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Performance of asmetric structures reviewed with based plastic design performance (case study of application on building in Pekan Baru)

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Abstract. Performance-Based Plastic Design (PBPD) is a structural analysis that can be used to review structural performance. This method is increasingly popular to be used in the earthquake-prone area. This method is based on energy method that can be applied to steel or concrete structures. Meanwhile, Indonesia has already SNI 1726:2102 to be used as a guide in designing the thrust load to review the level of structural performance. Both of these things need to be used as a reference in areas that were initially considered safe from the earthquake but based on the development of earthquake micro zonation maps, it is very possible to become potential areas that also become earthquake regions. For this reason, the case of the structure that was built in the Pekanbaru area was taken. From the analyses of structural behavior, the structure that applied PBPD has greater displacement than the structures that apply the thrust load of SNI 1726: 2012. The percentage of displacement that occurred was 8-37 %. Based on performance analysis, the structures according to PBPD shows a better level of performance to the application of SNI 1726: 2012 thrust load.

1 Introduction

The Government of Indonesia, through the Indonesian National Standardization Agency together with national earthquake experts, has set a standard in the planning of buildings that are earthquake-safe. This standard is contained in the Indonesian National Standard SNI 03-1726-2012 concerning Procedures for Planning Earthquake Resilience for Buildings. In this regulation, the planned earthquake is designated as an earthquake with the possibility of exceeding its magnitude over the life span of a 50-year building structure of 2 percent. The maximum earthquake is an earthquake with a 2500 year return period. The targeted risks considered are MCER - Maximum Considered Earthquake Targeted Risk-taking into (1) Hazard earthquake (damage hazard - MCE), (2) probabilistic MCER (3) deterministic MCER (fault) (4) Risk coefficient (4) Cr) or Collapse Fragility (Vulnerability): probability of structure collapse with earthquake risk = 2% of building age 50 years.

While the energy concept used in the Performance-Based Plastic Design (PBPD) method is very similar to the basic approach used by Housner (1956), Housner uses the difference between the energy inputted with elastic tension energy to obtain the plastic energy absorbed by the structure for the design of melting plan.

The PBPD method uses the selection of drift targets and yield mechanisms as base performance constraints. Both of these limits have a direct effect on the level and distribution of building damage. The basic earthquake shear force of the plan for the specified hazard level is calculated by equalizing the amount of load that works to push the structure monotonically to the target drift limit used for the distribution of new lateral loads from the plan load

PBPD uses lateral force calculation and refers to the energy balance method so that the value of the energy balance modification factor is obtained.

1.1 Purposes

The purpose of this paper is to analyze the structure's performance if it is subject to earthquake loads based on SNI 1726: 2012 and Performance-Based Plastic Design (PBPD). The performance reviewed is the process of plastic joints, structural displacement, displacement ductility and drift ratio of the structure.

1.2 Data structure

The technical data of the four-story office building reinforced concrete structure used are as follows :

Concrete strength, f_c' = 29 MPa,
Reinforcement steel strength, f_y = 400 MPa,
Building height = 14.5 m.

The Indonesian Earthquake Hazard Map used is the Map of 2010 and the Indonesian Spectra of 2010 contained in SNI 1762: 2012 on the Procedures for Earthquake Resilience Planning for Buildings and Non-

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Buildings. The Performance-Based Plastic Design method is based on studies by researchers Shih-Ho Chao and C. Goel (2005)

2 Loads on structure

The dead load used in the calculation is the own weight of building materials and building components taken by the Indonesian Load Regulations for Buildings 1983 as well as the Indonesian Loading Standards for Buildings (SNI 1727-1989). For self-weight, the structure is automatically calculated in the structural analysis program used.

2.1 Response Spectrum

The earthquake load used is for office buildings in the city of Pekanbaru. This dynamic load is in the form of a spectrum response contained in SNI 1726: 2012 with soft soil conditions, as shown in the following figure.

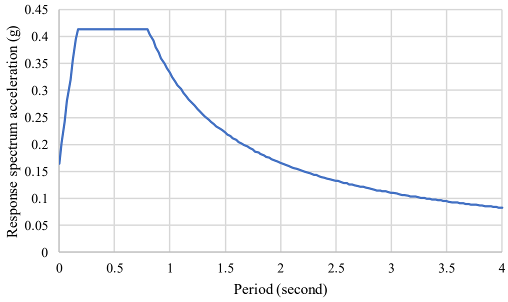

Fig. 1. The spectrum response of Pekanbaru City according to SNI 1726:2012

2.2 Earthquake load base on PBPD

Earthquake Shear Force used in Performance-Based Plastic Design (PBPD) is to use the following equation.

2.2.1 Plastic rotation (θ_u).

The value of the target drift (θ_u)is planned with a value of 2%, and the value of the yield drift ratio (θ_y)for reinforced concrete structures is 0.5%, then a value of 1.5% is obtained.

2.2.2. Ductility (μ_s)

The ductility is $\mu_s = \frac{\theta_u}{\theta_y}$ (1),

so the value of ductility is 4

2.2.3 A changing factor for the energy balance equation (γ)

$$\gamma = \frac{2\,\mu_s - 1}{{R_\mu}^2} \quad (2)$$

Value of R_μ is 2,65. Thus the value of the change factor for the energy balance equation is (γ) = 0,997

2.2.4 Shear force comparison factor (β_i)

$$\beta_i = \left(\frac{\sum_{i=1}^{n} w_i \ h_i}{w_n \ h_n}\right)^{0.75T^{-0.2}} \quad (3)$$

The value of period is (T) = 0,517 second, where $w_n \ h_n$ is the multiplication between the weight of the structure and the height of the structure on the top floor, so β_i the values for each floor on the second floor to the 5th floor are 3.3; 2.8; 2.0 and 1.

2.2.5 Plan shear force parameter ($\propto$)

$$\alpha - \left(\sum_{i=1}^{n}(\beta_i - \beta_{i+1})h_i\right)\left(\frac{w_n \ h_n}{\sum_{j=1}^{n} w_i \ h_i}\right)^{0.75T^{-0.2}} \left(\frac{\theta_p \ 8\pi^2}{T^2 g}\right)$$

The value of (α) = 4,598

2.2.6 The basic shear force of earthquake plan (V)

$$\frac{V}{W} = \frac{-\alpha \pm \sqrt{\alpha^2 + 4\gamma {C_e}^2}}{2} \quad (5)$$

Value of the basic shear force of earthquake plan V = 200848,74 kg

2.2.7 Lateral load on top roof (F_n)

$$F_n = V\left(\frac{w_n \ h_n}{\sum_{j=1}^{n} w_i \ h_i}\right)^{0.75T^{-0.2}} \quad (6)$$

The value of (F_n) = 488319,821 kg

2.2.8 Laeral load per floor i (F_i)

$$F_i = (\beta_i - \beta_{i+1})F_n \quad (7)$$

(while i = n, so $\beta_{i+1} = 0$)

Based on the loading according to SNI 1726: 2012 and the PBPD, then in Table 1 can be seen the lateral force value of each floor.

Tabel 1. Lateral force of each story (F_i)

Storey	Fi (SNI 1726:2012), (N)	Fi (PBPD), (N)
Rooftop	72236.855	49672.001
4th floor	90383.020	49796.213
3rd floor	82945.425	42062.805
2nd floor	46524.427	22652.992

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3. Analyses dan discussion

3.1 Structural Model

The structure design is carried out following the Procedures for Calculating Concrete Structures for Buildings (SNI 03-2847-2002). The structure is modeled as shown below

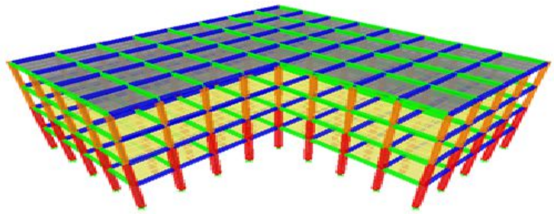

Fig 2. 3D model of the structure

3.2 Location of displacement observation

In analyzing the large differences in the value of displacement in the beams of the two structures, it is first necessary to determine the locations of displacement observation points that can be seen in Fig. 3.

3.3 Plastic hinges

Based on the results of pushover analysis on structures that apply SNI 1726.2012, it is known that the structure begins to experience the condition of the plastic joints in the 12th step, and then experiences the first melt in the 34th step with a displacement of 74.9895mm and then collapses in the 80th step with displacement of 171.5469mm with the actual structural ductility value obtained at 2.29. Based on the results of pushover analysis, it is known that the structure begins to experience the condition of the plastic joints of the 3rd step (Fig.4.), and then experiences the first melt in the 10th step with a displacement of 70.9935mm and then collapses in the 24th step (Fig. 5) with a displacement of 185.4619mm. The actual structural ductility value obtained was 2.612.

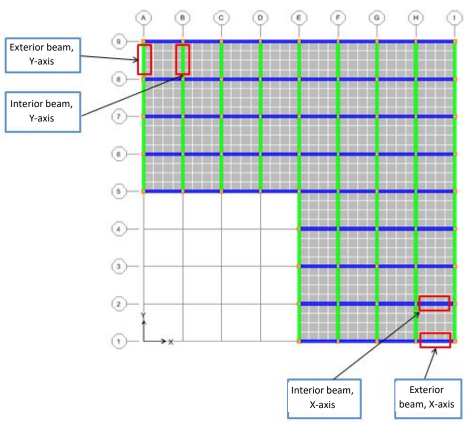

Fig.3. Location of displacement observation on beams

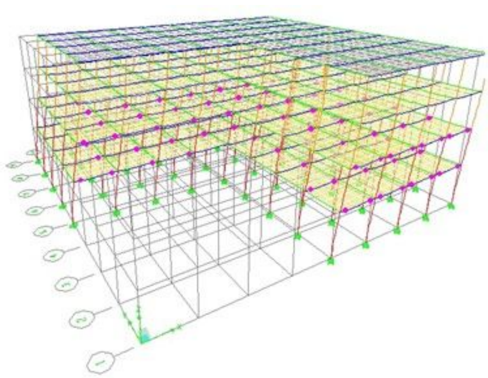

Fig.4. The first plastic hinge is based on Performance Based Plastic Design (PBPD) in step 3

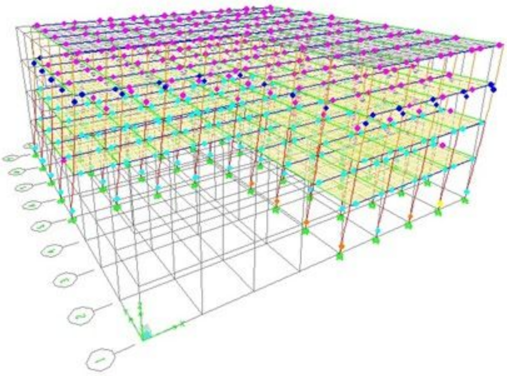

Fig.5. When a collapse occurs based on PBPD in step 24

3.4 Displacements of structure

The structural displacement that occurs according to the point of view is as illustrated in Fig. 6 to Fig. 9 below.

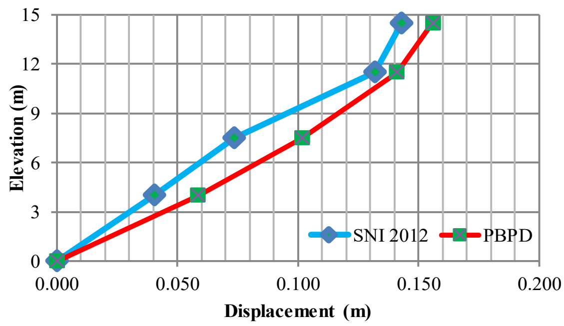

Fig. 6. Graph of total displacement (x) on X beam exterior

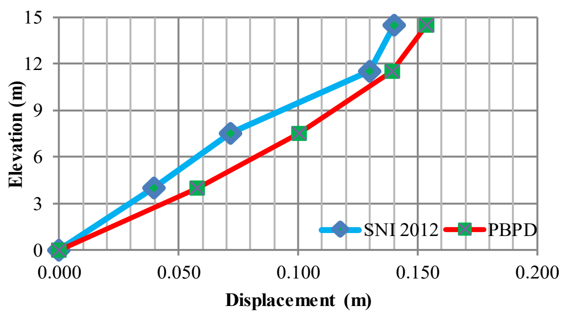

Fig. 7. Graph of total displacement (x) on X beam interior

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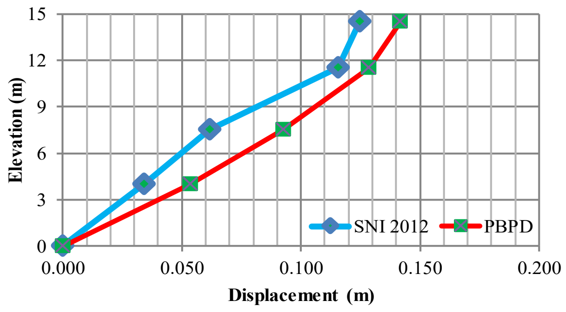

Fig. 8. Graph of total displacement (x) on Y beam exterior

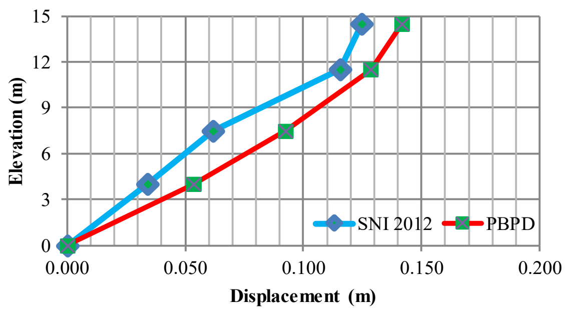

Fig. 9. Graph of total displacement (x) on Y beam interior

Based on the graph above, it appears that the displacement that occurs in the structure caused by earthquake loads based on Performance-Based Plastic Design (PBPD) is greater than SNI 1726: 2012. The percentage of the increase occurred at 8% - 37% at each review point.

3.5 Drift Ratio

At the beginning of planning, for structures analyzed using the method of Performance-Based Plastic Design (PBPD) it was determined that the value of the Yield Drift ratio was 0.5% (table 2.2). After a Pushover analysis, it is found that the Yield Drift Ratio value obtained is close to the planned Drift Ratio value of 0.49%. For structures with SNI 1726: 2012 analysis the Yield Drift Ratio value is obtained after a pushover analysis with a Yield Drift Ratio value of 0,00037 or 0.037%

4. CONCLUSION

From the analysis of structural responses that have been carried out, it can be concluded as follows: (1) Lateral force for modeling based on Performance-Based Plastic Design (PBPD) is greater than modeling based on SNI 1726: 201 (2) Actual ductility value for structures designed based on Performance-Based Plastic Design (PBPD) is higher compared to structures designed based on SNI 1726: 2012 (3) Percentage of increase in displacement (displacement) in building structures between 8 - 37%

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