THE CONSTRUCTION WORKER KNOWLEDGE OF EARTHQUAKE RESISTANT BUILDING

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Abstract

Earthquake is one of frequent natural disasters in Indonesia. Earthquakes cause damage to facilities and infrastructure, such as buildings collapsed or cracked. Earthquake damage to buildings is caused the buildings is not designed to has the strength to withstand earthquakes. There are three things that must be considered in the designing of the building to has the resistant to the earthquake, which is a good building materials, correct construction methods, and skilled workers.

In this study, assessment of the construction workers knowledge of earthquake resistant building is done through tests and interviews 30 construction workers in Yogyakarta. The next investigation is the correlation between the construction worker knowledge of earthquake resistant construction with construction worker background (age, place of origin, work experience, the number of houses that have been done, and level of education). Observations also made on the house making process to determine whether its process in accordance with the principles of earthquake resistant buildings. Observations were made on the structure elements of the building include sloop work, column work, brick wall work, ringbalk work, and concrete mix work.

From the research conducted, it is concluded that the level of worker knowledge about methods of earthquake resistant building construction is good. Background of the workers have a fairly strong correlation with their knowledge about the concept of earthquake resistant buildings. The category of studied houses based on the principles of earthquake resistant buildings are "good enough", since they are close to the terms and conditions of earthquake resistant construction methods.

Keywords: *earthquake, residential, construction workers, construction of earthquake-resistant building methods*

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1. BACKGROUND

Earthquake is one of the frequent natural disasters in Indonesia. An earthquake is the process of moving ground vertically and horizontally due to the shift of tectonic plates or volcanic eruptions. The impact of earthquake is damage around the site of the earthquake, damage to facilities and infrastructure such as houses collapsed or cracked [4]. According to a map of the earthquake in Indonesia, Yogyakarta is located in Region 4 and lies near the confluence of the two plates, Eurasian plates and Indian-Australia plates. In 2006 an earthquake in Yogyakarta with the strength of 5.9 on the Richter Scale cause the massive destruction of tens thousand houses and death toll [1]. The death toll from the earthquake are mainly due to falling debris of their homes. Almost all people build brick wall house that has a mass of heavy and brittle. This house type is prone to earthquakes. Earthquake resistant houses have ductile properties and light, so that the load received by the quake is small. Earthquake resistant houses made with the selection of high quality materials, construction methods are correct, and a good worker [3]. This research held the assessment of construction worker knowledge of earthquake resistant building for simple houses, also investigate the house making process based on the construction of earthquake resistant building method.

2. RESEARCH PURPOSES

The purposes of this study are :

1. Knowing the level of construction worker knowledge about earthquake resistant building construction methods.
2. Knowing the correlation between construction worker knowledge about earthquake resistant building construction methods with worker background.
3. Knowing the house making process based on the construction of earthquake resistant building method.
4. Determine the knowledges needed in the training of construction worker on the construction method of earthquake resistant building.

3. LITERATURE REVIEW

Nearly 80 percent of houses in Yogyakarta classified as non-engineered building [4]. Earthquake will cause death toll and huge material losses. This was evident on May 27, 2006, Yogyakarta earthquake causing 5,749 deaths of people [9], 570,490 heavy/light injured people and 38,423 damaged houses. Tens thousands of people have to live in temporary shelters (displaced). Department of Public Works of Indonesia stated that houses that collapsed as much as 127,879 units, 182,392 units were severely damaged, and lightly damaged 260,219 units [7].

Indonesia is an archipelago located at the confluence of three major plates world, that are Australian plate, Eurasian plate, and Pacific plate. Therefore, Indonesia is prone to earthquakes, especially in areas adjacent to the plate assembly line as shown in Figure-1.

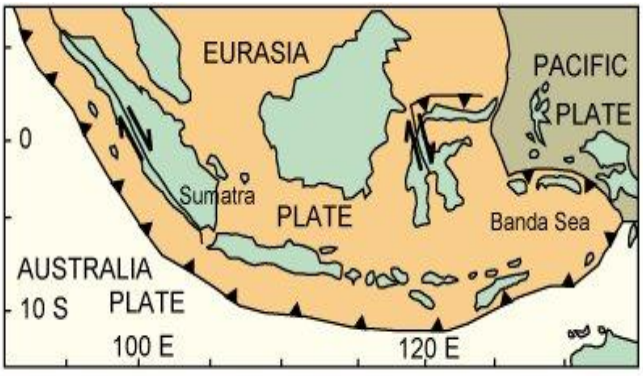

Fig-1: Map Plate Earthquake in Indonesia [8]

Mitigation is the effort in the form of preventive measures to mitigate or reduce the impact of natural disasters on people and the environment [2]. Various mitigation processes including standby for evacuation measures in the event of an earthquake, earthquake resistant building construction, and improvement of people's ability to face the disaster. Making earthquake resistant houses are preventive measures to minimize the incidence of fatalities when the earthquake occur [5].

Criteria for earthquake resistant buildings are:

1. When the earthquake rocked light, the building suffered no damage whatsoever.
2. When the earthquake rocked being, the building only suffered damage to non-structural elements only.
3. When a large earthquake rocked, the building may be damaged in the non-structural and structural elements, but the building had to remain standing and must not collapse.

Terms of earthquake resistant buildings according to Indonesian Ministry of Public Works - Housing Research and Development Agency are as follows:

3.1 Architecture Overview

3.1.1 Lay Out

Building lay out must be symmetrical to eliminate torsional force. If the lay out of the building is not symmetrical, asymmetrical parts need to be separated. Building shape that is too long will reduce the power (performance) of the building in case of loading and movement due to differences in the behavior of non-structural realistic effects and realistic effects of loading. The building should be separated according to the conditions of soil uniformity and homogeneity of the building.

3.1.2 Roof

Too big and too heavy roof might jeopardize the security of the structure, as it will result in a large earthquake loads. Recommended roof of the building wearing lightweight materials such as zinc, asbestos wave or aluminum.

3.1.3 Aperture Wall

Total width of openings in the wall area should not exceed half the length of the wall. If the wall openings exceed half the width of the wall, the wall has to strengthen by column of reinforced concrete, the doors and windows jamb were given iron anchors embedded in the wall.

3.2. Structure Overview

To be safe buildings against earthquakes, the foundations, columns, beams, walls, and roof should be well designed.

1. The foundation is under structure that holds the upstructure and pass on the burden to the ground, so the foundation must meet the following conditions.
   a. The foundations must be placed on the hard ground. The bottom of foundation must be laid deeper than 45 cm below the soil surface.
   b. The foundations must be connected to the sloop.
   c. Under the foundations must be added layer of sand as "shaking reductor" or vibration absorbers. Foundation soil must be compacted.
   d. Anchor fastener must be installed between sloop and foundation at a distance of 1.5 m.

2. The column serves to strengthen the walls to withstand the load on it, as well as making walls are ductile. Here are the things that need to be considered in the column:
   a. Buildings must use the column as a loadbearing element.
   b. Between the column and the sloop should be installed anchors, or bonding column forwarded to the foundation.
   c. Frame building (sloop, beams, and columns) must have a solid relationship. Columns must be equipped with a beam stiffeners (ring balk, beam latei) to resist lateral forces earthquake).

3. Beams on house building consists of ring balk and “latei” beam. Latei beam located above the frame, serves as horizontal reinforcement.

4. The brick walls must meet the following requirements.
   a. The thickness of the species among the bricks on the horizontal and vertical direction is 1.5 cm to strengthen the bricks wall.
   b. Maximum brick wall work is one meter in a day to maintain the stability of the wall and avoid the brick walls become skewed.
   c. Brick wall work must be done first before casting the column is done. It is intended that there is a strong bond between the columns with the wall because of the cracks filled with cast concrete columns. Anchors must be installed in column along the 40 cm at any height of six layers of brick.

d. Doors and windows should be attached to the wall with the anchors. It can be used steel anchor diameter of 6 mm, or can also be used spikes along 12 cm. Details of the jamb anchor installation are described in Figure-2.

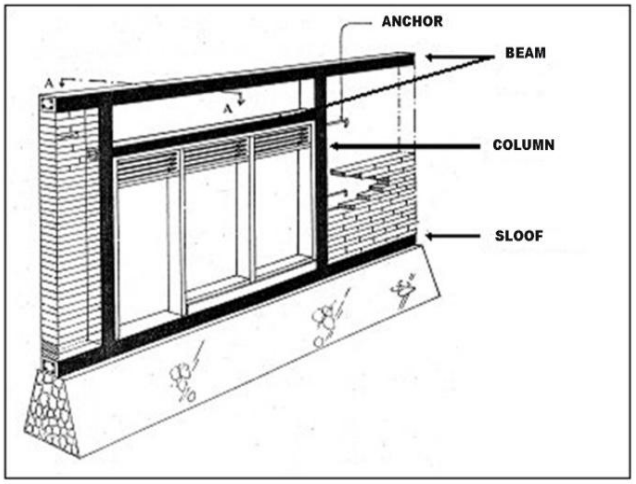

Fig.-2: Installation of Anchors on Window Sills [6]

e. The position of brick wall must be vertical at an angle of 90 degrees to the base/sloof/ foundation.
f. The distance between the columns not exceed 3 meters to maintain the stability of the wall
g. Pieces of brick whose size is less than ½ stone should not be used.
h. Plastering of brick walls should be made with a mixture of 1 cement: 2 sand to be strong and not easily broken. The plaster thick between 1.5 cm - 2 cm.

4. RESEARCH METHODS

Research methods are interviews and direct observation in the field. The following are the steps in conducting research.

1. Identify the variables of the study, namely:
   a. Worker knowledge about earthquake resistant houses
   b. The constructing process of observation house
2. Describe the variable at the point 1.a. into 3 sub variables, namely:
   a. Worker knowledge of building materials
   b. Worker knowledge about the function of building elements
   c. Worker knowledge about earthquake resistant house construction methods

In addition to worker knowledge variables and house making process, there are worker background variables consisting of 6 sub-variables: (1) local worker origin, (2) worker age, (3) worker experience in the field of construction, (4) number of houses which have been made by worker, and (5) worker education.

3. Finding aspects of each sub variables
   a. Sub variable of worker knowledge of building materials translated into 11 aspects, namely: sand (X1), gravel (X2), stone (X3), cement (X4), water (X5), reinforcing steel (X6), brick (X7), cement brick (X8), wood (X9), concrete (X10), and stucco (X11).
   b. Sub variable of worker knowledge about the function of building elements consist of 8 aspects: roof coverings (X12), roof truss (X13), ceiling (X14), ringbalk (X15), walls (X16), column (X17), sloop (X18), and foundation (x19).
   c. Sub variable of worker knowledge about earthquake resistant housing construction method consists of 10 aspects are shown in Table 1.
   d. Field observations variables on the house making process of earthquake resistant housing includes work sloop, columns, brick walls, ringbalk, and concrete mix.

Table-1: Aspects of Earthquake Resistant Houses Construction Methods

As Aspects	Earthquake Resistant Houses Construction Methods
X20	Installation method armature from foundation to sloof
X21	Installation method armature of practical columns to the wall
X22	Installation method armature from the jamb to the wall
X23	Installation method of reinforcing steel from a practical column to foundation
X24	Installation method of reinforcing steel from the practical column to the sloop
X25	Installation method of reinforcing steel of the practical column to ring balk
X26	Installation method of reinforcing steel lintel beam to practical column
X27	Installation method of reinforcing steel at a meeting of the T-shaped ringbalk
X28	Brick wall treatment method
X29	Installation method of reinforcement stirrup

5. DATA ANALYSIS

The analysis used in this study are:

1. Quantitative analysis is used to analyze the cognitive knowledge of worker about earthquake resistant housing construction methods. The results of the analysis of worker knowledge of construction methods of earthquake resistant houses are categorized as follows.
   a. Assessment categorized as very good, if the mean value is> 80
   b. Assessment categorized as good, if the mean value is 61-80
   c. Assessment categorized as enough, if the mean value is 41-60
   d. Assessment in the category of less, if the mean value is <40

2. Correlation analysis was used to analyze the relationship between worker background and worker knowledge of construction methods of earthquake resistant houses. The correlation coefficient indicates the level of the relationship as shown in Table 2.

Table-2: Interpretation of Correlation Coefficient

Interval Correlation Coefficient	Le Level of Relations
0,800 – 1,000	Ve Very Strong
0 0,600 – 0,799	St Strong
0, 0,400 – 0,599	St Strong Enough
0, 0,200 – 0,399	W Weak
0, 0,000 – 0,199	Ve Very Weak

Hypothesis test on SPSS output to determine whether the number of correlation obtained is really significant, and can be used to explain the relationship between the two variables studied. The hypothesis is organized as follows.

Ho: There is no relationship (correlation) between the worker background and the worker knowledge of earthquake resistant houses

H1: There is a relationship (correlation) between the worker background and the worker knowledge of earthquake resistant houses

3. Qualitative analysis is used to analyze the houses making process, based on the construction of earth-quake resistant houses method.
   a. Assessment categorized as good, if compliance with earthquake resistant housing construction methods achieve 71% - 100%
   b. Assessment categorized enough, if compliance with earthquake resistant housing construction methods achieve 41% - 70%
   c. Assessment in the category less, if compliance with earthquake resistant housing construction methods achieve 10% - 40%

6. RESULTS AND DISCUSSION

6.1. The Level of Construction Worker Knowledge

The mean value for each variable aspect is calculated by SPSS 17. Results of calculation of the mean which indicates the level of worker knowledge shown in Table-3.

Table-3: The Level of Worker Knowledge for Every Aspect

Specification	No.	Variable	Test Results Mean	Specification
Knowledge of Building Materials	1	X1	60	Enough
	2	X2	75	Good
	3	X3	61,667	Good
	4	X4	40	Less
	5	X5	88,333	Very Good
	6	X6	57,5	Enough
	7	X7	63	Good
	8	X8	50	Enough
	9	X9	48,75	Enough
	10	X10	50	Enough
	11	X11	53,333	Enough
Knowledge of Building Elements Function	12	X12	76,67	Good
	13	X13	72,5	Good
	14	X14	43,75	Enough
	15	X15	70	Good
	16	X16	49	Enough
	17	X17	92,5	Very Good
	18	X18	75	Good
	19	X19	85	Very Good
	21	X21	90	Very Good
	22	X22	75	Good
	23	X23	97,5	Very Good
	24	X24	90	Very Good
	25	X25	90	Very Good
	26	X26	92,5	Very Good
	27	X27	90	Very Good
	28	X28	51,667	Enough
	29	X29	97,5	Very Good

6.2. The Correlation between Worker Background and Worker Knowledge

The correlation between worker background and worker knowledge about construction of earthquake resistant houses is processed usingSPSS17. Background workers include age, place of origin, work experience in construction, the number of houses that have been made, and worker education. Worker knowledge include knowledge of building materials, function of building elements, and methods of construction of earthquake resistant houses. The results of the analysis are used to prove the hypothesis of a relationship between two variables studied, namely worker background and worker knowledge of earthquake resistant housing construction methods, as shown in Table-4.

Table-4: Correlation Coefficient, Significance, and Hypothesis Testing

Variable	Correlation Coefficient	Level of Correlation	Significance	Hypothesis Testing	The Meaning of Hypothesis Testing Results
Worker Age	0,6168	Strong	0,004	Reject Ho	There was a significant correlation between age of worker with knowledge of earthquake resistant houses
Origins of Worker	0,515	Strong Enough	0,02	Reject Ho	There was a significant correlation between origin of worker with knowledge of earthquake resistant houses
Work Experience in Construction Sector	0,548	Strong Enough	0,012	Reject Ho	There was a significant correlation between work experience in construction sector with knowledge of earthquake resistant houses
Amount of House Created	0,589	Strong Enough	0,006	Reject Ho	There was a significant correlation between amount of house created with knowledge of earthquake resistant houses
Education	0,167	Very Weak	0,482	Accept Ho	There was no significant correlation between education with knowledge of earthquake resistant houses

7. CONCLUSION

After analyzing the results of this study, four conclusions can be drawn as follows.

1. Research of the level of worker knowledge give mixed results. For the variables of building materials, in general worker has adequate level of knowledge (scores for each aspect between 40-60). For variable of worker knowledge about building elements function, in general worker has a good level of knowledge (scores for each factor laid between 61-80). For variable of worker knowledge about earthquake resistant housing construction methods, in general worker has a very good level of knowledge (scores for each factor> 80).
2. Worker background such as age, place of origin, experience of work in construction, and the number of earthquake resistant houses that have made the most of having a fairly strong correlation with knowledge about building earthquake resistant houses, as indicated by the value of the correlation coefficient from 0.400 to 0.599. Worker education level have a very weak correlation with worker knowledge about earthquake resistant houses, indicated by the value of the correlation houses, indicated by the value of the correlation coefficient from 0.000 to 0.199.
3. Work of sloop, columns, making the brick wall, and mix concrete/casting on the houses object of studies included in the category of fairly good (41% - 70%) is based on the method of construction of earthquake resistant houses. Unless the job ringbalk included in the category of less (10% - 40%).
4. 4.Worker knowledge about building materials fall into the category of less. It can be concluded that the required training to worker is about building materials.

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REFERENCES

[1] Martono, 2013, Mengenang Gempa Tektonik 2006 di Yogyakarta dan Sekitarnya (1),http://sosbud.kompasiana.com/2013/05/27/mengenang-gempa-tektonik-2006-di-yogyakarta-dan-sekitarnya-1-559539.html (accesed Mart 22, 2015)

[2] [Raffeqi, Aspects Of Earthquake Disaster Mitigation, Special Reference To Non-Engineered Construct-ion ,http://www.neduet.edu.pk/Civil/aspects.pdf (accesed Mart 22, 2015)

[3] Sabaruddin, A., (2012). Membangun Rumah Sederhana Tahan Gempa Pada Konstruksi Bangunan Rumah Tembok ½ Bata, Badan Litbang Departemen Pekerjaan Umum, Jakarta.

[4] Sarwidi, (2010), Manual Barrataga Dinding Tembokan, CEEDEDS UII, Yogyakarta.

[5] Undang-Undang Republik Indonesia Nomor 24 Tahun 2007 Tentang Penanggulangan Bencana, http://www.litbang.depkes.go.id/sites/download/regulasi/uu/UU_No._24_Th_2007_ttg_Penanggulangan_Bencana.pdf (accesed January 10, 2015)

[6] http://architecturoby.blogspot.com (accesed December 15, 2014)

[7] http://ciptakarya.pu.go.id/dok/gempa/main.htm (accesed November 6, 2014)

[8] http://www.drgeorgepc.com/Tsunami1833 Indonesia.html (accesed November 14, 2014)

[9] http://www.mapsoftworld.com/thematic-maps/earthquake/indonesia-earthquake-history.(accesed January 13, 2015)

[10] http://www.wikipedia.org/wiki/Earthquake(accesed December 21, 2014)

BIOGRAPHIES

Tuti Sumarningsih is a lecturer at the Islamic University of Indonesia since 1987. She pursue the field of Construction Management and has been teaching for years in Project Management, Quality Management, and Disaster Risk Management. At this time she is pursuing doctoral studies in the field of Construction Management at the University of Diponegoro, Semarang, Indonesia.

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