Assessment of safety performance level on simple urban residential building: Case study at Bogor city Indonesia

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Abstract. Simple urban residential building must meet the technical requirements set forth in the building and structure law number 28 of 2002. In the city of Bogor, especially in the densely populated village of Kayumanis, there are areas that have the potential of landslides. In that area, there are some houses that have been damaged by the movement of land and landslides that can threaten the safety of its inhabitants. Therefore they need to stay aware about potential collapse of several parts of house structures, and then understand how to evacuate to safer area, outside of the house after the incident was stopped. Based on these conditions, it is necessary to evaluate buildings in accordance with FEMA on the safety level of buildings. The structure and modeling analysis using SAP 2000-V10 and Indonesia Standard. Specification of simple urban residential building using the reinforced concrete material with the quality of concrete (fc') 17 MPa, 15x15 cm column dimension, 15x18 cm beam dimension and 4D12 BJTP main reinforcement, and shear reinforcement D8-20. The results of the analysis of urban residential building structures shown in 3D form, obtained values for column structure elements almost close to failure are marked with orange color, while for the element of the beam structure is declared safe marked with green color. From result of modeling analysis referring to FEMA 356 obtained value C_0 = 1.0; C_1 = 1.378; C_2 = 1.0; C_3 = 1.0; Sa = 1.011; and Te = 0.2206, which states the value of the displacement target is 0.02 m which is categorized to be at 'The Life Safety' (LS) performance level. This means that if there is a movement of land, the structure of the house is declared stable and has adequate service capacity and damage non-structural part is still controlled.

1. Background

Losses due to earthquakes/disaster in Indonesia are mainly caused by lack of public awareness, knowledge, preparedness, and low quality of home construction [1,2]. Simple urban residential buildings should meet the technical requirements set forth in the Building and Building Law number 28 of 2002 [3,4]. One of the residents residing in landslide area of RT02 RW02 Kayumanis Sub-District Tanah Sareal Sub-district of Bogor City has been damaged caused by the movement of land that can threaten the safety of its occupants [5,6]. Therefore they need to stay aware about potential collapse of several parts of house structures, and then understand how to evacuate to safer area, outside of the house after the incident was stopped. Based on these conditions, it is necessary to evaluate the building to know the safety performance of the building, and then plan the evacuation route. Evaluation of residential buildings refers to FEMA 356 standards regarding building safety performance. Initiation of evaluation begins with the analysis of building structures using SAP2000 V10 applications and based on SNI 2847-2013, where the results of structural analysis of the building can be said to be safe or not. This study was conducted with limitations of problems such as, reviewing only one of the houses that were damaged by the movement of the land, the loads observed due to dead load, live load, and earthquake load on beams and columns.

2. Research Methods

The research place conducted at Kayumanis Road RT02 RW02 Kayumanis Sub-District Tanah Sareal Sub-Province Bogor. Analysis structure and modeling using application SAP2000 V10 and SNI 2847-2013 which then evaluated in accordance with FEMA 356 on building safety performance level. Stages of research starting from the literature study are the assessment or first step in doing research, the usual reference in the use of books, theses, journals, thesis and research related to the title of research. The next stage is to collect data in the form of existing data of simple residential buildings. The data obtained are 15x15 cm column dimension, 15x18 cm beam dimension, 4D12 BJTP main reinforcement, and shear reinforcement D8-20 using 17 MPa concrete qualities. Next, illustrate the existing construction with the help of AutoCAD Aplication 2007 and the SAP2000 V10 application for structural modeling. Finally, evaluate the modeling results referring to the FEMA 356 building safety criteria level. The Federal Emergency Management Agency (FEMA) method is a calculation performed to determine the safety level of a building by modifying the linear elastic response of Single Degree Of Freedom (SDOF) system equivalent to coefficient factor C_0, C_1, C_2, and C_3 so that maximum global displacement can be obtained (elastic and inelastic) called the displacement target (δT). The resulting displacement target will result in the building deformation limit shown in Table 1 that will be categorized at the level of building safety performance. The target value of the transfer is determined by the following formula [7]:

$$\delta_T = C_0 . C_1 . C_2 . C_3 . S_a . \left(\frac{Te}{2\pi}\right)^2 . g \qquad (1)$$

Where:
C_0 = modification factor to relate spectral displacement of an equivalent SDOF system, C_1 = modification factor to relate expected maximum inelastic displacements to displacements calculated for linear elastic response, C_2 = modification factor to represent the effect of pinched hysteretic shape, stiffness degradation and strength deterioration on maximum displacement response, C_3 = modification factor to represent increased displacements due to dynamic P-Δ effects, Sa = response spectrum acceleration, Te = fffective fundamental period of the building in the direction under consideration, and g = acceleration of gravity.

Table 1. Limit of building deformation [8]

	Performance Level			
Interstory Drift Limit	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 – 0.0015	No Limit	No Limit

Based on FEMA, there are 4 levels of building safety performance as shown in Table 2.

Table 2. Building safety performance level [9]

No.	Performance Level	Description
1	Operational Level	Utility equipment still works, there is little damage
2	Immediate Occupancy Level	The building receives a green sign (safe to use), the results of the examination need a little improvement
3	Life Safety Level	The structure remains stable and has adequate service capacity, nonstructural parts damage is still controlled
4	Collapse Prevention Level	The building stood, almost collapsed. Other damages are still permitted

3. Result And Discussion

The result of modeling and structural analysis according to SNI 2847-2013 in a simple residential building is obtained for column structure element almost near the failure which is marked with orange color, while the beam structure element is declared safe marked with green color. Furthermore, the result of evaluation using SAP2000 V10 application refers to the FEMA 356 obtained value of displacement target of 0.02 m, which is categorized at the level of a safety performance of the building is at Life Safety (LS) level.

3.1 Structural modeling and analysis

The specifications of the existing residential buildings are 520 cm X-direction and 1190 cm Y-direction, 300 cm height Z-direction using 15x15 cm column dimension, 15x18 cm dimension beam, 17 MPa concrete (FC), 4D12 BJTP main reinforcement, and shear reinforcement D8-20, is in quake zone 4 with the medium type of soil (Figure 1).

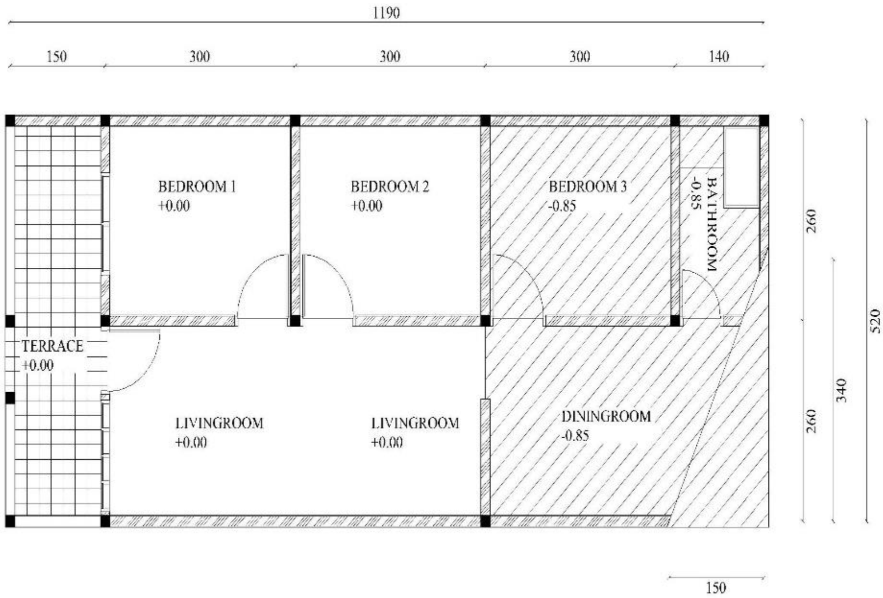

Figure 1. Existing residential building

The chart is then modeled in 3D using the SAP2000 V10 application, shown in Figure 2.

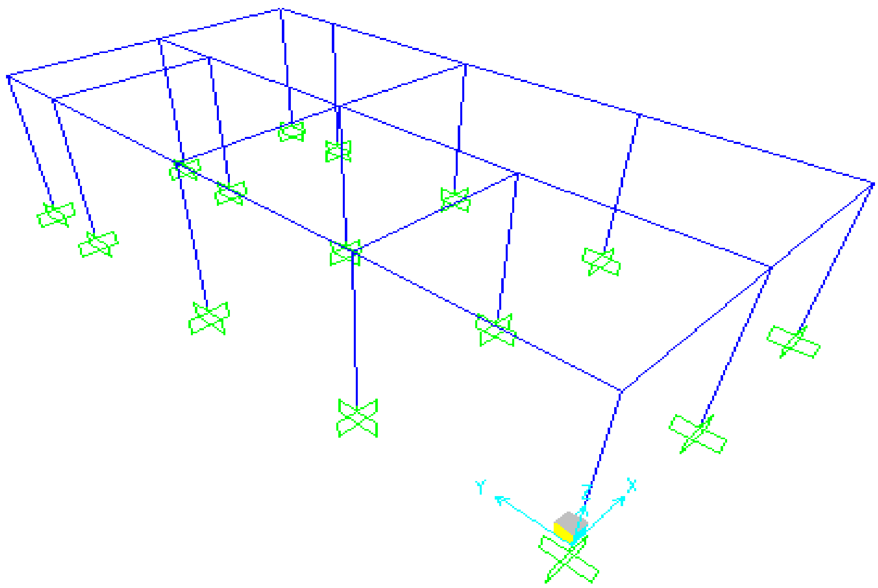

Figure 2. Structured modelling

From the modeling, we performed a structural analysis with a load combination of dead load covering roof 3 m x 10.4 m x 50 kg/m^2=150 kg/m^2, ampig wall (1.54 m x 250 kg/m^2) / 2 = 192.5 kg/m^2, hanging = 11 kg/m^2. Live load on roof = 100 kg/m^2. Earthquake loads using spectrum response data based on the Public Works Research and Development Center [10,11,12]. The results of the load combinations analysis obtained for the column structure elements are almost close to failure which is indicated by orange color, while for the beam structure elements expressed which are indicated by the green color shown in Figure 3.

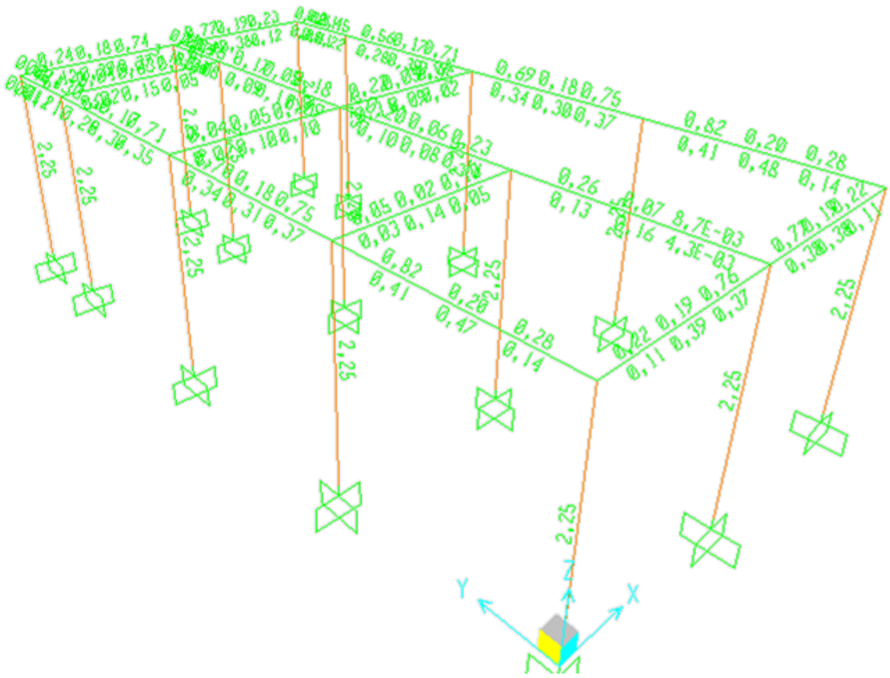

Figure 3. Modeling and analysis results

3.2 Modeling referring to FEMA 356

Furthermore, modeling with FEMA 356 was obtained from the pushover method found in SAP2000 V10 to produce plastic joints in the beam and column structure elements. In steps 1 up to step 6 with colorful nodes shown in Figure 4 and Figure 5. Description of pushover color nodes in plastic joints is based on Table 1 which is divided into 7 levels described in Table 2. According Figure 5, the front part of the house is not able to withstand the shear and shattering forces, while the back part is still function. Therefore some reinforcement is necessary to keep the evacuation route through the house front.

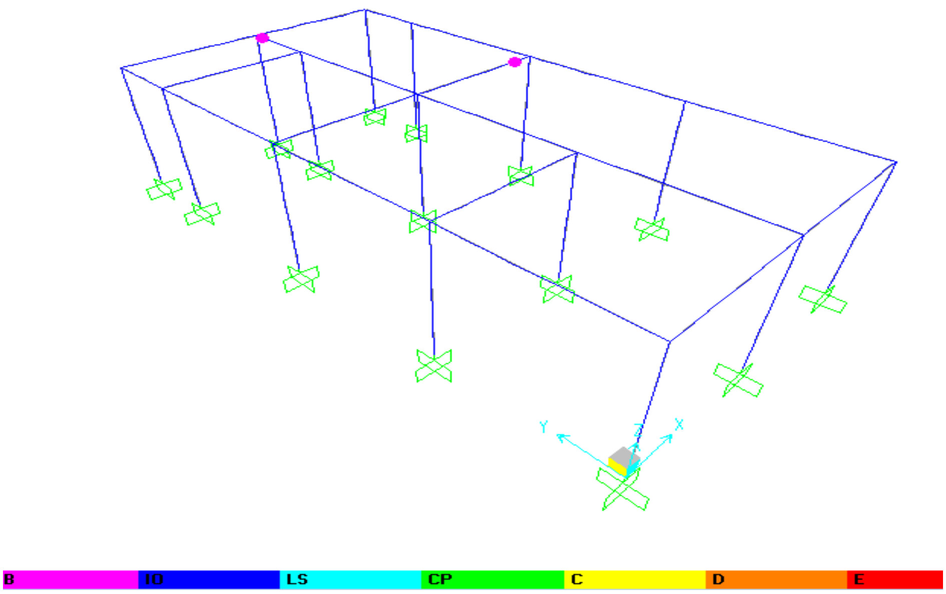

Figure 4. Plastic joints that occurs in step 1

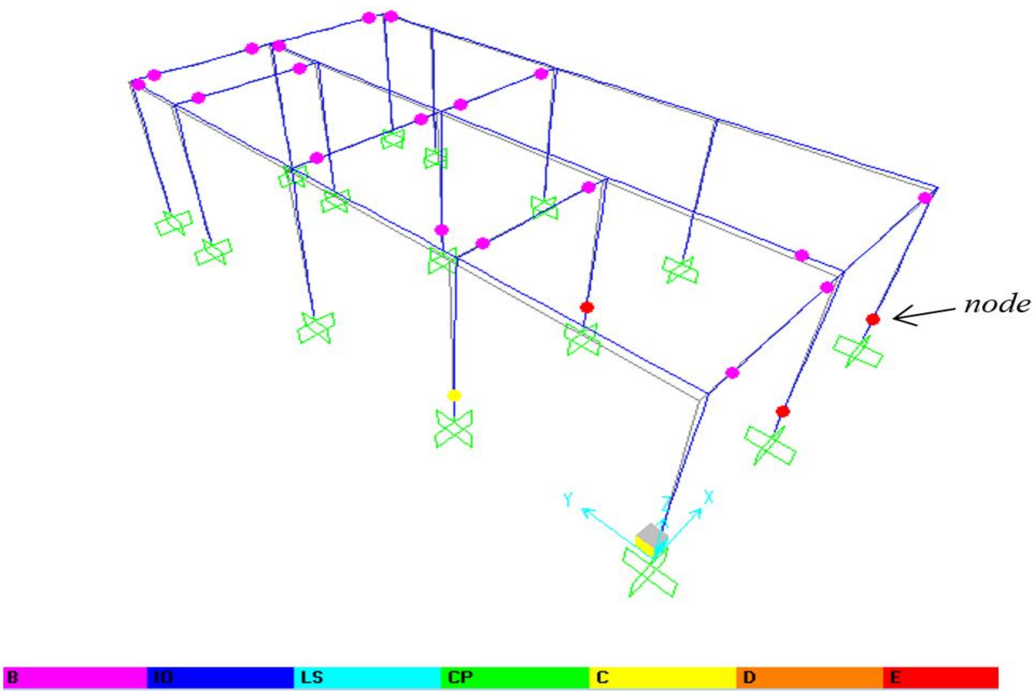

Figure 5. Plastic joints that occurs in step 6

Table 2. Node color pushover

Level of Performance	Symbol	Explanation/description
B		There is no significant structural and non-structural damage, the building can still function
IO		No structural damage occurs, non-structural components are still in place and buildings can still function without undoing repair problems
LS		Structural damage occurs but no collapse occurs, non- structural components are not working but buildings can still be used after repair
CP		Damage occurs in structural and non-structural components, buildings are almost collapsed, and accidents due to the collapse of building materials are very likely
C		The maximum limit of shear forces that can still be retained
D		The degradation of large structural trajectories, resulting in unstable structural conditions and almost collapse
E		The structure is not able to withstand the shear and shattering forces

Pushover also produces curves referring to FEMA 356 shown in Figure 6 and generates the values required for the displacement target (δT). The values obtained from the FEMA 356 curve are C_0 = 1.0; C_1 = 1.378; C_2 = 1.0; C_3 = 1.0; Sa = 1.011; and Te = 0.221.

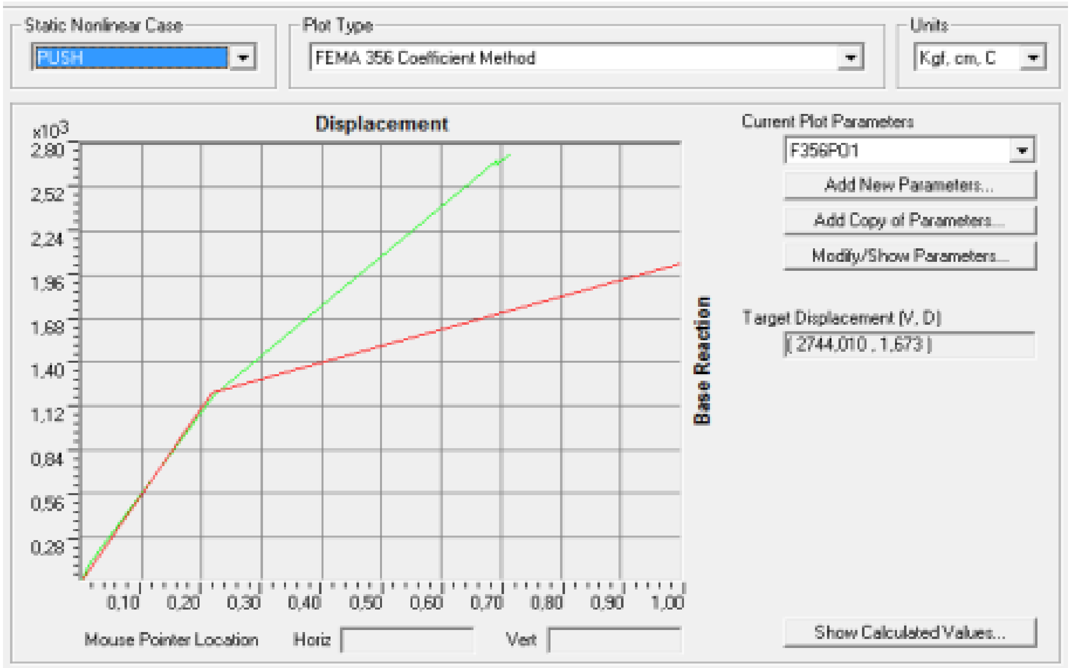

Figure 6. Pushover curve which refers to FEMA 356

Furthermore, the values are calculated using the equation (1) so that the result of the displacement target value is 0.02 m categorized under table 1 at the Life Safety (LS) performance level. This means that if there is a movement of land, the structure of the house is stable and has adequate service capacity and damage non-structural part is still controlled.

4. Conclusion

Based on the analysis and discussion, by modeling with SAP2000 V10 application in simple residential building obtained the following conclusion. The result of evaluation and modeling of the simple residential building structure in RT02 RW02 of Kayumanis Sub-District of Tanah Sareal Sub-Province of Bogor, it is found that the column structure element almost closer to the failure is characterized by orange color, for the element of a beam structure is declared safe with green color. The modeling results referring to FEMA 356 resulted in a building displacement target value of 0.02 m located at the Life Safety (LS) building performance level.

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