STRENGTH AND STIFFNESS BEHAVIOR OF CONCRETE MODULAR HOUSE

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ABSTRACT
One of the benefits of modular houses is the process of making structural components that do not have to be in a building location to be built, as well as a shorter assembly process. These two advantages can be utilized with regard to building needs as an example for post-disaster areas. This study aims to develop the concept of earthquake-resistant modular house, which is made of reinforced concrete beam structure, reinforced concrete column, and join box made of steel material. The research scope is modular house made of reinforced concrete structure component, calculated loadsare gravity and earthquake loads. Earthquake load calculation refers to the Aceh region according to earthquake maps based on SNI 1726:2012. The house reviewed is type 36 m^2. In general, result of this research is modular house consist of beam component 52 pieces, component of column 22 pieces, component of join box 20 pieces, special plate component 4 pieces, 12 mm diameter bolts 48 pieces, and bolt 16 mm 18 pieces. Modular home have a grood agreement with earthquake resistant building design in accordance with SNI 1726: 2012. These results indicate that modular homes are safe to build in areas prone to earthquakes. The modular house ductility ratio is 2.93 so it is included in the category of partial ductility.

Keywords: Modular, Beton bertulang, Kekuatan, Kekakuan, Gempa

A. INTRODUCTION

Modular houses with prefabricated structural components have several advantages that can be mass-produced components at workshop locations, modular systems that are ready-raft can be shipped to locations that require residential homes, modular systems also accommodate interests the concept of a home grows in the sense that it can evolve according to the needs of its inhabitants.

One of the important factors to be considered in the design concept and modular house planning is that the house must be able to withstand gravitational and lateral loads, considering that most of Indonesia is categorized as moderate to severe earthquake hazard. In general, modular house structures must meet the rules of strength, stiffness and stability requirements in accordance with Indonesian regulatory standards. Some modular homes have been developed and applied in Indonesia, other by Puskim, Balitbang, PUPR Ministry (source: URL: puskim.pu.go.id) which is a modular house of RISHA products from Puskim, which has been built in several regions of Indonesia.

This study aims to develop the concept of earthquake-resistant modular house, which is made of reinforced concrete beam structure, reinforced concrete column, and join box made of steel material. The research scope is modular house made of reinforced concrete structure component, calculated loads are gravity and earthquake loads. Earthquake load calculation refers to the Aceh region according to earthquake maps based on SNI 1726:2012. The house reviewed is type 36 m^2.

B. LITERATURE STUDY

Classification of Fabricated House

The analysis and design of the house in this research aims to produce safe, safe, economical, and safe 36 type house of type 36 fabrication houses, and the construction process is fast and practical. The classification of model house type 36 refers to Keputusan Menteri Permukiman Dan Prasarana Wilayah Nomor: 403/KPTS/M/2002.

House with the grown concept, is the ideal of the community in particular the middle to lower class. With the existence of a safe house, comfortable, earthquake resistant, and affordable prices then the welfare of the community in particular the lower class can increase.

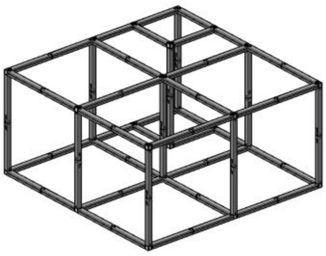
With a comfortable and clean house can support all residents to be able to live comfortably and peacefully, to prepare the future of his children become the next generation of the tough nation. Rapid and practical modular home systems (in terms of assembly process) also have the benefit of emergency needs if a disaster area and requires new dwellings that are used as a dwelling place for the inhabitants who are affected.

Concept of Fabricated House

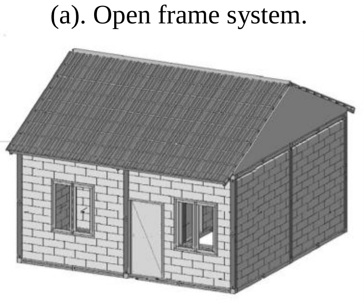
The concept of a manufactured house system in this research is a modular home comprising a main structure component of a column (HK) and a beam (HB), with a join box (HBo) and a special connecting plate (HP). Based on the reference of the Modular House Beam and Column (Frame) components, the proportion of the use of cement-based concrete materials is 91% (in terms of the volume of concrete versus the volume of steel used).

Figure 1a shows a schematic of a structure system in the form of an open frame system. Figure 1.1b shows a 36 m^2 house schematic complete with walls and roof covering structures. Working loads are planned that is the burden of gravity and lateral load (earthquake). The modular home system is designed to be safe in accordance with the rules of strength, stiffness and stability based on reference to applicable relevant with SNI.

The roof structure uses a truss structure with Meranti wood (*Shorea spp.*), bolts, and roof coverings using zincalume. Figure 2 shows the schematic and view of the type 36 housing. Figure 3 shows the schematic 3D model and 2D beam component image (HB), the component of the column (HK), the join box (HBo), and the special connecting plate (HP).



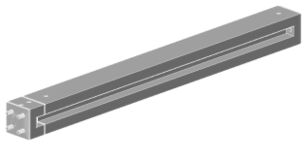
(a). Open frame system.



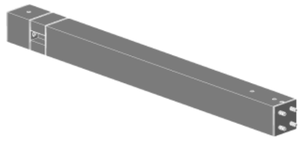
(b). Modular house type 36 m^2.
Figure 1. Modular house type 36 schematic.

List of modular compiler components are: Beam Structure Components (HB), Column Structure Components (HK), Join Box (HBo), and Special Plates (HP). The connecting tool used is As-drat (headless bolt) diameter 16 mm, and As-drat (headless bolt) diameter 12 mm.

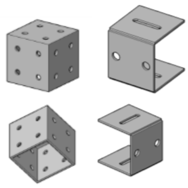
(a). Front view. (b). Back view.
Figure2. View of houses.



(a). Beam component (HB).



(b). Column component (HK).



(c). Joint Box (HBo) and Special Plates (HP).
Figure 3. Modular house components.

C. RESULTS AND DISCUSSION

Modeling and Analysis of Fabricated House

Modeling and analysis of roof truss structure is done by using SAP2000 Nonlinear software. Modeling and performance analysis of modular house building structures not multilevel type 36 m^2 was done using the help of ETABS Nonlinear software. The analysis was conducted to know specifically the performance of strength, stiffness, and structural stability due to gravitational load and lateral load (earthquake). Analysis of non-linear static structures (pushover) was conducted to obtain capacity curves due to lateral loading of stages from zero load to building failure.

Mechanical Property of Materials

The properties data of mechanical properties of concrete materials used are K-125 (f_c'= 9,8 MPa) according to the guidance which refers to Keputusan Menteri No. 403/KPTS/M/2002. The modulus of elasticity of concrete (E) is calculated 4700 x √ fc '. The longitudinal steel reinforcement grades are fy 390 MPa and for shear fy 250 MPa.

Next Figure 4 shows a 3D modeling schematic of modular type 36 m^2 modular house structure with non-linear ETABS software. The planned loads working on the building are gravitational loads and lateral loads (earthquakes). The gravity load consists of the roof load, the worker's live load, and the load of brick walls. The living load of the occupants is not taken into account, given that the living load of the inhabitants works on the floor of the house that is immediately detained by the ground underneath.

Figure4. Modeling of open frame system using finite element analysis.

Roof Structural Analysis

The roof truss structure (Fig. 5) uses Meranti Merah wood (Shorea Spp. with specific gravity is 650 kg/m^3) with elastic modulus E 11506.77 MPa (Pranata et al., 2012).

The size of the bar's cross section are 50x50 mm and 50x100 mm, wind bonds and gording using 20x60 mm wood. Dead load (DL) working on roof 0.96 kN/m^2 (SNI 1727-2013). Live load (LL) 100 kg/m^2 The roof cover uses zincalume. Combination load used 1.2 DL + 1.6 LL.

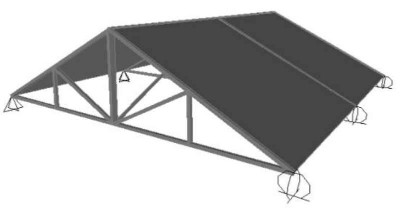


Figure5. Modeling of roof systems.

Behavior of Structure Model

Figure 6 shows the modeling of gravity loads ie roof load and wall load. The roof load, the result of a previous roof structure analysis. The occupant burden shouldered by the ground, not taken into account. Wall load 250 kg/m^2 x wall height.

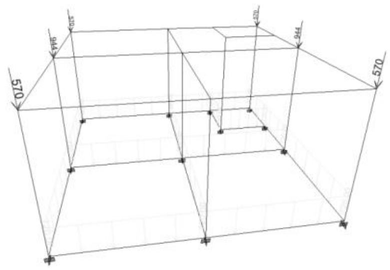


Figure 6. Modeling of gravity loads.

Calculation of earthquake load of the plan using the reference of SNI 1726: 2012 poin 6.4. The building is designed to be located in Banda Aceh area with medium type of soil. S_{DS} calculation results is 0.90 and $S_{D1}$is 0.54 which are then used to make the spectrum curve of the plan earthquake response.

Analysis due to Gravity and Lateral Loads

Structural analysis is done based on structural model that has been made and the input data of gravity loads. For analysis due to earthquake load, dynamic analysis of spectrum response is used. The combined load used is 1.2 DL + 0.5. LL ± E. where E is the earthquake load which calculates the influence of 100% x-direction quake load and 30% y-y earthquake load, and vice versa.

The results of the analysis are shown in Figure 7. The results show that the deformation due to earthquake load (E) at +3.00 elevation (roof beam) is 3.23 mm. Based on the earthquake regulation of SNI 1726:2012, the limitation of inter-grade permits for the I-II risk category region is 0.020 x 3000 mm (60 mm). then the modular house structure meets the requirements.

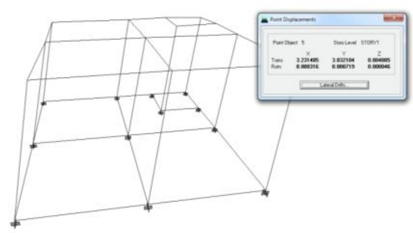
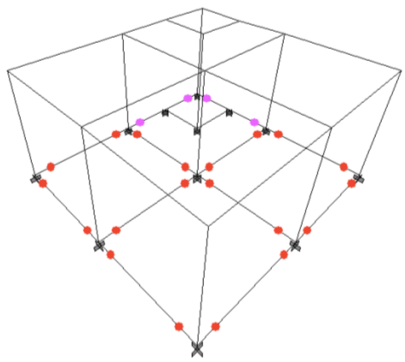


Figure7. Deformed shape of house (unit mm).

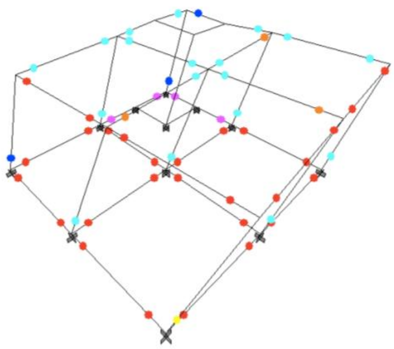
Static Nonlinear Pushover Analysis

Structural performance analysis can be done by using static analysis of nolinier (pushover) with the concept of building structure analysis with gradual loading until the building fails, to obtain the capacity curve of building structure.

The loading pattern used is the load thrust pattern. The loading pattern used for the analysis is due to the gravity load (own weight) and the first mode (variance) pattern. Figure 8 shows the pattern of plastic joint distribution occurring. Figure 9. shows the capacity curves of buildings.



(a). Step-1 of Pushover Analysis.



(b). Final step of Pushover Analysis.

Figure 8. Plastic hinge distribution.

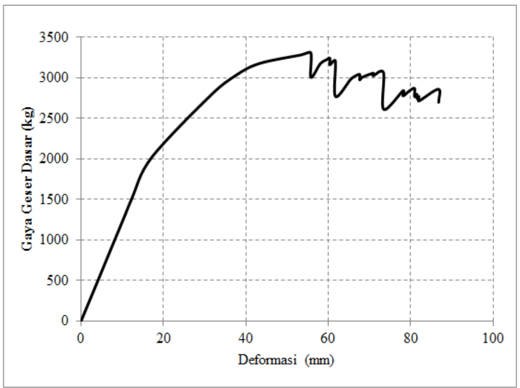


Figure 9. Capacity curves (note in Indonesian).

The result of the pushover analysis shows that in the elastic condition (before the shear force vs. deformation curve is changed from linear to nonlinear, the base shear force is 1950 kg and deformation is 18.7 mm) performance evaluation result with ATC-60 (ATC,1996) shows that building performance is obtained at V 2212 kg and D 22.9 mm, the drift ratio based on point performance reference is 0.00763.

Based on ATC-40 (ATC, 1996) it is still included in the category of Damage Control. This indicates that the building is in the range between Immediate Occupancy and Life Safety categories. In this category the modeling of new buildings with earthquake loads plan with the value of earthquake loads that opportunities exceeded within the span of 50 years building service is 10%.

The result of the capacity curve shows that the behavior of Hasan's manufacturing house structure is ductile with 2,93(partial ductility).

D. CONCLUSION

The conclusions that can be obtained from this research are as follows:

1. Modular house consists of beam component (HB) weight 42.96 kg (the proportion of 91.03% cement based concrete and 8.97% steel reinforcement and plate), the number of 52 pieces. For component of column (HK) weight 47,28 kg (the proportion 94,41% cement based concrete and 5,51% steel reinforcement and plate), number 22 pieces. For Joint Box (HBo) components 2.81 kg, steel plate, 20 pieces. For special plate components (HP) weighs 1.68 kg, 4 pieces. The required bolt is 12 mm diameter (48 pieces) and 16 mm bolt (18 pieces).
2. Modular house meets the requirements of earthquake resistant building design in accordance with SNI 1726:2012. These results indicate that modular house are safe to build in areas prone to earthquakes.
3. The modular house ductility ratio is 2,93 so it is included in the category of partial ductility.

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