

Performance evaluation of existing building structure with pushover analysis

MAP Handana*, R Karolina, Steven

Civil Engineering Department, Universitas Sumatera Utara, Jl. Perpustakaan Kampus
USU, Medan 20155, Indonesia

*Email: agung22handana@yahoo.com

Abstract. In the management of the infrastructure of the building, during the period of buildings common building damage as a result of several reasons, earthquakes are common. The building is planned to work for a certain service life. But during the certain service life, the building vulnerable to damage due to various things. Any damage to cultivate can be detected as early as possible, because the damage could spread, triggering and exacerbating the latest. The newest concept to earthquake engineering is Performance Based Earthquake Engineering (PBEE). PBEE divided into two, namely Performance Based Seismic Design (PBSD) and Performance Based Seismic Evaluation (PBSE). Evaluation on PBSE one of which is the analysis of nonlinear pushover. Pushover analysis is a static analysis of nonlinear where the influence of the earthquake plan on building structure is considered as burdens static catch at the center of mass of each floor, which it was increased gradually until the loading causing the melting (plastic hinge) first within the building structure, then the load increases further changes the shapes of post-elastic large it reached the condition of elastic. Then followed melting (plastic hinge) in the location of the other structured.

1. Introduction

A building is planned to function during certain service period. However, during the service period, buildings are vulnerable to damage caused by various things. Any damage attempted can be detected as early as possible, because one damage can spread, trigger and aggravate other damage. Thus re-evaluating the seismic performance of the building structure, is an urgent matter as part of concrete steps in handling the impact of earthquakes. Potential collapse of the structure will endanger the safety of the occupants or users of the structure. Therefore, engineers are required to design structures with earthquake-resistant capability. The design of earthquake-proof buildings should pay attention to the criteria and details according to the applicable code.

The latest concept for earthquake engineering is Performance Based Earthquake Engineering (PBEE). PBEE is divided into two, which is Performance Based Seismic Design (PBSD) and Performance Based Seismic Evaluation (PBSE). In this study, the seismic engineering concept used is Performance Based Seismic Evaluation (PBSE). Evaluation on PBSE one of them is with nonlinear pushover analysis. Pushover analysis is a nonlinear static analysis in which the effect of the earthquake plan on the structure of the building is considered as static loads that capture at the center of each floor mass, whose value is gradually increased to exceed the loading causing the first melting (plastic joint) Within the structure of the building, then with further load increases undergoes a large post-elastic shape change until it reaches the elastic state. Then followed by melting (plastic joints) in another location of the structure. Therefore, the authors conducted a study of seismic building performance



evaluation with a pushover analysis using the help of SAP 2000 program which then examine and discuss the output produced by the program. In this study, Wari Medan Building became the research object of the writer. Wari Medan building consists of 3-storey building (3) Front view of the old building facing Jln. Brigjend Katamso.



Figure 1. Front View of Wari Medan Building

The assumptions used in modelling and 3D structure analysis include:

1. The structure model under consideration is Wari Medan Building.
2. The structure of the building serves as an office building consists of 3 floors.
3. The structure used is a concrete structure, including:
 - a. Structure of reinforced concrete portal
 - b. Floor plates 1,2,3 and reinforced concrete roof
 - c. Non structural components such as stairs
4. Building loading includes:
 - a. Dead load (in the form of own weight structure)
 - b. Life expenses (in the form of load due to building function in accordance with SNI 2002)
 - c. Lateral load (in the form of earthquake load in accordance with SNI 03-1726-2002 Tata Cara Perencanaan Ketahanan Gempa untuk Gedung, without taking into account wind load).
 - d. Rules of imposition based on Peraturan Pembebanan Indonesia untuk Rumah dan Gedung SNI 03-1727-1989.
5. The performance of the building will be determined based on the guidance contained in FEMA-356 and ATC-40.
6. Behavioural structures are analysed using pushover method with the help of SAP 2000 program.
7. If the structure is not safe, the recommended retrofitting method for column structure with concrete jacketing and beam reinforcement method with Fiber Reinforced Polymer (FRP)

2. Purpose and Objectives

This study is intended to evaluate whether the structure system is still safe or insecure against workloads and know the performance of the building structure when the plan earthquake occurs. If the existing structural system is not secure then what retrofitting action should be done to make the structure system safe. Then the performance of this building will be expressed in the form of plan displacement which will be calculated based on the guidance of FEMA-356 and in the form of performance point which will be calculated based on ATC-40 guideline.

3. Structure modeling

In this journal, the model of the building structure is using an open frame system that made of reinforced concrete which is a unified structural system (monolith) consisting of columns, beams, and

plates. It is assumed that the lateral load is borne by the parent column and the parent beam as the unity of the moment retaining portal system (resisting frame moment).

Table 1. General data of Wari Medan Building

No	Parameter	Value
1	Length of the building	15.22 m
2	Width of the building	10.04 m
3	Primary factor of the building, I	1.0
4	Type of earthquake retardant system	Reinforced concrete frame of ordinary moments
5	Coefficient of response modification, R	3

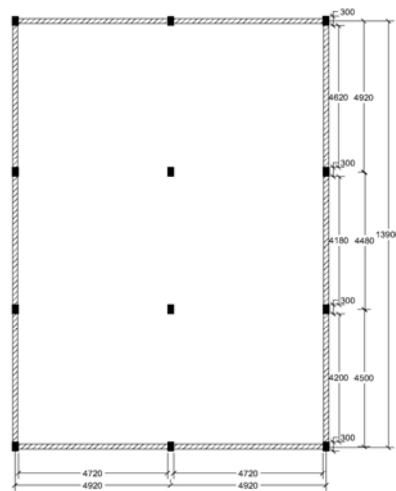


Figure 2. Floor 1 Plan of Wari Medan building

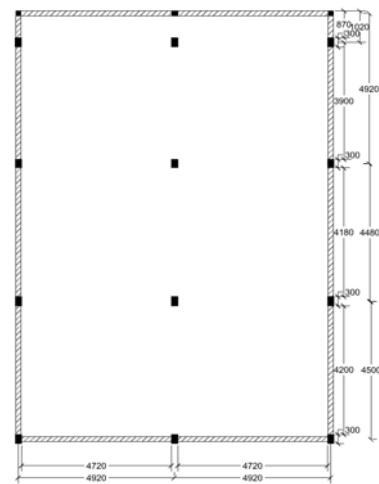


Figure 3. Floor 2&3 Plan of Wari Medan building

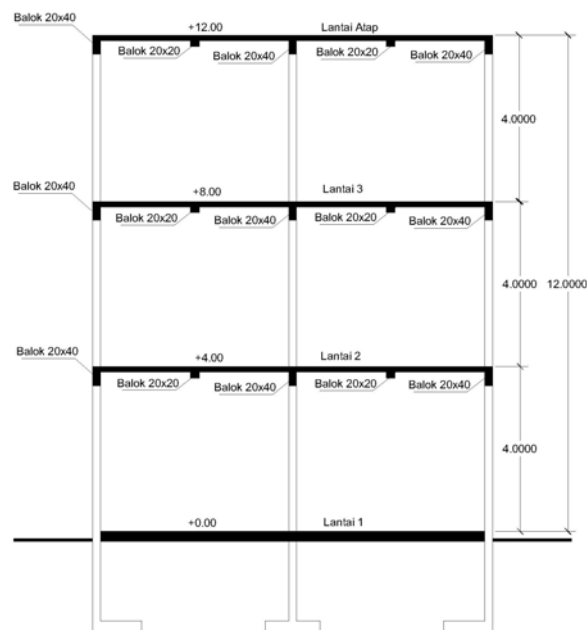


Figure 4. Section of Wari Medan building

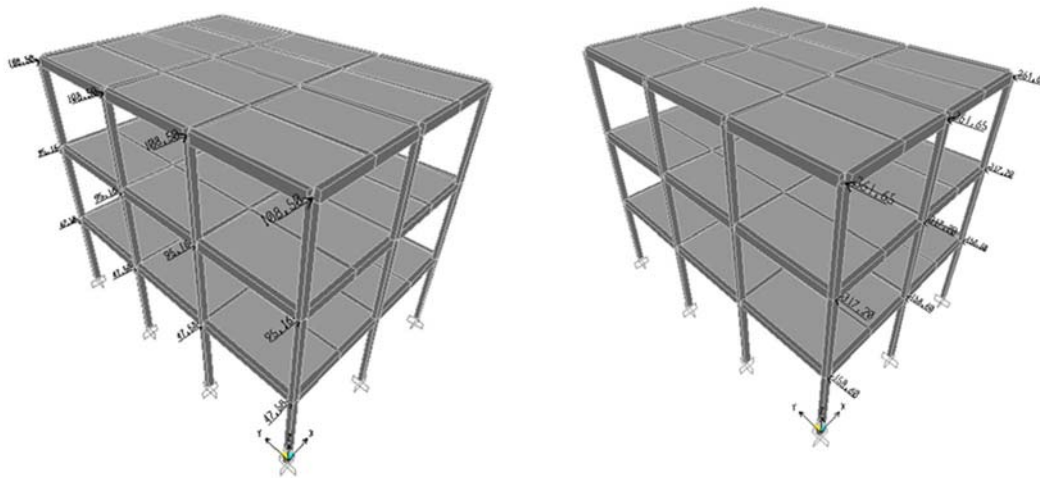


Figure 5. Lateral load modeling of X and Y direction in SAP 2000 program.

The building to be analyzed is a regular building so that the equivalent static analysis method will be used to calculate the effect of earthquake load and the building will be analyzed with pushover analysis.

4. Analysis of thrust load and building performance

Pushover analysis is performed to obtain the capacity curve of the building structure which will then be used to analyze the performance of the building in the event of a certain scale earthquake. Thrust load analysis is a type of static analysis procedure that takes into account the nonlinear state of the structure component. The plastic joint property of each structure component plays an important role in determining the behaviour of the building structure under the influence of the load acting on the structure.

Then the performance of the building will be determined using the help of SAP2000 program . Several types of methods can be used by SAP2000 to determine the performance of the building:

1. ATC-40 Capacity Spectrum Method.
2. FEMA 356 Coefficient Method.
3. FEMA 440 Equivalent Linearization Method.
4. FEMA 440 Displacement Modification Method

According to ATC-40, the criteria of earthquake- resistant structures are as follows:

1. Immediate Occupancy, "IO", When an earthquake occurs, the structure is able to withstand the earthquake, the structure does not suffer structural damage and does not experience non structural damage. So it can be directly used.
2. Level of damage control (Damage Control), "DC". At this stage the structure of the building may be damaged, but not collapsed. The risk of casualties is very low. The damage varies between IO and LS categories. This is useful where the performance targets to be achieved have more strict criteria than the LS level, but habitation is not the main problem. Examples are historic buildings.
3. Level of life safety (Life Safety), "LS". When an earthquake occurs, the structure is able to withstand earthquakes, with minimum structural damage, humans living / residing in the building is safeguarded from earthquakes.
4. Level of structural stability (Collapse Prevention or Structural Stability), "CP". When an earthquake occurs, the structure undergoes severe structural damage, but has not collapsed.

According to ATC-40, the drift ratio limit is as follows:

Table 2. Roof drift ratio limit according to ATC-40.

Parameter	Performance Level			
	IO	Damage Control	LS	Structural Stability
Maksimum Total Drift	0.01	0.01 s.d 0.02	0.02	$0.33 \frac{V_l}{P_l}$
Maksimum Total Inelastik Drift	0.005	0.005 s.d 0.015	No limit	No limit

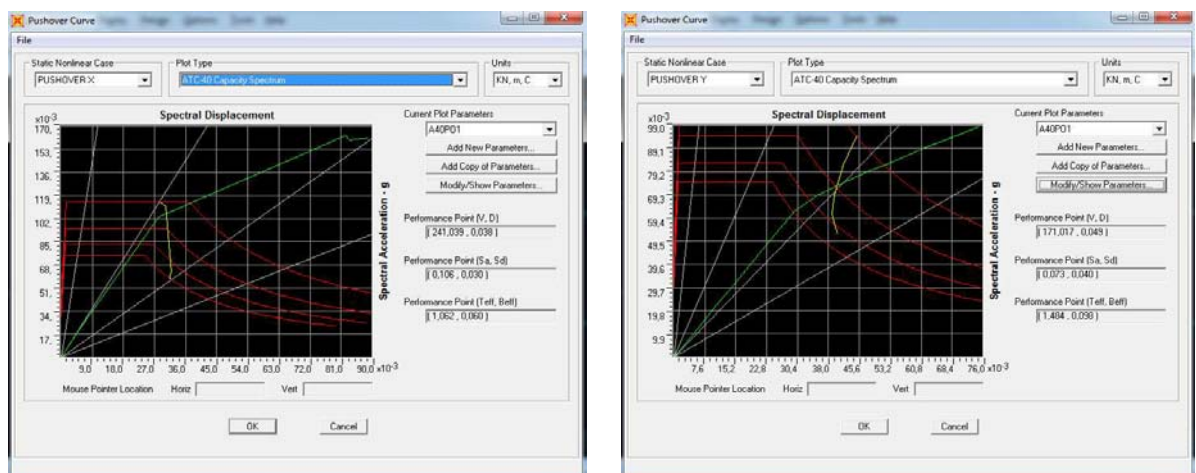


Figure 6. The capacity curves of X and Y Direction

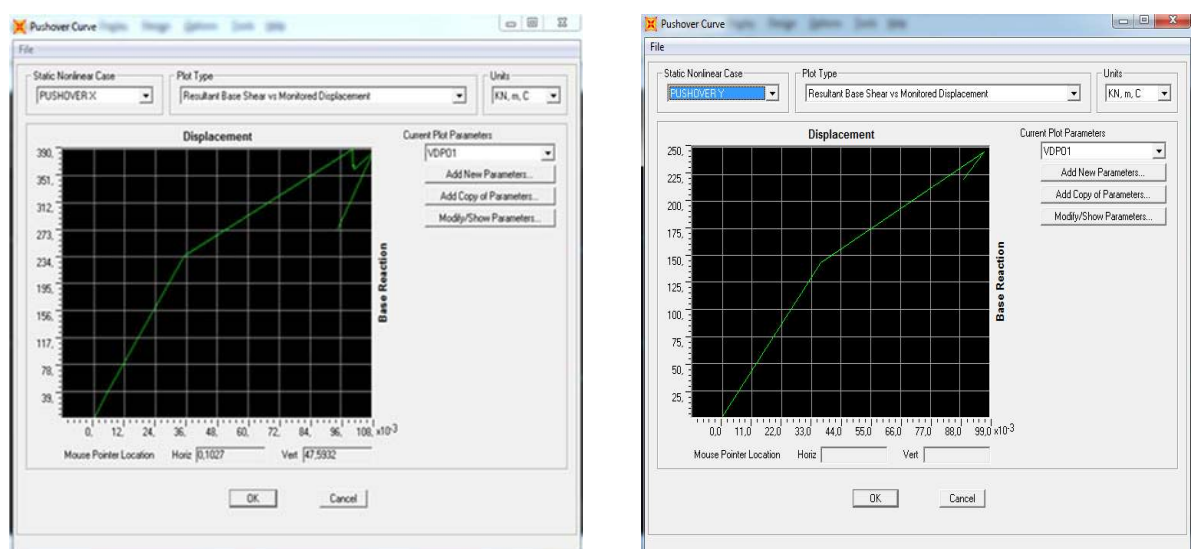


Figure 7. Graph of capacity spectrum of X and Y Direction

5. Results and Discussion

Based on the results of iteration calculations, the pushover analysis stops at step 17. Figure 1 shows that after a maximum displacement of structures of 0.1006 m, the structure shifts in the opposite direction and the base shear force decreases and undergoes collapse. In the spectrum capacity (ATC-40) method, the pushover curve with certain modifications is transformed into the capacity spectrum as shown in Figure 6. From the plan spectral response curve of SNI 1726-2002 for earthquake 3, soft soil conditions. The result of pushover analysis also shows the output of performance point of building structure with effective bath value (β_{eff}).

Table 3. X direction of Performance evaluation of structure according to ATC-40

Base shear force (ton)	Performance Point			
	V_1 (ton)	D_1 (m)	β_{eff} (%)	T_{eff} (second)
25.1235	241.039	0.038	0.06	1.06

Table 4. X direction of Performance evaluation of structure according to ATC-40

Base shear force (ton)	Performance Point			
	V_1 (ton)	D_1 (m)	β_{eff} (%)	T_{eff} (second)
83.745	171.017	0.049	0.0098	1.484

In Table 3 and 4 it can be seen that the value of base shear force $V_{tx} = 241.039 \text{ ton} > V_{yx} = 25.1235 \text{ ton}$ and $V_{ty} = 171.017 \text{ ton} > V_{yx} = 83.745 \text{ ton}$. Thus, based on the capacity spectrum method (ATC-40) the behavior of X and Y direction structures in the plan earthquake has undergone an inelastic condition caused by melting on the plastic joints. Maximum displacement limit = $0.02 H = 0.02 \cdot 12 \text{ m} = 0.24 \text{ m}$. Target displacement result of pushover analysis for X direction = 0,038 m and Y direction = 0,049 m $< 0,24 \text{ m}$, so the security requirement is fulfilled.

Based on table 4:13 and 4:14, it can be seen the limits of the roof drift ratio evaluated on the performance point (PP), whose parameters are the maximum drift and maximum inelastic drift. The calculation is as follows:

$$\text{Maksimum total drift} = \frac{D_t}{H_{total}} = \frac{0,049}{12} = 0.00408 < 0,01 \text{ (IO)}$$

$$\text{Maksimum inelastik drift} = \frac{D_t - D_1}{H_{total}} = \frac{0.049 - 0.0095}{12} = 0.004 < 0.005 \text{ (IO)}$$

Based on Table 2 the limit of roof drift ratio according to ATC-40, the calculation results above shows that the building reviewed in this study is included in the level of performance of Immediate Occupancy (OI).

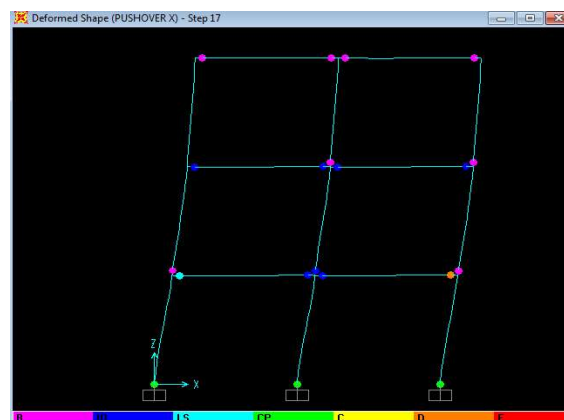


Figure 8. Spreading of Plastic Joints on Buildings Due to Push Load of X Direction**Figure 9.** Spreading of Plastic Joints on Buildings Due to Push Load of Y Direction

6. Conclusion

Based on the evaluation of the existing structure of buildings, which is Wari Medan Building in Brigjen Katamso road, it is obtained the following conclusions.

Based on the performance point, the base shear force was 241,039 ton, displacement at step 3 > 0.038 m (Dt), from the plastic joint distribution of structural performance did not pass LS (Life Safety). Maximum total value drift = 0.00408 and maximum inelastic drift = 0.004. This indicates that the building under review is included in the performance of Immediate Occupancy (IO), then in case of earthquake, the building does not suffer structural and non structural damage, so the building is safe and can be directly used.

If Wari Medan Building is not safe, it is necessary to repair the existing structure of Wari Medan Building. The improvements made in this research are using performance improvement methods of existing structural elements in the form of concrete jacketing techniques on columns and composite fiber coating (FRP) on the beams that lack the nominal strength in bending and shear to withstand the seismic loads caused by the earthquake plan.

References

- [1] Anonim 1996 *Seismic Evaluation and Retrofit of Concrete Buildings*, Applied Technology Council (ATC-40), Volume 1, Report No. SSC 96-01, California
- [2] Anonim 2 2000 *Prestandard and Commentary for The Seismic Rehabilitation of Buildings*, FEMA-356, Reston. Virginia
- [3] Anonim 3 2005 *Improvement of Nonlinear Static Seismic Analysis Procedure*, FEMA-440, California.
- [4] FEMA-273 1997 *NEHRP Guidelines For the Seismic Rehabilitation of Buildings*. Virginia. American Society of Civil Engineers
- [5] Badan Standarisasi Nasional 2002 *Tata cara perencanaan ketahanan gempa untuk bangunan gedung*, SNI-1756-2002, Jakarta
- [6] Pranata YA *Evaluasi Kinerja Gedung Beton Bertulang Tahan Gempa dengan Pushover Analysis (Sesuai ATC-40, FEMA 356, dan FEMA 440)*
- [7] Dewobroto W 2000 *Evaluasi Kinerja Bangunan Baja Tahan Gempa dengan SAP 2000*
- [8] Nugroho F 2008 *Evaluasi Kinerja Seismik dengan Analisis Statik Nonlinear Pushover Pada Gedung Berdenah*, Skripsi Jurusan Teknik Sipil, Universitas Sebelas Maret, Surakarta