fire that dangerous to earthquake effects. Several major earthquakes happened in Indonesia. Some of the earthquake phenom overthrow a lot of buildings and killed a lot of man. In 2012 the Indonesian government revised code for design of buildings under earthquake loading, 03-1726-2002 SNI revised by 1726:2012 SNI. This SNI is based on the American Society of Civil Engineering 7-10 [1].

Rohman studied comparison 2 code above, the using of 03-1726-2002 SNI and 03-1726-201X RSNI. The object of analysis the building structure 5 stories that located in Madiun city. The results of analysis is calculation of earthquake load based on 03-1726-201X SNI enhance 27,5% [2].The planned building is based on 03-1726-2002 SNI required to be evaluated to determined its performance. If the structure of the building is insufficient the requirements, the building structure must be strengthened to enhance structural capacity of building.

The pushover analysis is a static non-linear analysis under incrementally increasing pattern of lateral loads. By pushover analysis obtained capacity curve. Capacity curve is curve between the base shear versus roof displacement of model structure [3]. The pushover analysis used to evaluate the capacity of the structure and included an effective tool for Performance Based Seismic Evaluation (that is the latest concept of earthquake engineering). Pushover analysis can be used to investigate the structural seismic response of the existing buildings and newly designed building. Analysis can be done using computer software analysis of structure such as Structural Analysis Program (SAP) 2000, ETABS, ADINA, Staad Pro, etc.

There is a lot of research about pushover analysis used to determine capabilities of building structures, such as Abhijeet A. Maske et. al [3], Rohman, et. al [4], Mohammed Ismail [5], Deep and Raju [6], Daniel and John [7], Patel Jalpa R, et.al [8], Raut and Prasad [9], Handana, Carolina and
Steven [10] and etc. From their study can be concluded that the pushover analysis can be used to know performance level of building structure. This paper will analyze Parking lot building of Pasar Besar Kota Madiun at Sudirman street, Madiun city, Indonesia. This building structure was constructed in 2015. This building planning reference is 03-1726-2002 SNI. The modelling of structure and pushover analysis of this building structures using ETABS software 9.00 version. The structural analysis will be applied to the existing structures and then analyzed with pushover analysis.

2. Methods
The method used in this research is structure modeling and analysis by computer software.

2.1. Structure Modeling and Analysis
The structure modeling using computer software ETABS 9.0. The object of this modeling is Parking Building of Pasar Besar Kota Madiun (PBM) buildings. The PBM parking building is located at Panglima Sudirman street, Madiun city, Indonesia. The PBM Parking building structures are reinforced concrete structures. The stories numbers are 3 and column height each story 4.0 meters. The concrete grades is 26.4 MPa’s (base on Hammer test results from Civil Engineering Laboratory Merdeka University of Madiun). The steel grade is 400 MPa for longitudinal reinforcement and shear reinforcement steel with 240 MPa’s grades. In modeling, the support of base was assumed fixed. The structural model’s shown in figure number 1 and the building data that used for the modeling of building structures was shown in the table number 1 below.

![Fig. 1. Model of structure](image)

| Table 1. Building Data |
|------------------------|
| Property               | Value   |
| Length of building     | 40 m    |
| Width of building      | 40 m    |
| Thickness of slab      | 150 mm  |
| Beam B1                | 500 x 700 |
| Beam B2                | 400 x 600 |
| Columns K1             | 600 x 600 |
| Coefficient of response modification (R) | 5.5 |
| Primary factor of building (I) | 1.0 |

2.2. Static Equivalent Analysis
Earthquake load’s calculate is using the static equivalent analysis (for regular buildings) [11]. The calculation of base shear (V) base on SNI 1726:2012 [12] by following equation below:

\[ V = Cs \cdot W \]  

(1)

Where the Cs’s is coefficient of seismic responses, and W’s is effective seismic weight. The base shear is distributed as a lateral forces that assigns at the selected joint of each level stories of the building. The calculation of lateral forces (Fx) of each story applied by using the equation below:
Fx = Cvx.V \quad (2)

\[ \text{Cvx} = \frac{\sum_i w_i h_i^k}{\sum_i w_i h_i^c} \quad (3) \]

where
\- wi = story weight
\- Cvx = vertical distribution factor
\- hi = column height
\- n = story number
\- k = exponent related to structural period

3. Result and Discussion
3.1. Equivalent Static Load Analysis

The earthquake analysis is using the static equivalent load based on SNI 1726:2012.

Coefficient seismic response \( C_s = 0.114 \)

Weight of structure \( W = 32644.41 \text{ KN} \)

Base shear \( V = C_s \cdot W = 0.114 \times 32644.41 = 3722.94 \text{ KN} \)

The calculation results of lateral force each story can be shown at table 2 below. The lateral force assigned on diaphragm joint each story.

| Table 2. Lateral Force |
|------------------------|
| Story | Cvx | Lateral Force (KN) |
|-------|-----|-------------------|
| 3     | 0.470 | 1749.24 |
| 2     | 0.344 | 1280.24 |
| 1     | 0.186 | 693.46 |

3.2. Pushover Analysis

The pushover analysis was done after analyse of structural model finished. The step for analyse including modeling, define property of material, define static load case, define load combinations, assign load and running analyse. The last step is concrete frame design.

For pushover analysis first define non linear hinge properties. Next step assign frame hinge property and define static non linear pushover case. In this step apply the permanent gravity loading and then subsequently use lateral force due earthquake load to get capacity curve. Pushover analysis results known the ultimate base shear is around 15301 KN. The maximum displacement is 197 mm. The spectrum capacity curve of the model is shown by number 3 Figures. Red curve in the number 3 figures shows the response of the spectrum curves of various damping ratios. At the performance point, the number of base shear is 10607 kN and the corresponding displacement is 63 mm. Value of the base shear at performance point is less than value of base shear from equivalent static load 3722.94 KN.
Fig. 2. Base Shear vs Displacement

Fig. 3. Capacity Spectrum

Fig. 4. Plastic Hinges
The pushover analysis was including 8 steps (fig. 2 shows resultante base shear vs displacement, fig. 3 shows capacity spectrum curve, fig. 4 shows plastic hinges location at step 4 and fig. 5 shows plastic hinge pattern for pushover analysis). On the observation, the subsequently push to the model of building structures, the plastic hinges started forming in the beams at story number 1 (not in columns). Initially the plastic hinges were B-IO stages, then proceed to IO-LS stage and to LS-CP’s stage. At performance point, out of 2100 assigned hinges, consist of 1785 hinges were in A-B stage, 57 hinges formed in B-IO stage, 115 hinges in IO-LS stage and respectively 143 hinges are in LS-CP stages. At performance point, plastic hinges shown in LS-CP range. Overall performance of this building could be categorized in between Life Safety (LS) to Collapse Prevention (CP) stages.

4. Conclusion
The Pushover analysis using ETABS version 9.00 software can be use to know performance level of building structure. Result analysis known performance level the Building Parking of PBM Madiun city is Life Safety to Collapse Prevention (LS-CP). At performance point, where the capacity and demand meet, value of base shear 10607 KN.

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