EARTHQUAKE DAMAGE INTENSITY RELATIONSHIP FOR RESIDENTIAL HOUSES IN WEST SUMATRA

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Abstract

The Sumatra 30 September 2009 earthquake has damaged hundred thousand buildings in West Sumatra Province. The earthquake is located in 100 km offshore of Padang City, the Capital City of the province. Survey has been conducted to assess the damage of the building in few days after the earthquake. In this survey, the damage of buildings are categorised into 3 level that are heavily, moderate and slightly damages. This paper explores the level damage of building and then the intensity of the shaking in the affected area. Then based on the coordinate of every building location, the buildings are scattered in a map together with the intensity level. The relationship between the damage level and intensity for West Sumatra then is developed. This special damage-intensity relation is very important to be used for predicting the damage level due to a specified earthquake. The damage level is needed by The Government to develop an emergency and reconstruction budget plan for earthquake disaster in future.

Abstrak

Hubungan Intensitas Kerusakan Gempa untuk Rumah Rakyat di Sumatera Barat. Gempa Sumatera 30 September 2009 telah merusak ratusan ribu bangunan di Provinsi Sumatera Barat. Gempa tersebut berlokasi di 100 km lepas pantai dari Kota Padang, ibu kota provinsi tersebut. Survei telah dilakukan untuk menilai kerusakan bangunan dalam beberapa hari setelah gempa. Dalam survei ini, kerusakan bangunan dikategorikan menjadi 3 tingkat yaitu berat, sedang, dan ringan. Tulisan ini membahas tingkat kerusakan bangunan dan intensitas getaran di daerah yang terkena. Selanjutnya berdasarkan koordinat dari setiap lokasi, bangunan yang disurvei diplotkan di dalam sebuah peta bersamaan dengan tingkat intensitas. Hubungan antara tingkat kerusakan dan intensitas gempa untuk Sumatera Barat selanjutnya dibuatkan. Hubungan unik kerusakan-intensitas ini merupakan hal yang sangat penting digunakan dalam memprediksi tingkat kerusakan akibat gempa tertentu. Tingkat kerusakan tersebut dibutuhkan oleh pemerintah untuk menyusun rencana anggaran pada tahap tanggap darurat dan rekonstruksi untuk bencana gempa di masa yang akan datang.

Keywords: earthquake, damage assessment, earthquake intensity

1. Introduction

On 30 September 2009 an earthquake with 7.6 on the Richter scale was shock in West Sumatra. The time of occurring earthquake is at 17:16:10 local time. The epicentre was at a depth of 80 km in about 50 km to the west-northwest of Padang, the capital city of the Province. The earthquake resulted in relatively severe ground shaking in and around Padang. The Modified Mercali intensities are about VII or VIII. More than one million people were affected by the earthquake through total or partial loss of their homes or building. In this paper, it is shown the relation between the intensity of the earthquake and the damage of the houses in Padang. Padang is in the dense populated city in West Sumatran and one of the most seismically active regions of the world.

In Indonesia, there is an earthquake design code that firstly was published in 1970 by Public Work Department [1]. In the practical works, the code was applied for engineered building only. There is no statement to force people to consider the earthquake safe for their houses. According to the code, for buildings that higher than 40 m must be designed using dynamic analysis and the others can be designed for equivalent static forces. The corresponding peak ground acceleration (PGA) is about 0.025 g, 0.05 g and 0.10 g with three earthquake zones. Meanwhile, the Padang 30S'09 an earthquake has the PGA of about 0.30 g to 0.40 g.

The earthquake design code was updated in 1987 by Public Work Department [2] with the Region then was divided into six earthquake zones. Padang was located in the highest zone. The peak ground acceleration in that code was not significantly increased. The highest PGA coefficient is 0.13 g. Further, in 2002 there was a significant increase in the seismic design loads as reveal in SNI 2002 code [3]. The important engineered buildings at that time were designed with PGA of 0.3 g. This story indicates that many building were design and built with very low seismic load before they were suffering the West Sumatra 30S'09 earthquake.

In the past, study on the relationship between earthquake damage and intensity in New Zealand has been performed [4]. In this study, the damage of building is expressed in term of the "mean damage ratio" (MDR) value and the earthquake shaking in term of Modified Mercalli intensity (MMI). It is found that the MDR and MMI relationship clearly depends on the nature of the building structure. Then, unreinforced brick wall would experience greater damage than a modern reinforced concrete building at a given value of modified Mercalli intensity.

Recently, the research is to understand the potential for fatalities and damage in future earthquake disasters in Indonesian has been doing [5]. The goal of this research is to provide tools for capturing information on earthquake disaster risk reduction efforts following future events including the development of an Earthquake Damage Model. The earthquake damage model will be useful for the government of Indonesia to estimate the number of damaged buildings and fatalities within minutes of an earthquake occurring – in combination with Shake Maps from BMKG. In his study the damage data is classified based on buildings classification in Indonesia.

After the large earthquakes in the West Sumatra region, a new version of the Indonesian earthquake code is released in 2010. A further increase in the maximum PGA is declared fantastically until more than 1.0 g. Based on the recorded of September 2009 earthquake, spectral accelerations for design is published as in Figure 1. Here, the design spectra in the 1987 and 2002 codes are plotted along with. The response spectra for the 30S'09 ground motion initially recorded in Padang as reported by BMKG/USGS 2009 [6].

However, until now there is no a formal Indonesian design code for ordinary housing (residential houses). But there are many construction details for the use of non-engineered buildings which published by personal

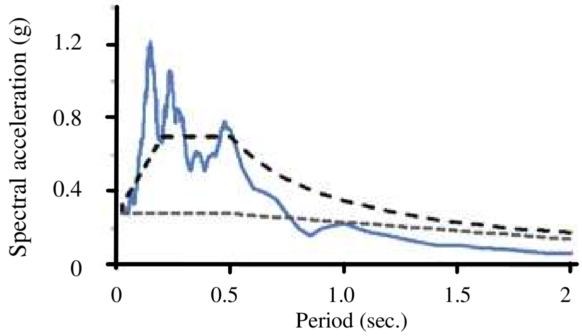


Figure 1. Padang 30S'09 Design Response Spectra by BMKG/USGS, 2009 [6], Measured (—), SNI-2002 (— —), SNI – 1987 (- -)

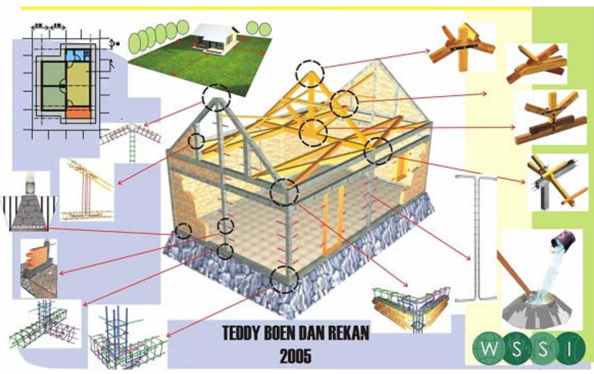


Figure 2. Building the Earthquake Safe Masonry House [7]

authors or organizations. Many authors presented drawings of recommended design details for single-storey buildings which included details for what was referred to locally as simple houses. The very famous of those is proposed by Teddy Boen [7] who has been studying for simple housing for more than 40 years around the world. The well known of his work of creation is shown in the Figure 2.

2. Methods

Soon after the earthquake an emergency team lead by the University of Andalas conducted the damage survey of building in the West Sumatra Province. As one public university in West Sumatra, Andalas University initiated a process of damage survey and data collection on the ground in order to obtain an accuracy and validation data. The budged survey is supported by Government which has purpose to avoid duplication of data that already exposed by the media. It was reported by a National newspaper that the West Sumatra provincial Government has been collected invalid data, since the discovery of mismatch total population in the district of Padang Pariaman with a population of data owned by the Padang Pariaman regency.

Figure 3. A Heavily Damage Houses

Padang city consists of 13 districts involving 104 villages. There are 116,476 houses scattered in the city of Padang. The survey recorded at around 37,587 houses were heavily damaged, 38,485 and 40,406 suffered moderately and slightly damage respectively. The data is very important information for Government to do the next steps in implementation of rehabilitation and reconstruction of buildings after the earthquake in West Sumatra and Padang in general.

In order to obtain accurate data then the assessment survey team directly went to the field. The data collection had been carried out by the team supported by students and engineers as volunteers from the 6th until October 31st, 2009. The volunteers fell directly into the field to retrieve quantitative data of the number of buildings were damaged by the earthquake. Data retrieval residential houses equipped with photographs of damaged houses. Every house then pasted with stickers as a mark of verification has been recorded and avoided to be re-recorded.

Determination of the extent of building damage was done by visual observation. Based on the visual observation, the affected buildings can be classified according to three level of damage which follows the Indonesia government criteria. There are three initial given for the damaged building: RB for a heavily damaged building/house, RS for a house with a level of moderate and RR for the slightly damaged house. For the example, the condition of a house that referred to be suffering from heavily damage is shown in Figure 3.

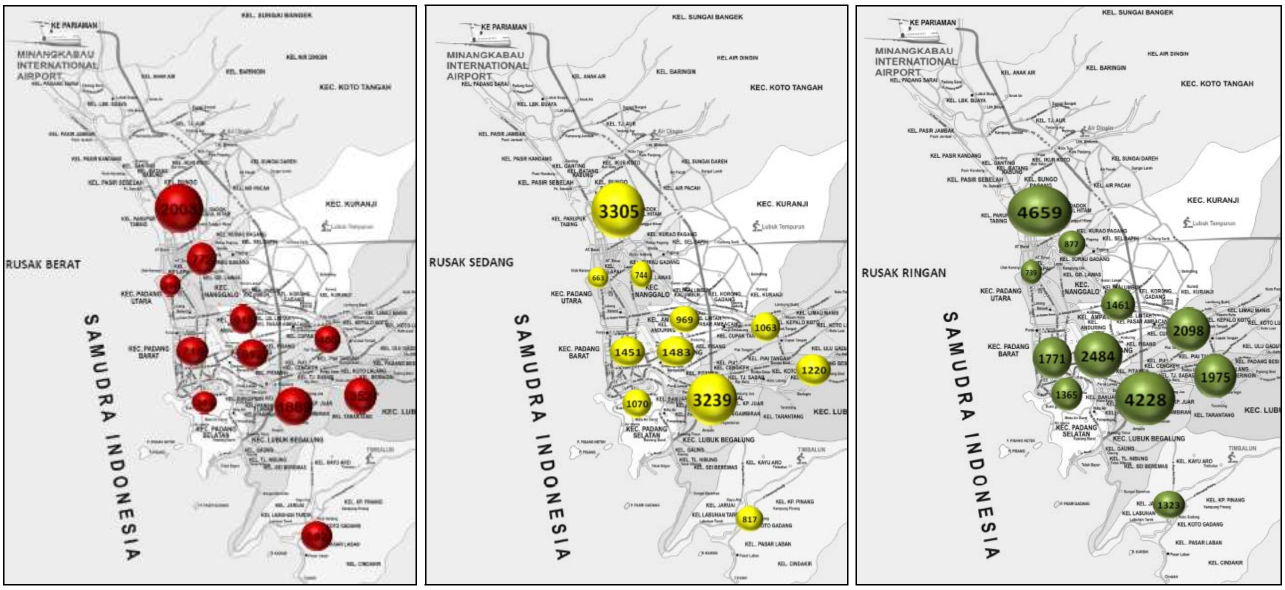
3. Results and Discussion

This paper shows the plot results of survey of the damage homes in Padang. The results are displayed in the term of map which is divided by districts in the city. Figure 4a, 4b, and 4c show damage to the residential houses with the category of heavily, moderate and slightly for the city. In every figure, the number that indicated the damaged houses is displayed in. The size of the bubble also presents of the ratio damage in each district. It seems that there is quite diverse spread of damage to the house. However this spreading data may be figuring the seismic ground condition that has been reported by Sengara *et al*. in 2009 [8] (Figure 5).

Furthermore, by dividing the area based on the level of earthquake intensity, it can display a graph of the distribution of damage to houses related to the peak ground acceleration. In the Figure 6 can be seen that there may relationship between the percentage the earthquake intensity with the distribution of the damage. In the figures also plotted the percentage of damaged houses in the city of Pariaman where located only a teens kilometres from the epicentre. The straight line curve is built in the figure to fit the relation between the damage level and the earthquake intensity in West Sumatra.

In this study, the houses generally are made of masonry brick structure. In order to compare the results, the damage-intensity relationships also for masonry structures are adopted in here. However, the modification of the damage and intensity of the earthquake must be modified. The mean damage ratio in the study of Birss [4] is assumed to be the same as the percentage of total damage in this study. The same thing applied for damage index that presented by Sengara [5]. The MMI scale which describes non-engineering value must also be transformed to the peak ground acceleration (PGA) which is the most important earthquake parameter for civil engineer. The relationship of the MMI and the peak ground acceleration is following the equation proposed by Wald *et al*. [9]:

$$PGA\ (\%\ g) = 10^{[(MMI+1.66)/3.66]} \times 10.19$$



a. Heavily damage b. Moderately damage c. Slightly damage

Figure 4. Damage Houses in Padang

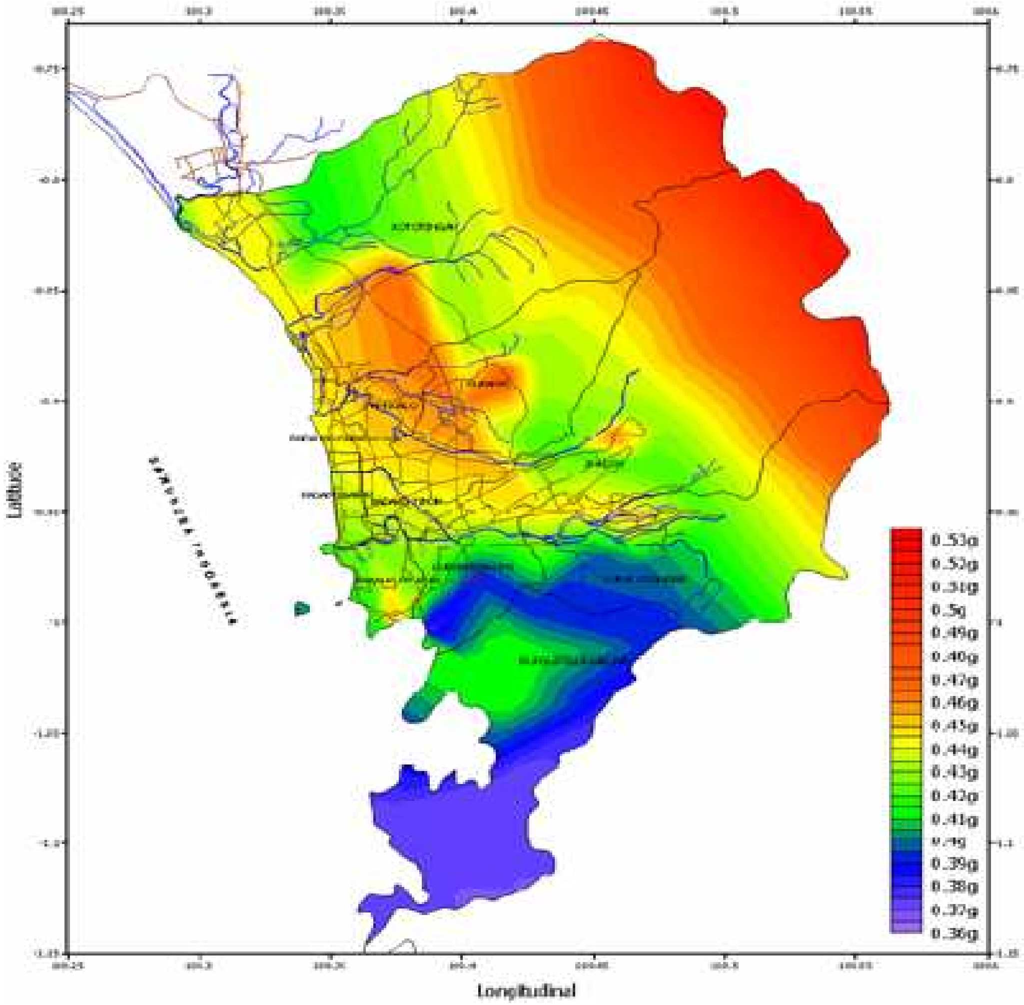


Figure 5. Seismic Microzination Map for Padang by Sengara *et al.*, 2009 [8]

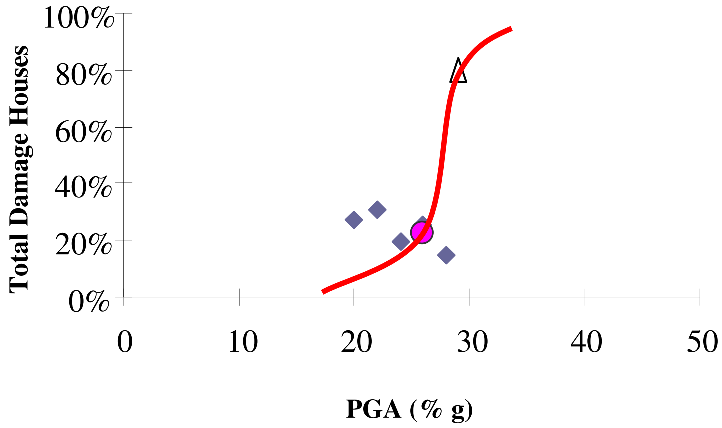


Figure 6. Damage and Earthquake Acceleration, Padang in Average (●), Padang in Districts Area (◆), Pariaman in Average (△)

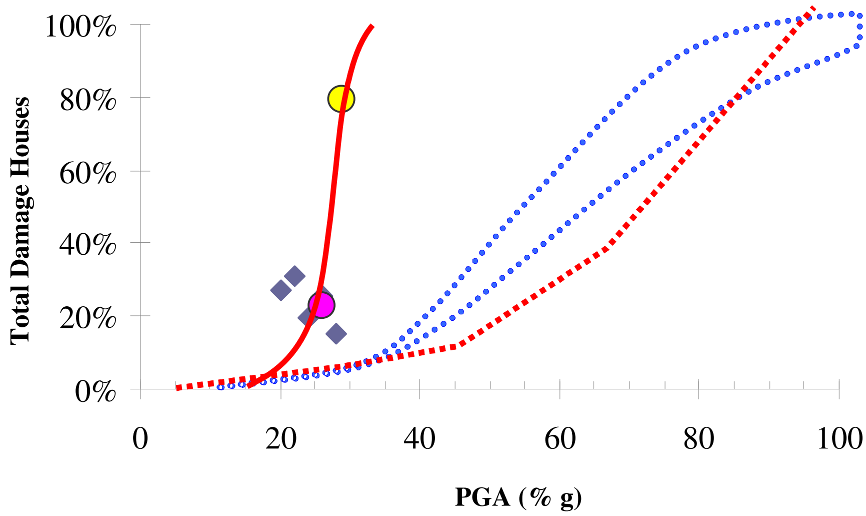


Figure 7. Earthquake Damage Intensity Relationship, West Sumatra (—), Sengara, 2011 (●●●), Birss, 1985 (▪▪▪)

The results of Birss and Sengara both for brickwork structures then are plotted together with the results of this study (Figure 7). It can be seen that the predicted curves given by the other authors give over estimate to the strength of the brick masonry houses in West Sumatra.

In realty the quality of residential houses in West Sumatra depends three main factors that are: a) The quality of materials, such as the strength of the bricks; b) The process of the construction which including the skill of the worker and material composition, and c) The detailing of the construction that including the connectivity and dimension of the element of the residential structures.

It can be concluded that the quality of the residential houses in West Sumatra are very poor. The earthquake intensity to destroy the houses in West Sumatra is lower compared to the New Zealand or the other place in Indonesia.

4. Conclusion

The West Sumatra Province has been badly damaged by 30 September 2009 earthquake. The earthquake has epicenter 100 km offshore of Padang City, the Capital City of the province. To learn the affect of the earthquake to the damaged houses in West Sumatra, the survey has been conducted in few days after the earthquake. The damage of buildings are categorised in 3 level that are heavily, moderate and slightly damages. Based on the survey and the peak ground acceleration, the relationship between the damage house and intensity for West Sumatra is then developed. It is shown that the fairly relationship of the damage and the intensity in

West Sumatra. This special damage-intensity relation is very important to be used for predicting the damage level due to a specified earthquake in the future. The Government can use the relation for developing an emergency and reconstruction budget plan for earthquake disaster.

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