ANALYSIS OF MASONRY BEHAVIOR ON NON-ENGINEERED HOUSE BUILDING TOWARDS LATERAL DEFORMATION BY USING FINITE ELEMENT METHOD BASED ON GUIDELINES

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ABSTRACT

This study is based on the abundant damaged house building during the earthquake. Wall is an important part of a non-engineered house. Dynamic simulation towards the non-engineered construction would reveal the displacement value that happened to the structure of mansory that applies the guidelines from SNI, ACI, and condition in the field. The dynamic simulation of an ordinary non-engineered house employed finite element method. The purpose of this research is to find out the mechanical performance of the mansory when the earthquake is occurring. The method implemented in this research is a scientific analysis through collecting the available theories and data from the previous research. A scientific method is started with deciding a concept based on the events frequently and generally happened in the field which are also considered a novelty. The following step is conducting data analysis by using finite element method where the maximum deformation displacement value reached ux 0.008 cm, uy 0.044 cm and uz 0.008 cm.. The loading carried out with the same magnitude on the three non-engineered house models resulted in different deformation values. The maximum deformation is in non-engineered house buildings that use field data, so the worst damage is likely to occur in house buildings based on field data.

Kata-kata Kunci: *deformation, earthquake, Finite element, Masonry, non engineered, .*

1. PENDAHULUAN

A non-engineered house building is a building to live or a commercial building consisted of 2 floor build by the owner, employing the nearest workmen, and using materials which had been measured by the structural expert. There are many non-engineered building can be found in Indonesia. The non-engineered buildings which have become a culture until today is a wall building which put the wall as system bearing the heavy load which is constructed from clay brick or concrete bricks as the main materials [1].

The major factor that must be possessed by a construction or building which is also considered vital is safety. The safety of the non-engineered building from the earthquake is such a priority that must be put first considering that in the medium to severe seismic zone in developing countries is where 90% of the citizens live in ordinary non-engineered houses. Most of the victims during the earthquake is the impact of the collapsed building [2]. To date, the basic planning of an engineered building is generally based on the studies on the damages of non-engineered building from the past earthquake and involve the structural expert. Thus, the building could guarantee the safety of the possible huge earthquake that may happen as well as to avoid and minimize the structural damage of the building and victims of the earthquake that frequently happened.

In the planning of the earthquake resistant building, standards and guidelines in building plans are needed to guarantee the safety of the residences from the huge earthquake that may probably happen as well as to avoid and minimise the structural damage of the building and victims of the earthquake that frequently happened [3]. When the earthquake is happening, it is vibrating in a complicated location and spreading to all directions. When it is happening, each building located on the surface of the ground will give different responses—different size towards the vibration [4]. The responses of the building towards the initial vibration of the earthquake would also shake although the roof stays still on its position. Further, the roof will be revoked due to its connections with walls and column.

Many of the earthquake lately cause victims due to the non-engineered house building. Therefore, a research related to the damages on the non-engineered house building is needed to decrease the negative impact of the earthquake. In this research, the analysis on the walls of ordinary house using clay bricks which was constructed by adhering to the guidelines of SNI and ACI and comparing to the condition of the wall in the field is discussed. The analysis result is expected to be the comparison and also knowledge about the walls of non-engineered house building. Thus, this research could create a novelty as the latest earthquakes are considered numerous and in the future, the estimation of the effect of the earthquake particularly on the non-engineered house building is needed. The objective of this research is to figure out the mechanical performance of the masonry when the earthquake is happening particularly on the non-engineered building based on the field condition, SNI, and ACI.

The performance of a clay brick can be revealed through its physical and mechanical characteristics. The physical characteristics of the clay brick cover dimension, colour, and texture. Clay bricks used to build a wall must be a rectangular prism whose elbow ribs are sharp, has flat plane, no cracks, no excessive deformation, not easily crushed or broken, uniform in colour and makes a loud sound when hit. Based on the colour, clay bricks must have a cross section (break) which becomes flat when the colour is yellowish, reddish, pink, maroon, and so on.

Several things that should be noted when planning an earthquake-resistant building. They are the strength, strength, stiffness, ductility and the capacity of buildings to dissipate earthquake energy. It aims to decrease the possibility of big damage in a building when the earthquake is happening. This research analyses mansory on the walls of ordinary non-engineered house by paying attention to the continuity between the guidelines of the guidelines related to building an ordinary non-engineered house with field condition.

Figure 1. The effect of Earthquake in Malang, 10 April 2021

2. LITERATURE REVIEW

2.1 Earthquake

Indonesia is a country which is vulnerable to the earthquake as the location is between the meeting of three active and interconnected tectonic plates. Earthquake is a process when the earth is shaking which is caused by the shift of the moving tectonic plates due to the force beneath the earth surface or rock debris. The damage caused by the earthquake depends on the magnitude and duration of the earthquake, or the numbers of vibration happening. The structural design and materials used in a construction of a building will also affect the intensity of the damages that happened.

2.2 Wall

Wall in a house building is a vital component in a construction particularly an ordinary house. Generally, people still used the conventional way in building the wall by using clay brick or concrete brick as the main materials. Wall in an ordinary house only consist of several materials which are usually used such as wood, board, plywood asbestos, red brick, brick, lightweight concrete, water, cement and various other alternative materials. Generally, wall functions as the structural part that hold and spread the loads above it, such as loads of roof and floor above. Wall can also give a stabilization function on the structure of the building, particularly in receiving the lateral loads caused by the earthquake or a quite big storm.

The main construction materials of mansory are clay bricks and mortar [4]. These two materials decides the strength capacity of the shear strength capacity of the clay brick mansory towards the working load. According to SNI [5], it is stated that clay brick is a building material in the form of rectangular prism. Solid or hollow has a maximum hole volume of 15% and is used for the construction of building walls from the clay as the raw materials with or without the mixture of active substance and is burnt in a certain degree. Clay bricks are one of building materials which is mostly used in Indonesia. Generally, it is used as the boarder wall in a building/construction of an ordinary house as the support or bearer of the loads above it.

2.3 The Concept of Earthquake Resistant Building

On the planning of an earthquake resistant building, standard and guidelines of planning a building is needed to guarantee the safety of the residences towards a huge earthquake that may probably happened besides to avoid and minimising the damage of the structure of the building and victims. When the earthquake is happening, the vibrations that happened in a complicated location would spread to all directions. However, each building located on the surface of the ground will give different responses towards the vibration. The initial response of the wall towards the vibration tends to move yet the roof is still on its position [6]. Further, the roof will be pulled due to the connection between the wall and column. The vibration propagation that occurs in the house is occurred when the vibration reaches the soil layer under the construction of the house, then it will spread to the foundation construction.

2.4 Non Engineered Ordinary House

The non-engineered building is a house building for living and a commercial building consisted of 2 floors built by the owners by employing the nearest workmen, and using materials which can be obtained from the nearest location, without the help from the engineer and structural expert [7]. According to the guidelines of SNI and ACI, the clay bricks used in building an ordinary house has been regulated.

3. RESEARCH METHODOLOGY

Indonesia is a country located in an area which is vulnerable to earthquake so that earthquake resistant buildings are needed. When the earthquake is happening, the biggest damage of a building would be on the non-engineered house building. The clay brick masonry of a non-engineered house would experience a damage mainly on the wall since the building of an ordinary house in Indonesia is usually built without the help of the building and structural experts or is only made based on the experience of the nearest local workmen [8].

In this research, the method used was a scientific analysis which was conducted by collecting the already available theories and data from the previous research. The scientific method was started with deciding the concept based on the event frequently happened in the field and characteristically general as well as possessing a novelty. Further, the analysis was conducted based on the data obtained by using finite element method.

The data were obtained from the previous research and the related guidelines. A house building used in the modelling is the type of 36 of house building which are considered minimalist which is mostly applied in Indonesia. The wall of the first modelling would be designed based on the confined mansory structure where there are columns, beams, and sloof. Modelling was done to all houses so that there is a load working on the wall of a house.

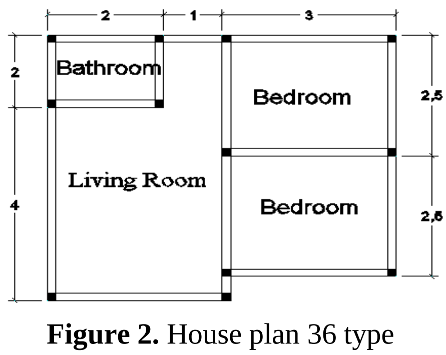

Figure 2. House plan 36 type

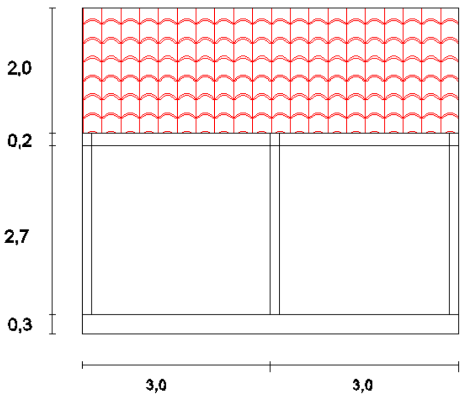

Figure 3. Front of view

The foundation used is the river stone foundation by using mortar. The concrete use is equal to K-175. The quality of plain iron used is U-24 (fy = 2.400 kg/cm2) where fy is the iron yield stress. The foundation used is the river stone foundation.

Table 1. Dimensions of structural elements

Elements	Dimensions (cmxcm)	
Practical columns	15 x 15	4-D12
Practical beams	15 x 15	4-D12
Sloof beams	30 x 15	4-D12

The loading applied is the dead load which was determined based on the sum of gravitation load the load of the structural element alone and the available non-structural load. The live load which is relevant to the SNI for an ordinary house for living is as big as 125 kg/m2. The live load of the roof used was 100kg/point. The wind load was also used based on the Regulation of Indonesia's loading which was taken as big as 25 kg/cm2. The planning of the quake load used is in the form of response based on the spectrum response model according to the Development and Research Centre of Residency, with Peak Ground Acceleration (PGA) = 0.399 g with 1% collapse probability in 50 years.

4. RESULTS AND DISCUSSION

4.1 Structural Planning

The analysis was conducted in an ordinary house for living where the wall is made of the clay-bricks and mortar.

Technical specification of the house:

Structure : Rib Concrete

Wall : Clay Bricks and mortar as the adhesive

Building Area : 36 m^2

4.2 Loading

Weight of Clay Tile Roofing : 0,4903 kN/m2

Weight of ceiling : 0,107 kN/m2

Gording profile (C150.50.20 mm) : q = 0,066kN/m

Distance between gording : 1,5 m

Distance between sawhorses : 1,5 m

Roof Covers (1,5m x 1,5m x 49,03kg/m2) = 110,31kg

Gording (1,5m x 6,63156 kg/m) = 9,95 kg

Ceiling (0,107 kN/m2 x 1,5 m x 1,5 m) = 24,08 kg

= 144,34 kg

This research was conducted in an ordinary house building, where the walls are built from the clay bricks and mortar. The technical specification of the house building uses ribs concrete structure, the mansory as the adhesive, and the area of the building is 36 m2. The loading given to the house building is the weight of the truss weight in terms of live load and dead load. The wind load in the form of suction and compressed air based on the data of maximum wind speed was issued by the Meteorology, Climatology and Geophysics Agency for Malang City.

According to the procedure of planning the earthquake resistant building or non-building on SNI 03-1726-2012 Article 7.9, the value of spectrum response was given a multiplier between $\frac{I_e}{R}$ with I_e as the earthquake priority factor and R as the factor of modified responses. C value on the spectrum response was stated in an earth gravitation (g) so that it will be multiplied with 9.81 m/sec2. This research referred to the SNI [9] Table 1 in which the term of house building is part of the risk category II, so that the value factor of the earthquake priority factor (Ie) is 1.0 according to Table 2. The structure is planned to be the confined mansory by applying the response modification which is suitable with Table 9 on the SNI 03-1726-2012 as big as 3.0. It generated the multiplier factor as big as $\frac{1}{3}\ x\ 9{,}81 = 3{,}27$

Inputting the data of spectrum response design parameter obtained from the Meteorology, Climatology and Geophysics Agency for Malang City.

According to SNI [10] was stated into two kinds of summations i.e. CQC (Complete Quadratic Combination) for structure with the timing of natural vibration which is close by (15% difference) and SRSS (Square Root of the Sum of Squares) for a structure with the timing of natural vibration which is far apart. The data obtained on the medium ground in Malang city are listed in the following:

T1 = 0,270
T2 = 0,158
T3 = 0,112
T4 = 0,096

From the data aforementioned, the difference of each variety was calculated. For instance, taking the first four varieties as formulated in the following:

T1 – T2 = (0,270 – 0,158)/0,270 x 100% = 41,481 > 15
T2 – T3 = (0,158 – 0,112)/0,158 x 100% = 41,071 > 15

If the calculation result obtained the difference values which is more than 15, the summation of its varieties applies the SRSS (Square Root of the Sum of Squares).

Next, the analysis which aims to determine the variety of vibration and to figure out the timing of the structural fundamental natural vibration. The types of variation was determined by using rizt-vector which can generate a better base when used for analysing the spectrum response based on the super-position modal. The total variety of the vibration viewed from the summation of variety response of this method must be made in such a way that mass participation in generating the total response must reach at least 90%. The total of estimated variety can be determined by using a multiplication of DOF (Degree of Freedom) or the so-called structural degree of freedom with total viewed floors

Data collected based on the guidelines of SNI such as density, elastic modulus and poisson ratio was gained from SNI [11]. While data used for ACI analysis such as density, elastic modulus and poisson ratio were obtained from ACI [12]. The data which was analysed based on the field condition were taken from the previous research as delivered in Table 2.

Table 2. Masonry Data (ACI, 530-05/ASCE; SNI, 15-2094-2000; Wisnumurti, 2013)

	Massa jenis (gram/cm3)	Modulus Elastis	Poisson Ratio
SNI	1,144	10500	0,230
ACI	2,724	38612	0,165
Field Condition	1.671	1364,710	0,208

4.3 Spectrum Respomse Analysis

Related to displacement analysis, the responses that should be highlighted from a structure of a building is the response towards the displacement. The displacement response of a building was obtained from the biggest displacement response happened to a house building with only one floor with various guidelines applied for the clay bricks alone.

In Table 3, the specification of clay bricks based on the data obtained from the field with displacement value from the biggest x-axis direction happened on point 40 that was 0.008 cm. The biggest y-axis happened to point 20 that is 0.044 cm while in z-axis the biggest direction happened to point 40 that is -0.008 cm.

Table 3. The analysis result of the displacement value (based on the data from the field)

Point	Masonry (based on data of the field)		
	U_x (cm)	U_y (cm)	U_z (cm)
10	0,008	-0,018	-0,008
20	0,007	0,044	-0,007
30	0,008	-0,021	-0,007
40	-0,008	-0,017	-0,008

(negative means the value is opposing the direction of the global axis)

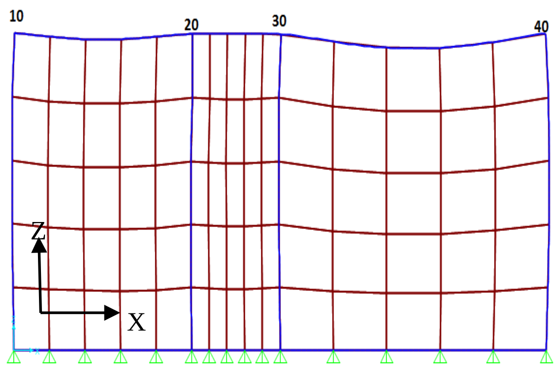

Figure 4. Point movement on mansory (the specification of clay bricks based on the data on the field)

In table 4, the specification of the clay bricks based on the data of displacement value of the SNI, the biggest direction of the x-axis happened on point 40 that was -0.0007 mm. While the biggest direction in y-axis happened on point 20 that is 0.002 cm and z-axis on point 40 that is -0.043 cm

Table 5. Analysis result of displacement value (based on SNI data)

Point	Masonry	(based on data of SNI)	
	U_x (cm)	U_y (cm)	U_z (cm)
10	0,0005	-0,007	-0,006
20	-0,0005	0,019	-0,006
30	0,0005	-0,012	-0,006
40	-0,0005	-0,010	-0,007

(negative means the value is opposing the direction of the global axis)

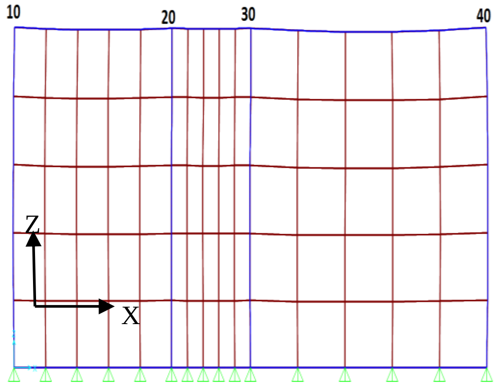

Figure 5. Displacement point of the mansory (specification of the clay bricks based on SNI data)

On Table 5, the specification of the clay mask was based on ACI data of the biggest displacement in x-axis on point 40 that is 0.0005 cm. The biggest displacement in y-axis is on point 20 that is 0.002 cm and in z-axis, the biggest displacement is on point 40 that is -0.0035.

Table 6. Analysis result of displacement value (based on ACI data)

Point	Masonry (based on data of ACI)		
	U_x (cm)	U_y (cm)	U_z (cm)
10	-0,0003	-0,0003	-0,0033
20	-0,0002	0,001	-0,0027
30	0,0002	-0,0009	-0,0027
40	-0,0005	-0,0008	-0,0035

(negative means the value is opposing the direction of the global axis)

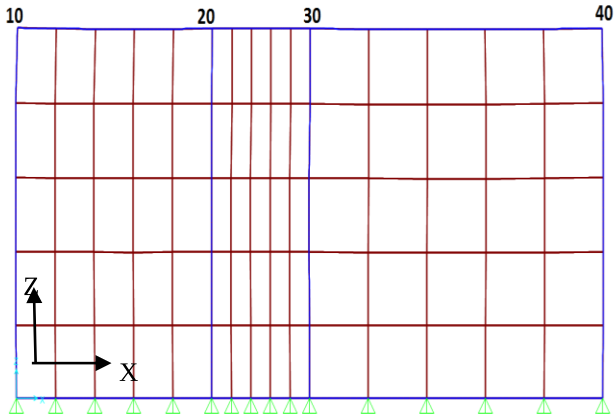

Figure 6. Displacement point on mansory (the specification of clay bricks based on ACI data)

Table 7. Result of dynamic simulation of a house for living

	Maximum Displacement		
	U_x (cm)	U_y (cm)	U_z (cm)
Mansory structure based on SNI guideline peraturan SNI	0,0007	0,002	-0,0043
Mansory structure based on ACI guideline	-0,0005	-0,001	-0,0035
Mansory structure based on field condition	0,008	0,044	0,008

Table 7 revealed the result of dynamic simulation conducted towards a one-floor house which was analysed by using finite element method. The values aforementioned are the maximum score obtained from the combination load of U = 1.2DL + 0.3EQx + 1EQy + 1LL. From the table, it can be seen that the displacement value for Ux, Uy and Uz on the structure of masonry based on the field condition is bigger than the mansory built based on the guidelines of SNI and ACI. Based on the specification of the mansory which is based on the field condition, the biggest ux score happened on point 40 is 0.009 cm, uy 0.044 cm on point 20, while the uz axis was 0.008 cm on point 40. Based on the specification of the SNI clay bricks, the biggest value for ux happened on point 40 that is -0.0007 cm, uy 0.002 mm on point 20 while in uz axis, it happened on point 40 with value as big as -0.0043 mm. According to the ACI specification of the clay bricks, the biggest displacement of ux happened on point 40 with

a value as big as -0.0005 mm, uy -0.001 cm on point 20 while uz axis was -0.0035 cm happened on point 40.

5. CONCLUSION

From the result of the modelling towards the lateral deformation based on mansory behaviour on a non-engineered house building by using finite element method, the displacement values were obtained. The specification of the mansory based on the field condition obtained ux, uy, and uz values respectively 0.008 cm, 0.044 cm, and 0.008. Based on the SNI specification of mansory the value of ux, uy, and uz are respectively -0.0007 cm, 0.002 cm and -0.0043 cm. Based on the ACI specification of mansory the value of ux, uy, and uz are respectively -0.0005 cm, -0.001 cm and -0.0035 cm. The loading carried out with the same magnitude on the three non-engineered house models resulted in different deformation values. The maximum deformation is in non-engineered house buildings that use field data, so the worst damage is likely to occur in house buildings based on field data.

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