

博士論文

**Development of Assessment Tools
for Disaster Reduction of RC Building due
to Future Mega Earthquake
in Padang City Indonesia**

（パダン市（インドネシア）の将来の巨大地震による災害軽減の
ための鉄筋コンクリート構造物の耐震性評価ツールの開発）

Eka JULIAFAD

エカ ジュリアファド

Abstract

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This research is aimed at developing assessment tools that can be used for disaster reduction of RC buildings due to Future Mega-Earthquake in Padang City, Indonesia.

Padang City is the capital city of West Sumatra province, Indonesia, located on the western coast of Sumatra island. On September 30th, 2009 at 17:16:09 West Indonesian Time (WIB), an earthquake with 7.6 magnitudes on Richter Scale (RS) happened. Padang city becomes the most damaged areas due to this earthquake, with more than 1000 fatalities. Building damage was dominated by housing, school, and office which made from Reinforced Concrete (RC). With the increasing population rate in Padang City and the threat of predicted Mega-Earthquake in the future, the effective disaster reduction strategy for RC buildings in Padang City is a must.

The first objective of this study is to identify the environmental system in Padang City. Using the analysis of building documents, street survey and google street view, have been found that more than 85% of the building population in Padang City is dominated by RC building. The field observation and the interview with building officers also found that even though the building code keeps improving, but due to the limitation on building staff number, the supervision effort is limited. This situation results in the poor quality of concrete, reinforcement arrangement and other building defects as the finding in our field survey. In case of this situation, the building owner has a crucial position to make the final decision for their building quality.

This research also found the structure of the local indigenous community in Padang City. Padang City has a unique culture which dominantly influenced by the indigenous Minangkabau tribe system. The Minangkabau system regulates the land acquisition system in the Padang area and another area in West Sumatra, which based on matriakhat (mother line) family system. The land which covers more than 70% of the total land area must be inherited from generation to generation to woman in the tribe. Then, by the time, the land area becomes not clear and complicated for the government to manage including to control building construction. However, the tribes have their leader who is called “mamak” that control the use of the land, including managing the tribe members that want to construct a building in the tribe land.

With the significant influence of Minangkabau tribe system in Padang City, tribe leader can be empowered as the agent of knowledge to influence the decision of their tribe members for making a correct decision on construct an earthquake resistance building for their safety. However, their potential has not been empowered. So, it is needed to provide the unique mechanism by using technical tools to bridge their understanding of RC buildings and increase their awareness towards earthquake resistance of RC building.

Hence, this research is aimed to reduce disaster of RC buildings due to future mega-earthquake in Padang City, West Sumatra, Indonesia by developing fragility function as the assessment tools that can give the information about RC building performance in Padang City when is subjected by the seismic load. This technical tool then will be used to bridge the understanding of local indigenous community in Padang City about the typical RC buildings in Padang city towards the seismic load.

To ensure the community believe in the provided tools, it is necessary to develop the fragility function based on the actual condition of RC buildings in Padang City. This research conducted the field study to get fundamental information of existing RC building including its construction year, a number of stories, building height, building layout, structural element and its cross section. The study on actual concrete, red brick, and steel strength also been conducted. Based on data, this research found five types of pre-dominant RC

building types in Padang City which cover more than 60% of RC buildings population. These types of RC building are low rise RC building with a red brick masonry wall.

The Incremental Dynamic Analysis method by applying real ground motion record that applied incrementally from 0.05 g, 0.1 g till collapse by utilizing the Applied Element Method (AEM). Damage patterns of each building types were observed, and damage level based on HAZUS criteria were judged. By using log-normal distribution, the fragility function for typical building types of RC building has been developed. This result can be used to communicate the performance of typical RC buildings to the target audience, in this research is the tribe leader.

By using Peak Ground Acceleration distribution map provided by Indonesia government and building damage data of 2009 September earthquake in Padang City, the comparison of damage ratio of actual damage data and developed fragility function has been done. The results show that the damage from fragility function for slight damage show a higher value than the actual one. This could be due to different damage patterns judgment between the actual and our fragility function. However, severe damage or more show almost the same damage ratio. The results will be more accurate if we increase the number of RC buildings types and cover other conditions that can be analyzed. While the actual damage was based on one earthquake event, the developed fragility functions were based on some earthquake ground motion and different condition of the building

This study also tries to transform the information of fragility function and seismic map as the scientific tools into simplified risk information of RC Buildings under earthquake load in Padang City. The target for RC Building risk information dissemination is the tribe leaders who can be the agent of knowledge to the people under their leadership.

Finally, this study recommends that the building typology is obtained in this study can be used by the government to update the building data inventory in Padang City. The government can use the fragility function based on the actual condition as the tool to make Padang City vulnerability map and to prepare for

a future earthquake. The tribe leader can be empowered to help the government to reduce the damage of RC buildings in Padang City. The mechanism which developed in this study can be used by the government to inform, disseminate and increase the awareness of local community towards earthquake resistance of RC buildings.

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Eka Juliafad
Tokyo, Japan
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List of Publications

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2. Survey Activities on Residential Building in West Sumatra, Indonesia” at 2017 Civil Engineering Symposium, The University of Tokyo in March 2017. The presentation was published on FSO Update, Vol.5, page 33, ISSN: 2187-9249.

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CHAPTER 1

INTRODUCTION

1.1. The Profile of Padang City

1.1.1. Location and Demography

Padang City is the capital city of West Sumatra province, Indonesia. It is located on the western coast of Sumatra island. Figure 1.1. show the position of West Sumatra and Padang City in Indonesia and its administration boundary with other provinces.



Figure 1.1. Map of Padang City, West Sumatra Province Indonesia

Source: <http://tourism.padang.go.id>

The total area of Padang city is 1,414.96 km²; consist of low land and mountainous area with 21 rivers and 19 islands. The average temperature is 22°C - 32°C. The exact location of Padang city is 00044'00" -01'08" 35" LS and 100 05'05"-100 34' 09" BT, lies along the shore facing Indian ocean with a total length of the seashore is 68,126 km excluded the small islands. Figure 1.2 shows the 11 sub-districts (Kecamatan) in Padang City and its location.

ADMINISTRATION MAP OF PADANG CITY

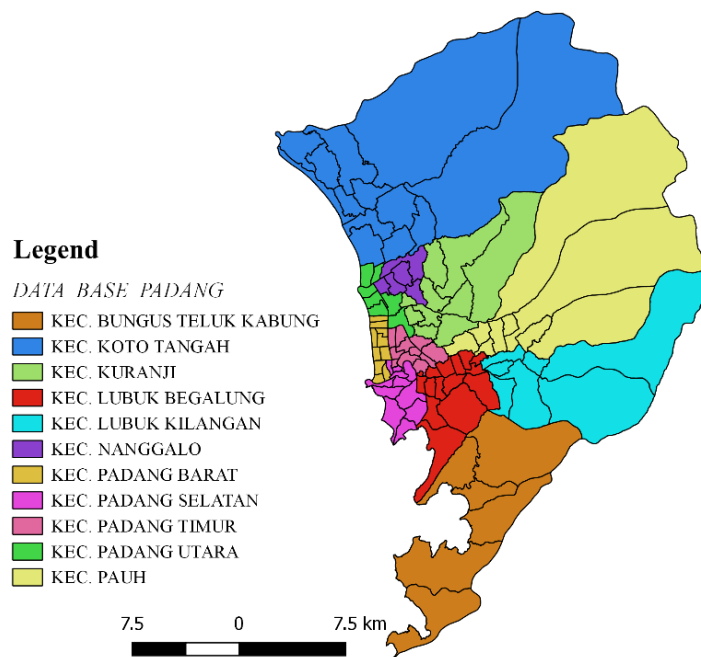


Figure 1.2. Sub-district Map of Padang City

The total population of Padang city is 914,968 people as of 2016, and the density is 8500 people/km². Padang also becomes a center of education with 110,043 elementary schools, 38,815 Junior High School, 14,812 Senior High School and 60 public and private Universities/Institutes. The students come from inside Padang and outside Padang such as Pariaman, Solok, Bukittinggi, Payakumbuh and other provinces in Sumatra Island. This situation results in the actual demography data become bigger than recorded data. Padang city also become centers for economic and health. Most of the people from cities in and outside West Sumatra will come to have some medical treatment in many hospitals in Padang city. There are also many shopping centers and tourist spots that attract people to come. All of the above statement make Padang city become the most populated and busiest city on the west coast of Sumatra Island

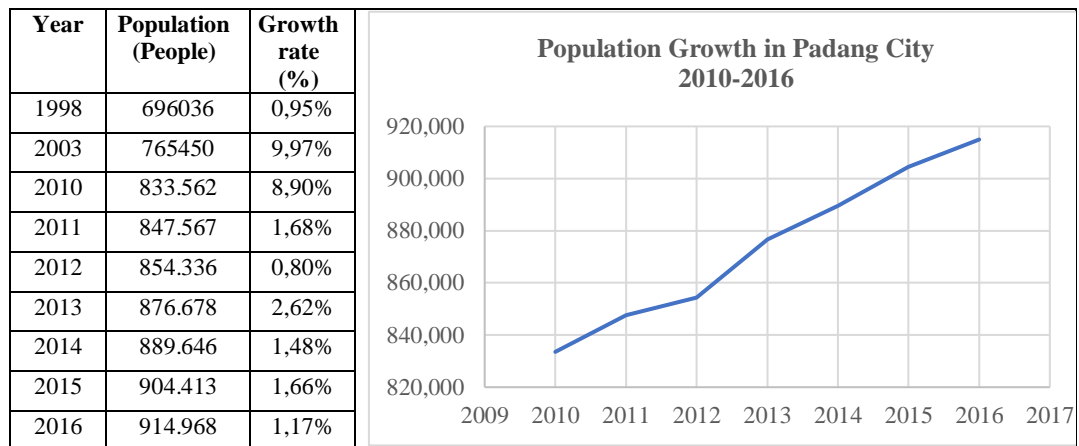


Figure 1.3. Population Growth in Padang City 2010-2016

Figure 1.3. show the population growth in Padang City from 2010 to 2016. When the growth rate is increasing each year, it seems to be followed by the increase in residential building(Coleman & Karagedikli, 2018). While the density of the population is concentrated in the city center, the density decreases towards the area near the boundary of the city.

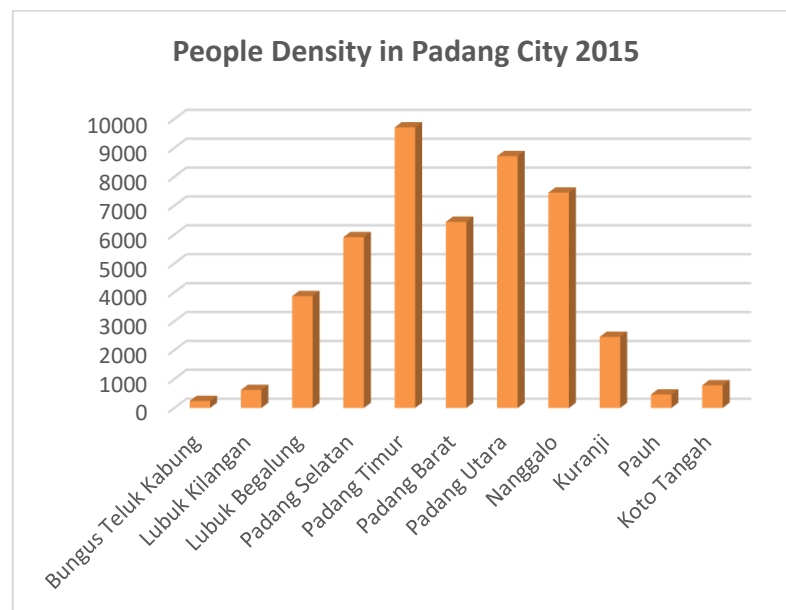


Figure 1.4. People Density in District in Padang Area

West Sumatra has a very specific local culture which dominantly influenced by the Minangkabau, which is said and based on the history of The Hindu-Malay kingdom of Pagaruyung and Pariangan which appeared in this area between 12th and the 14th

centuries. Nevertheless, after the coming of Islam, the Minangkabau increased again, and its original governmental system was settled again. This system called as `Nagari` which is headed by the head of Nagari called `wali Nagari.` The Minangkabau system also regulates the land acquisition system in the Padang area and another area in West Sumatra. Then, Dutch colonialism tried to control the influence of this system to simplify the city planning of Padang city. This controlled system continued under British colonialism from 1781 to 1784. After the reformation era in 1998, the Nagari system was revived again and take control of the local government system in The Minangkabau (Padang city and surrounding area) (Andaya, 2000),(Sadiq Bhanbhro, 2017).

1.1.2. Earthquake Disaster in Padang City

a) Important earthquake history in Padang City

Sumatra island is located at the plate boundary between subducting Indian and Australian plates and overriding Sunda land plate. Indonesia located within the Pacific Ring of Fire, where some of the largest recorded earthquakes in the world have taken place. The seismicity in the region is controlled by the subduction of the Australian plate beneath the Eurasian plate. The subduction between these tectonic plates occurs along the western side of Sumatra forming the Sunda trench. The dip angle of the subducting zone in the uppermost part of the contact between the plates is about 13° – 15° (Hanifa, Gunawan, Irsyam, & Abidin, 2016). Natawidjaja (2002) illustrated the velocity of the relative motion between the Australian and Eurasian plates varies according to the area studied; it is calculated at about 52 mm per year at the northern part of Sumatra and 62 mm per year at the southern part, as illustrated in Natawidjaja (2002)(Kerry Sieh et al., 2008).

Big Padang Earthquake in 2009, historically is a part of a long history of earthquake happened in the past. Up to 2009, has been recorded at least 14 times major and destructive earthquake occurred in this region since 1822. Based on USGS data (2016), there were 13 times earthquake with $M_w > 7$, 77 times $M_w > 6$, and 584 times $M_w > 5$ only at the region of West Sumatra province and nearest neighboring province consist of in-land and subduction area earthquake. Those records confirm this area is active and complex seismic zone.

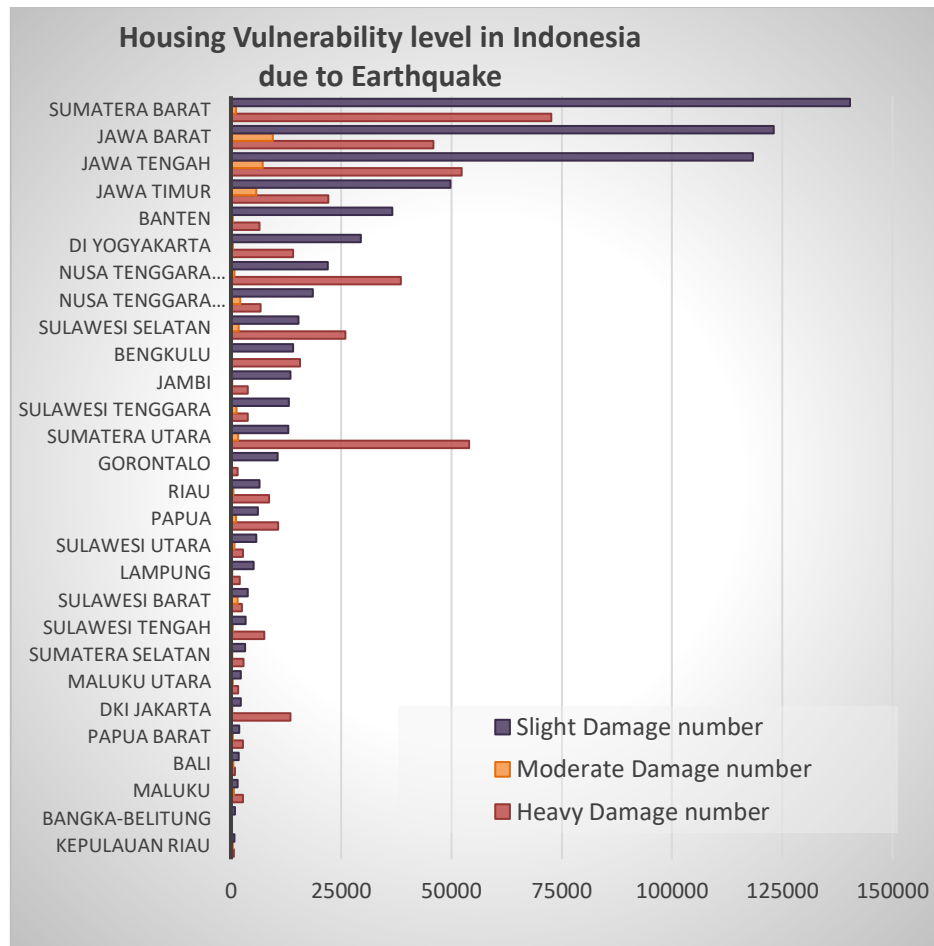


Figure 1.5. Housing Damage Data of Indonesia due to Earthquake Hazard based on BNPB data 2017

Two main fault zones generate a source of seismic activity in this area, First, subduction zone on the west part of Sumatra island which is potentially generating strong ground motion and followed by a tsunami. Another one is the Sumatra fault zone named by Semangko fault, which is located on the mainland of Sumatera. Semangko fault dimidiates Sumatera island and lies 1900 km along the island started from Sunda Strait to the north part of Aceh city. Based on the record, the activity of Semangko fault near Padang area generates an earthquake for every five years. Even though the magnitude is smaller than earthquake generated by a subduction zone, the damage intensity becomes high since the location is near the populated area and the focal depth is shallow.

Regards to the data of the BNPB of Indonesia has been recorded that West Sumatra province suffered the highest number of building damage especially residential building due to earthquake event. Figure 1.5. show comparison of

damage data of all of the provinces in Indonesia, excluding Aceh province where the damage mainly caused by tsunami hazard. Provinces located in Kalimantan island are not included also since Kalimantan island is not vulnerable to earthquake based on the seismic zone of Indonesia in Indonesia seismic code 2012.

b) Damage due to 30th September 2009

September 30th, 2009 at 17:16:09 West Indonesian Time (WIB), an earthquake with 7,6 magnitudes on scale Richer (SR), with epicenter located at 0.84LS- 99.65 BT at 71 km depth and 57km southwest direction on the coordinate of Pariaman district West Sumatra and 54km west-north-west of low-lying coastal of Padang City. After 22 minutes, another earthquake occurred with magnitude 6.2 SR at 110 km depth at 0.72LS-99.94BT coordinate with 22 km distance. The first earthquake was not followed by a tsunami since the depth was deep, but the shaking was felt by neighboring area including Singapore, Malaysia, Aceh, Jambi, Riau, Bengkulu and North Sumatra province. One day after that, another earthquake with a magnitude of 7,0 SR shook Jambi next province of West Sumatra, Jambi province with 10 km depth. The 2009 event happened in the same region as the 2004 Sumatra-Andaman earthquake that generated a tsunami which causes the deaths of over 200,000 people (Wilkinson, Alarcon, Mulyani, Whittle, & Chian, 2012)

The Indonesian Meteorology and Geophysics Agency (BMKG) recorded that the Padang 2009 Earthquake generated peak ground acceleration of 0.306 g. The recording was taken from a relatively stiff soil around 13 km northeast of the Padang City (Fig. 1.6)

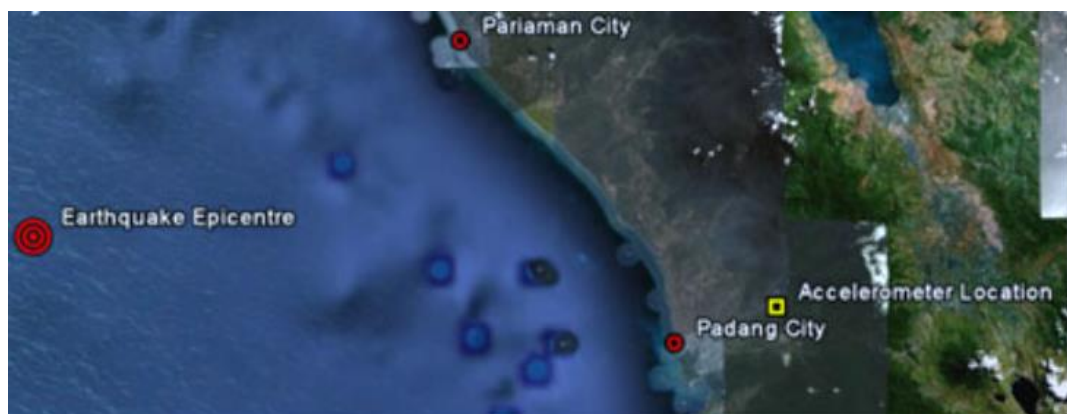


Figure 1.6. Location of Accelerometer in Padang City

With the highest population in (865,814 people as 2008) and very high density (2nd), 8500 people/km², Padang city becomes the most damaged areas due to this earthquake. With more than 1000 casualties, for exact 1117 people were killed, 1214 severely injured, 1688 slightly injured, and three were left missing. The earthquake also destroyed many houses, buildings, and infrastructure, reported 114,797 houses were heavily damaged, 67,198 moderately damaged and 67,837 slightly damaged.

Based on BNPB data in 2009, 5458 buildings sustained damage. If this event occurred earlier at working hours, the number of casualties would be higher. Document of Action Plan of Rehabilitation and Reconstruction of West Sumatra Earthquake 2011 of National Development and Planning Biro of Indonesian Government [1] compiled damaged building data for types of building in Padang city.

Table 1. 1. Building Damage data in Padang City

Type of building based on occupancy	Heavy	Moderate	Slight
Housing	33597	35816	37615
Hospital	13	17	51
Education	1464	906	781
Religious building	115	83	72
Social/Foster house	10	0	1
Commercial	10	1	13
Tourism	25	17	23
Government office	275	393	183
Bank	20	10	6

Source: Evaluation and monitoring report document of post-disaster of West Sumatera Year 2011, BNPB.

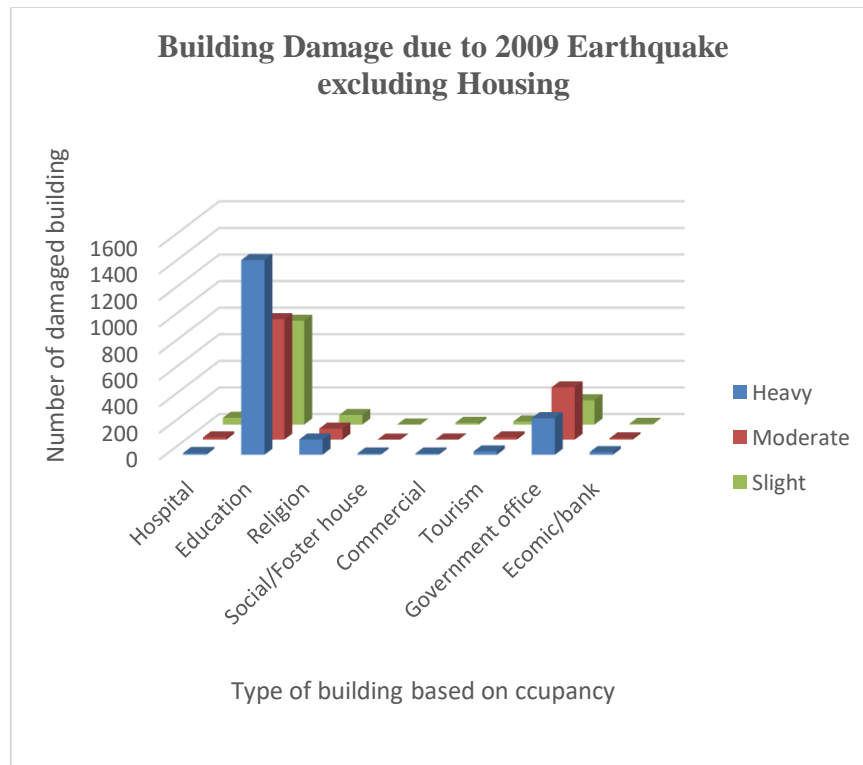


Figure 1.7. Building Damage due to 2009 Earthquake excluding Housing

Data of building which was damaged according to assessment record database conducted by the Indonesian government and confirmed by other international organizations. Housing becomes the most populated building which is become the most destructive one in number, followed by schools, government office, religious building, foster house and another type of buildings. Housing building type in this data means as pure residential housing and hybrid residential building. Hybrids residential building, in the document of West Sumatra Plan Scenario of BPBD West Sumatra, define as a residential building which is also used as commercial building/shop called as Rumah Toko (Ruko) (see Fig.1.7).

Meanwhile, damage ratio of each building compares to a total number of each type of buildings before earthquake show different results where schools become the most damaged one followed by foster houses, tourism buildings, government offices, and housing. can be shown in Figure 1.8.

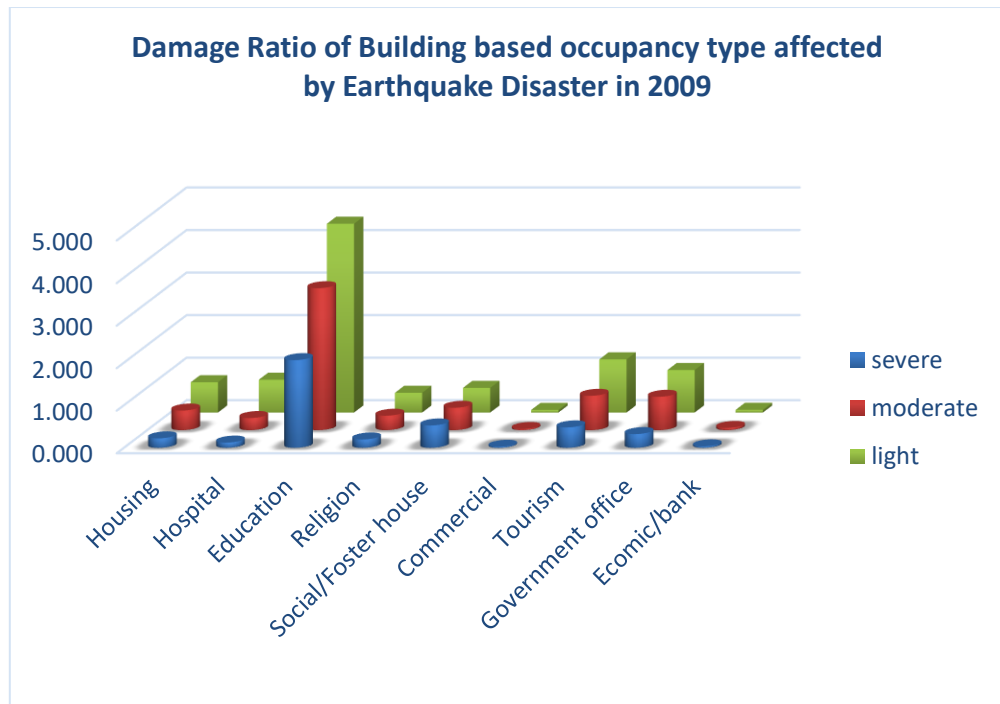


Figure 1.8. Building Damage due to 2009 Earthquake excluding Housing

This devastating earthquake destroyed not only modern building (reinforced concrete type) and housing, but also some historical buildings from the Dutch colonial era in Padang, located in Kota Lama (old town) area were more than 100 years old

c) Future Mega-Earthquake

Even though there were many big earthquakes occurred, including 2009 earthquake Mw 7.6 and 2007 earthquake Mw 8.4, the 700-year record of Sumatran megathrust super cycles implies that 8.4 Mw earthquake was the beginning of an episode of the failure of Mentawai patch. Those are not the one that is concerned more by the Indonesian government. There is another one which will be generated by the subduction zone with unreleased energy for 200-300 years ago, and the will be enough to generate an Mw 8.8 earthquake(K. Sieh, 2006; Kerry Sieh et al., 2008).

The subduction zone in Sumatra is known for producing mega-thrust earthquakes such as the Mw 8.8–9.2 in 1833, the Mw 8.3–8.5 in 1861, the Mw

9.0–9.3 in December 2004, the Mw 8.7 in March 2005 and the Mw 8.4 in September 2007 (Irsyam et al. 2008). By the recent seismic activity, Aydan et al. (2007) (Aydan, 2009) identified a segment of the subduction one facing Padang City that has not ruptured in the last 213 years. This seismic gap might produce an earthquake with a magnitude greater than 8.7. The seismic gap is located between the 1833 and 1861 fault ruptures, and it is estimated to have an approximate recurrence interval of 230 years (Zachariassen, 2001).

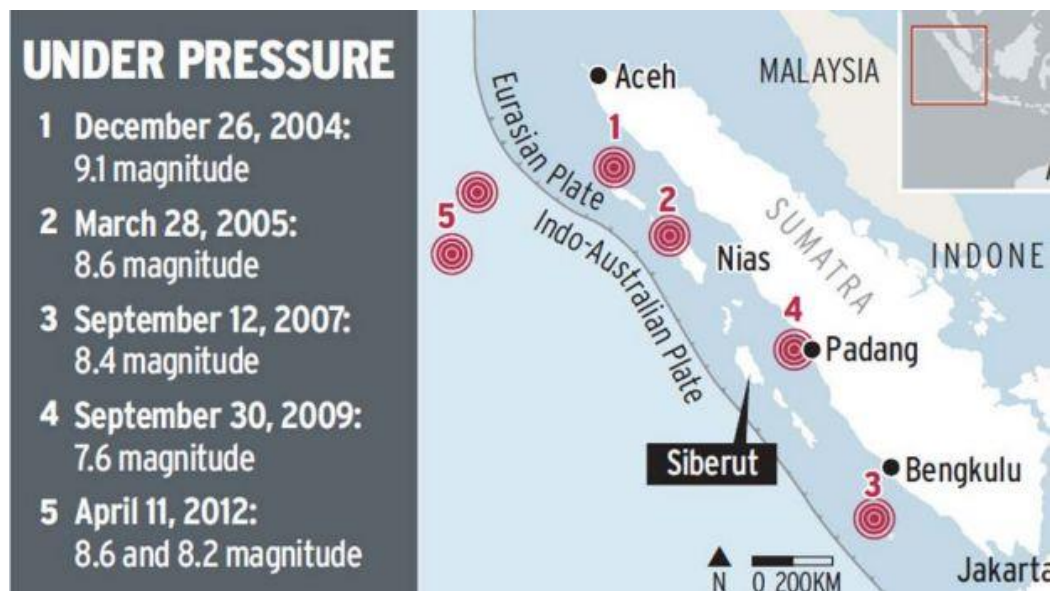


Figure 1.9. Building Damage due to 2009 Earthquake excluding Housing

Professor McCloskey from the University of Ulster in Northern Ireland said that Mentawai segment of megathrust further south under Siberut (Figure 1.8), would generate shaking in western Sumatra and can produce damage in Padang and neighboring cities and villages. (<http://www.smh.com.au/world/padang-now-the-prime-target-for-the-big-one-due-any-time-20120413-1wyv2.html>). Historically, this fault caused mega-earthquake which triggered a big tsunami which swept away west coast of West Sumatra and neighboring province.

1.2. Reinforced Concrete (RC) Building Vulnerability

Concrete is the most robust construction material available and has therefore obtained a favorite position in construction. Hence, Reinforced Concrete is the most widely used

structural system [1-4]. So, it becomes a disaster when a large urban dwelling made from reinforced concrete material constructed poorly [1].

The quality and performance of concrete is not known but assumed at the design stage and that the actual quality and performance characteristics are determined through the actual execution process. This fact is the unique situation for concrete structures compared to structures made from other building material and emphasizes the special needs to verify the actual quality of the buildings.

With locally available material and labor skill, which implied the low price of construction, the red brick material becomes widely used in Indonesia as the infill material for the wall of the RC structure. Moreover, the brick wall has good sound and heat insulation and waterproofing properties, resulting in greater occupant comfort and economy (Kaushik, Rai, & Jain, 2006).

The uncertain position of a masonry wall and opening in them increase the irregularities in plan and elevation of the RC Buildings. Frequently, the arrangement of masonry walls are based on the functional needs of the occupants, the changes being carried out without considering their effects on the overall structural behavior since masonry wall is generally regarded as nonstructural elements. Thus it is not only challenging to construct regular masonry RC frame but also it can not be guaranteed that it will remain regular after it is constructed.

While earthquake load is acting to RC frame with a masonry wall, the masonry wall which is usually stiff attracts most of the lateral load but may fail prematurely because of the brittle behavior.

The position of Indonesia which lies on the “ring of fire” with one of the highest seismic activities and some fatality and building damages in the history of its earthquake event. At the same time, Indonesia is still dealing with the economic problem for low-middle incomes families and lack of trained staff at the local level. Thus, the price of construction is prioritized then quality that results in low quality of RC building constructions.

Observation of building damages due to 30th September 2009 in Padang City West Sumatra, shows that the performance of RC building with infill wall was varied, with damage ranging from minor to total collapse. Majority of buildings suffered significant cracking in masonry infill, and out of plan failure are often observed. The failure due to the development of the plastic hinge at the top and bottoms of the column were majorly found (Wilkinson et al., 2012).

Those facts above shows the need for assessment of existing RC Buildings in Padang City due to the seismic load. It may be the best to assess the existing buildings one building at the time due to its uniqueness of the quality. However, this technique may not always be feasible if the building inventory at hand is enormous. An alternative to individual building analysis is fragility analysis of buildings. Fragility analysis provides information on the probability of exceedance of predefined performance under different earthquake intensity measures. Such analysis results in fragility curves, which when available for buildings with different structural characteristics, provide convenient seismic assessment tools.

Some fragility functions have been developing for seismic assessment tools in Indonesia. However, they were based on the empirical method which provides the damage information based on the specific one-time earthquake event, when the performance of undamaged structure keeps unknown for a different or future earthquake.

1.3.Review of Fragility Function as The Assessment Tools for Disaster Reduction

A critical component of the chain of risk assessment is fragility function that is defined as the probability of exceeding different limit states such as physical damage to the building at a given level of ground shaking. Fragility function can provide the necessary link between seismic hazard assessment at a site and the corresponding effect of the structure (Fotopoulou & Pitilakis, 2013)

To derive fragility function, three methods generally used

1. Empirical method

Empirical methods are based on the data of actual damage of element at risk after an earthquake event. Fragility function produced using this method is specific to particular sit and earthquake event covering parameter of magnitude, depth, etc., since it is based on the actual damage data, for that particular event and location, the reliability is high. However, the fragility function cannot be used for higher magnitude and different site condition. Disadvantages from empirical fragility function are:

1. Available data for fragility function is not reliable for higher magnitude events
2. In many cases, undamaged buildings are not appropriately accounted for in the survey, so the total number of buildings exposed is yielded to be uncertain.

3. Lack of knowledge of exact ground motion. Estimation must be made with macro-seismic intensity or through extrapolation of the recorded signals from the close station.

Table 1. 2. Show some fragility function has been developed

Researcher	Number of Buildings	DM and IM
Spence et al. (1992)	70,000 buildings 14 classes of buildings	The function of the macro-seismic intensity
Rossetto and Elnashai (2003)	Moment Resisting Frame Infill walls Shear wall Database: 340,000 buildings	HRS index
Subetta et al. (1998)	Italian Building Database: 50,000 damage buildings	PGA vs. damage state Using Spectral Response Parameter. PGA was converted from the observed macro-seismic intensity.

2. Expert opinion method

Fragility function based on expert opinion is used where there is little empirical information on the damage or where the element at risk is difficult to be modeled or analyzed. Expert panel need to be chosen, recruited or trained first before collecting the expert elicitation using mathematical or behavioral approach (Jaiswal et al.2012 and Clemen and Winkler 1999)

This method reliability is very dependent on the selection of expert panel member related to the level of expertise and confidence. Hence, the final results may be influenced by the composition of the panel, regarding sexes and personalities.

3. Analytical method

Analytical methods are based on the estimation of damage distribution through the simulation of the response of structural elements under seismic action. Seismic input can be represented by a static method (a respond spectrum) or a dynamic method (an acceleration time history). The results can reduce bias, and increased reliability of the vulnerability estimates for different structures compares to expert judgments.

Some critical points on conducting analytical fragility function methods are

1. Developing numerical models must be compromised to the accuracy of the representation of the non-linear behavior and the robustness and cost-efficiency of the model.
2. Representation of the model whether it is in 3D or 2D. For a structure that is in regular in plan, the torsion effects can often be ignored, and reasonably accurate results can be obtained by using 2D. Otherwise, the 3D model should be conducted.
3. The approach of analytical methods; direct or indirect.
 - a. Direct method involves Intensity Measure (IM), e.g., PGA, PGV, Sa(T), etc. this method does not rely on the structural response parameter.
 - b. Indirect method involves estimation of damage probability concerning structural response parameter (e.g., spectral displacement at the inelastic period), which is used in the HAZUS (NIBS 2004).
 - c. Capacity Spectrum Method has been used in HAZUS and RISK-UE Level 2 approach.
 - d. General dynamic analysis
This method is straightforward. On conducting fragility curve, it is necessary to account the significant variability of structural response.

4. Hybrid method

The hybrid method is a combination of two or more methods, using both analytical and empirical data, or completed by expert judgment. The advantages of this method are it compensate for the flaws of empirical data for the deficiencies of structural models and the subjectivity in expert opinion data.

Hybrid method also can be used to calibrate the analytical results or to fill-in some lack due to limited data at higher seismic levels (Calvi et al.2006). The additional data can be done through Bayesian updating, which can elaborate on the estimation of the median and standard deviation of the initial lognormal distribution (Singhal and Kiremedjian 1998).

Hence, the degree of reliability of the hybrid fragility function is dependent on the quantity and intensity covered by the data

This research focuses on using the analytical method for investigating RC buildings with masonry wall as the predominant building typology in the study area. The discussion about building typology determination is discussed in Chapter 2.

Most analytical fragility curves developed using two main demand parameters; real ground motion records and spectral acceleration and intensity measure used are S_d and drift ratio or inter-drift ratio. Some models are developed with SDOF and MDOF model and other using IDA which mainly developed with the numerical simulation FEM based model. Since mostly developed analytical model used FEM model, the response of numerical model usually will be global damage indicator such as displacement or inter storey displacement. The model will also be limited to frame-based model, especially for reinforced concrete structure. As we know, earthquake damage for reinforced concrete structure mostly caused by the damage to infill wall which is mostly made from brick masonry (especially on developing country), so it is necessary to develop a model that can show the response of masonry wall itself.

1.4. Available Fragility Curve in Indonesia

This part discusses the research related to fragility curve for RC building which is available in Indonesia. As the awareness of RC building vulnerability raised after the 2009 Earthquake in Padang City, some researchers built some assessment tools to inform the vulnerability of some typical buildings in Indonesia.

Hakam (2010) developed a vulnerability curve for housing in West Sumatra. The damage data for the building were based on building damage data of 2009 Earthquake in West Sumatra. However, the curve was based on the empirical data, which is in another side can show the actual damage, but it cannot show the probability damage of housing in the future for a different earthquake. The type of building that addressed on the curve also unclear and very general, especially for types of building structural system. The provided information also limited for severe damage only (Nur, 2012).

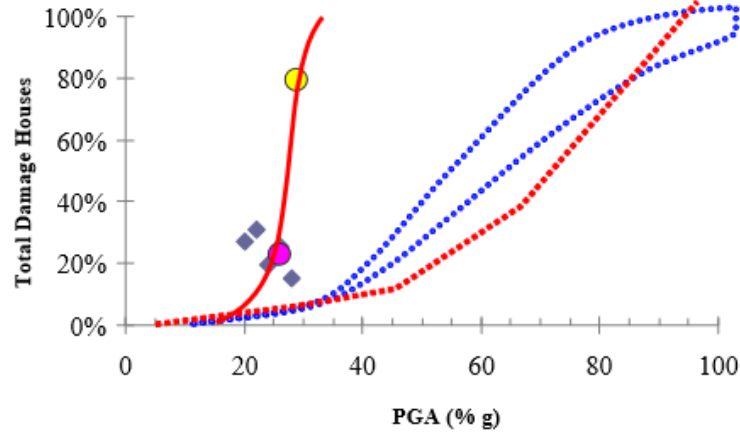


Figure 1.10. Vulnerability Curves for Residential Building in West Sumatra (—), Sengara, 2011 (blue dot), Birss, 1985 (red dots), for Masonry Structure

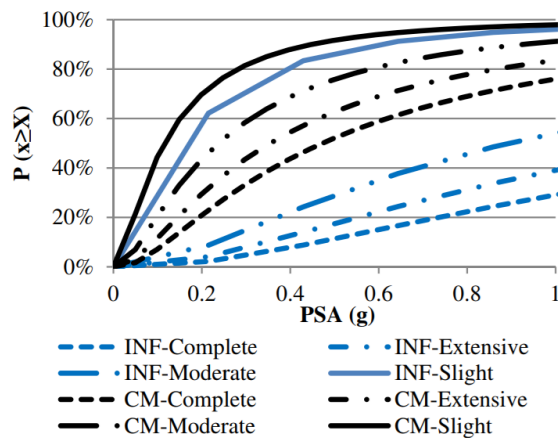


Figure 1.11. Fragility Curves for Two Types of Residential Buildings in Jakarta City (Irsyam et al., 2014)

Irsyam et al. derived fragility curves as shown in Figure 1.11. for two types of low rise buildings that dominate the residential building population in Jakarta. The fragility curves are derived based on FEMA 154 procedures for a different level of damage (i.e., Slight, Moderate, Extensive and Complete Damages), and the ground motion intensity is expressed in terms of Peak Surface Acceleration (Irsyam et al., 2014)

Based on the aforementioned review, we can conclude that fragility function for RC building based on an actual condition which causes many fatalities in earthquake event is not available in Indonesia.

1.5. Transforming Technical Knowledge into Locally Disaster Reduction Action.

As the above explanation, the fragility function can be a convenient assessment tool for some particular building types in a large area, which is in this study is for RC Building with masonry wall types in the urban area of Padang City, Indonesia. The information about damage probability of RC building in Padang City under earthquake load can be calculated to inform the risk and increase the risk awareness of related stakeholders for RC building performance in Padang City.

In the previous sub-chapter, we explained that many RC buildings were collapse due to the 2009 earthquake due to the poor quality of both the design and construction stage. This is due to lack of supervision and unskilled builder. Hence, the owner has significant roles in decision making for their building quality. However, it will be difficult and take time to approach the owner, one by one. So, we should study the structure of the local community and find the key person/position that can reach deeply as many as possible their own group/community.

This type of approach also has been emphasized and became one of the targets in Sendai formwork 2015 which is empowering the local and indigenous community on earthquake disaster reduction action (ISDR, 2015; UN General Assembly, 2015; UNISDR, 2015)

Once the key person can be found, the performance of actual RC building with the particular condition under seismic load can be disseminated to them by transforming the probability of building damage in fragility curve as a technical tool into simplified RC building risk information.

This hypothesis could result in more effective and efficient way to reduce the disaster of RC building in Padang City by emphasizing the indigenous local community uniqueness and potential.

Using this way, the difficulties on linking the earthquake disaster and RC building knowledge to the building owner can be solved for better disaster reduction action in Padang City.

However, to convince that the information from fragility function can represent the actual performance of RC building in Padang City, it is essential to collect the actual information of existing RC building and find the fundamental information of parameter that will be used to conduct an analysis of RC building numerical model and design the disaster reduction strategy. Applied Element Method can show the building performance from early elastic state till collapse state. So, this method can be used to observe the damage patterns from slightly to collapse state accurately.

1.6. Problem Statements

Finally, the problems can be stated as below:

1. Padang is the most vulnerable city in Indonesia and facing Mega-Earthquake in the near future.
2. From disaster experience, building a survey, and review of the environmental system, reinforced concrete (RC) building as the predominant building typology in Padang has the highest risk of damage due to the earthquake.
3. It is essential to find the locality uniqueness and build the mechanism to use developed tool to strengthen local community for disaster reduction of RC building due to the earthquake.
4. Currently, Padang City - Indonesia as the prone earthquake area and Indonesia, does not have fragility function which can show the actual condition of RC building.
5. It is necessary to conduct an assessment for existing RC structure and develop fragility function as the assessment tool for disaster reduction due to Mega-earthquake disaster in the future.

1.7. Research Objective

This research is aimed at reducing disaster of Reinforced Concrete buildings in Padang City West Sumatra by developing fragility function as assessment tools based on actual condition.

The fragility curves can be used to quantify the risk of earthquake hazards, influence the government policy and bridging the gap between technology and the understanding of local community towards earthquake resistance RC buildings.

1.8. Research Methodology

The research methodology follows the following scope:

- 1) *Literature review*: Related literature has been reviewed to identify the research needs, building selection, seismic record selection, analysis method and the Applied Element (AE) model, damage criteria, and damage levels
- 2) *Investigation on Environmental System of RC Building in Study Area*: As earthquake hazards of RC buildings in the specified area are influenced by the system which is supporting the buildings stock condition, it is necessary to understand the system which is then called an environmental system. We used some

methodologies, e.g., using interview, literature, and building code review, document inspections, google maps survey and the street survey. We also discuss with some government staff, experts and local people in Padang City and asking advice from related department head officers.

- 3) *Review of Disaster Reduction Action for RC Building in Indonesia*: discussion and literature review has been compiled to develop a timeline of existing disaster reduction strategy in Indonesia.
- 4) *Field Study*: A field investigation for existing RC buildings infills masonry wall from early 1970 to 2017 to get information about the actual condition of the buildings. The study also includes the testing of concrete sample and brick sample from demolished buildings. We also visited 65 construction sites and got 15 concrete cylinders of concrete that produced by the local builders. Hundred (100) builders have been interviewed to understand their profile and their method of RC building construction. Ten Minangkabau tribe leaders also have been interviewed to know their knowledge about earthquake resistance construction and ask their willingness if they can provide more services to their tribe for helping the community build a better building for their safety.
- 5) *RC Building structures selection*: Select RC building for numerical analysis based on the predominant type of RC Building in Padang City.
- 6) *Selection of Seismic Records*: 3 real ground motion records were selected with the consideration of its magnitude, duration, and frequency.
- 7) *Selection of suitable numerical tools*: Applied Element Method (AEM) utilized in Extreme Loading (ELS) software was selected as the numerical simulation tool to analyze the selected 3D RC building model's performance which is subjected by selected ground motion.
- 8) *Performing Incremental Dynamic Analysis and damage patterns observation*: seismic records were incrementally reduced and amplified to cover a range of earthquake intensities to develop IDA curve and complementary with the identification of damage patterns to identify the seismic behavior.
- 9) *Development of fragility curves*: Fragility responses were calculated, and fragility curves were developed for selected damage and performance levels.
- 10) *Development of disaster reduction strategy*: A disaster reduction strategy for RC Building which is utilizing fragility curves based on actual existing RC buildings is developed. Harmonization of disaster reduction strategy see that every component

in the environmental system in a city can play their role based on their capacity and capability. The developed assessment tools in this research can provide information about the real condition of the RC buildings and can play the role for tribe leaders and other key persons in the community to empower them for distributing knowledge and assisting the community about earthquake resistance building.

The research methodology is presented in Figure 1.9. below.

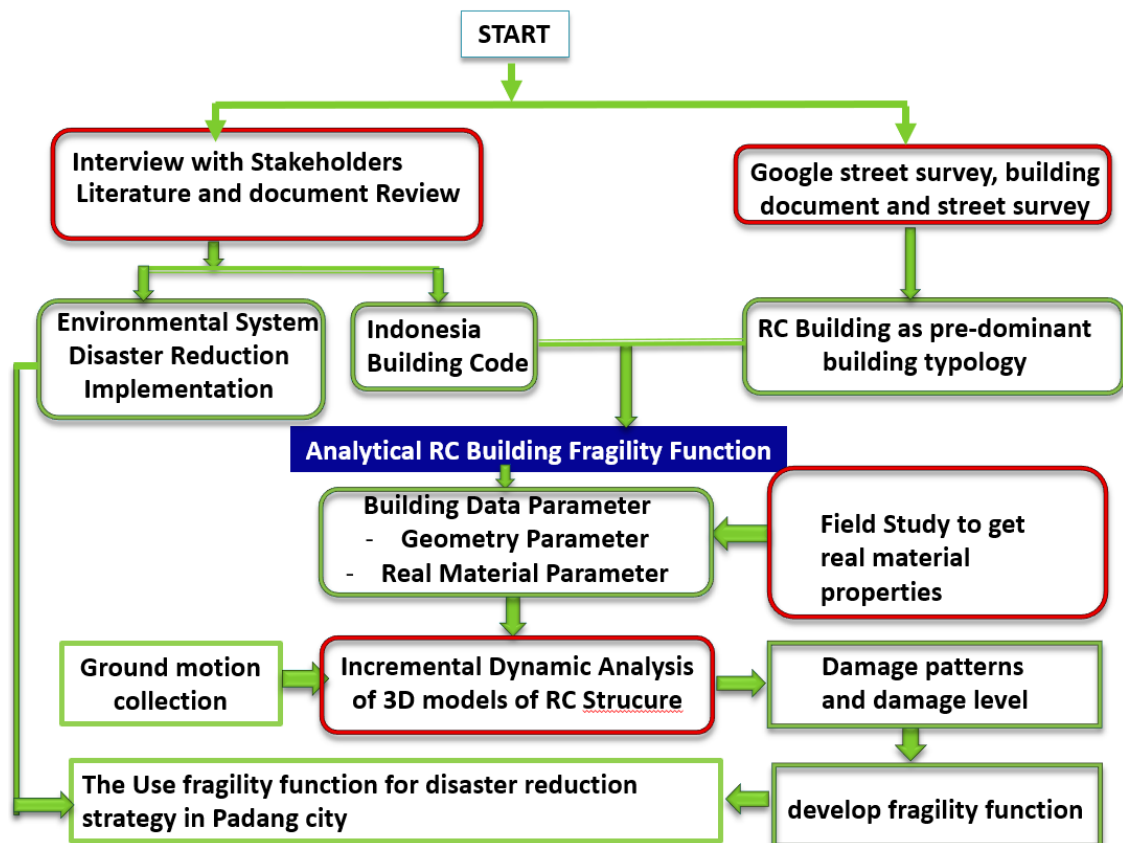


Figure 1.12. Research Methodology

1.9. Structure of Thesis

The thesis consists of 9 Chapters. The details of each chapter are described below:

- *Chapter 1:* Introduction chapter described the motivation behind the research, introduction of Padang City as the study area, objective and methodologies being used in this research
- *Chapter 2:* This chapter represents the study of the environmental system towards the development of assessment tools for disaster reduction of RC building in Padang City, West Sumatra Indonesia.

- *Chapter 3:* This Chapter review the disaster reduction acts for RC building due to earthquake hazards.
- *Chapter 4:* This chapter presents the field study which conducted in Padang city to get information about the actual condition of existing RC buildings, including the material quality and construction method conducted by local builders. This part also narrated the interview of an indigenous community in Padang City, Minangkabau people about their understanding of earthquake resistance buildings. Also explained the results from building official.
- *Chapter 5:* This Chapter presents the numerical analysis process of selected buildings that were subjected to selected ground motions. IDA technique has been utilized in understanding the quantitative measures as getting the visualization of damage patterns of buildings as a qualitative judgment which possibly obtained by using AEM technology. The fragility curves developed based on Peak Ground Acceleration intensity and damage level.
- *Chapter 6:* This Chapter presents the new fragility function for low rise RC Building with masonry wall in Padang City which considers the Peak Ground Acceleration and Ground Motion Frequency as the damage intensity parameter for measuring the collapse ratio of low rise building in Padang City.
- *Chapter 7:* This chapter discusses the comparison of developed fragility function in this study with the actual damage ratio based on information of building damage due to 2009 September Earthquake in Padang City
- *Chapter 8:* This chapter discusses the proposal of disaster reduction strategy for disaster reduction of RC buildings in Padang City, West Sumatra, Indonesia.
- *Chapter 9:* This chapter presents the summary and conclusion of this research.

1.10. Reference for chapter 1

- ACI. (2008). *Building code requirements for structural concrete (ACI 318M-08) and Commentary*. American Concrete Institute (Vol. 2007). [https://doi.org/10.1016/0262-5075\(85\)90032-6](https://doi.org/10.1016/0262-5075(85)90032-6)
- Amit, K. (1998). Economic Assessment of Seismic Retrofitting of Non-Engineered Buildings - Case Study from India.
- Andaya, L. Y. (2000). Unravelling Minangkabau Ethnicity. *Itinerario*, 24(2), 20–43.

- <https://doi.org/10.1017/S0165115300013000>
- ASCE 41-06. (2007). *Seismic rehabilitation of existing buildings*.
<https://doi.org/10.1061/9780784408841>
- ASTM C311-04 C512-02. (2002). Standard Test Method for Creep of Concrete in Compression. *Annual Book of ASTM Standards*, 1–4.
https://doi.org/10.1520/C0512_C0512M-15
- ASTM C823. (2016). Standard Practice for Examination and Sampling of Hardened Concrete in Constructions. *American Society for Testing and Materials*, 1–7.
<https://doi.org/10.1520/C0823>
- Aydan, Ö. (2009). a Reconnaissance Report on the Pariaman-Padang Earthquake of September 30, 2009. *Earthquake*, (October), 1–36. Retrieved from
http://www.jsce.or.jp/library/eq_repo/Vol3/12/20090930report.pdf
- Blackwood, E. (1993). *The politics of daily life: Gender, kinship and identity in a Minangkabau village, West Sumatra, Indonesia*. ProQuest Dissertations and Theses. Retrieved from
<http://search.proquest.com/docview/304063843?accountid=13771>
- Carlberg, C. (2011). *Statistical analysis - Microsoft Excel 2010*. Pearson.
- Chadwick, R. J. (1991). Matrilineal Inheritance and Migration in a Minangkabau. *Indonesia*, 50, 47–81. <https://doi.org/10.2307/3351065>
- Coleman, A., & Karagedikli, Ö. (2018). Residential construction and population growth in New Zealand : 1996-2016, (January), 1–59. Retrieved from
www.rbnz.govt.nz/research/discusspapers
- Dardiri, A., Sutrisno, Kuncoro, T., Ichwanto, M. A., & Suparji. (2017). Enhancing the competitiveness of skilled construction workers through collaborative education and training. *AIP Conference Proceedings*, 1887. <https://doi.org/10.1063/1.5003488>
- Education, P. (2017). Dynamics of Structures 5th Edition Chopra Solutions Manual Full clear download (no formatting errors) at : Solution :
- Fotopoulou, S. D., & Ptilakis, K. D. (2013). Fragility curves for reinforced concrete buildings to seismically triggered slow-moving slides. *Soil Dynamics and Earthquake Engineering*, 48, 143–161. <https://doi.org/10.1016/j.soildyn.2013.01.004>

- Fraser, I. A. N. (1983). a New Draft Code for Seismic Design of Buildings in Indonesia, (3), 247–254.
- Guragain, R. (2015). Development of Earthquake Risk Assessment System for Nepal (ネパールを対象とした地震リスク評価システムの開発), (February).
- Hanifa, R., Gunawan, E., Irsyam, M., & Abidin, H. Z. (2016). Outline Earthquake risk reduction strategy in Indonesia after the 2004 tsunami disaster Irwan Meilano Earthquake disaster in Indonesia Earthquake sources : slip-rate and maximum magnitude PSHA map of Indonesia Earthquake risk analysis Building code Conclu.
- Hazus-MH_2.1. (2015). Hazus–MH 2.1: Technical Manual. *Department of Homeland Security Federal Emergency Management Agency Mitigation Division Washington, D.C.*, 718. Retrieved from www.fema.gov/plan/prevent/hazus
- Intarti, Y. R., Damayanti, S., Rahmayanti, H., Rahmat Widyanto, M., Wahyudi, D., & Nadera, M. M. (2014). Development of Minangkabau Women ' s Roles as an Effort to Reduce Risk in Disaster - prone Cities in Indonesia A Case Study of Western District of Padang , Padang City , West Sumatra , Indonesia 1. *International Journal of Disaster Recovery and Business Continuity*, 5(November 2013), 29–42. <https://doi.org/10.14257/ijdrbc.2014.5.03>
- Irsyam, M., Dangkoa, D. T., Hendriyawan, Hoedajanto, D., Hutapea, B. M., Kertapati, E. K., ... Petersen, M. D. (2008). Proposed seismic hazard maps of Sumatra and Java islands and microzonation study of Jakarta city, Indonesia. *Journal of Earth System Science*, 117(SUPPL.2), 865–878. <https://doi.org/10.1007/s12040-008-0073-3>
- Irsyam, M., Hutabarat, D., Asrurifak, M., Imran, I., Widiyantoro, S., Sadisun, I., ... Pandhu, R. (2014). Development of seismic risk microzonation maps of Jakarta city. In *Geotechnics for Catastrophic Flooding Events* (pp. 35–47). <https://doi.org/10.1201/b17438-6>
- ISDR. (2015). Chart of the Sendai Framework for Disaster Risk Reduction, 2030.
- Juliafad, E., & Andayono, T. (2018). BUILDING OFFICIAL ` S AWARENESS IN TERM OF BUILDING PERMIT SYSTEM IN INDONESIA.
- Kaushik, H. B., Rai, D. C., & Jain, S. K. (2006). Code approaches to seismic design of masonry-infilled reinforced concrete frames: A state-of-the-art review. *Earthquake*

- Spectra*, 22(4), 961–983. <https://doi.org/10.1193/1.2360907>
- Megawati, Kusnowidjaja. (2012). Shear-Wave Velocity Structure underneath the City of Padang, Indonesia. *15th World Conference on Earthquake Engineering (15WCEE)*.
- Megawati, K., & Pan, T. C. (2010). Ground-motion attenuation relationship for the Sumatran megathrust earthquakes. *Earthquake Engineering and Structural Dynamics*, 39(8), 827–845. <https://doi.org/10.1002/eqe.967>
- Meguro, K., & Tagel-Din, H. S. (2002). Applied Element Method Used for Large Displacement Structural Analysis. *Journal of Natural Disaster Science*, 24(1), 25–34.
- Nur, O F. (2012). Earthquake Damage – Intensity Relationship Based on Sumatran 30 September Earthquake. *15th World Conference on Earthquake Engineering (15WCEE)*.
- Porter, K., Hamburger, R., & Kennedy, R. (2005). Practical Development and Application of Fragility Functions.
- Porter, K., Hamburger, R., & Kennedy, R. (2007). Practical Development and Application of Fragility Functions. *Structural Engineering Research Frontiers*, 1–16. [https://doi.org/10.1061/40944\(249\)23](https://doi.org/10.1061/40944(249)23)
- Porter, K., Kennedy, R., & Bachman, R. (2007). Creating fragility functions for performance-based earthquake engineering. *Earthquake Spectra*, 23(2), 471–489. <https://doi.org/10.1193/1.2720892>
- Pribadi, K. S., Kusumastuti, D., & Utami, A. (2008). Earthquake Risk Perception in Indonesia : Government Officers and Builders View, (2007), 259–267.
- PusGen. (2017). *Peta Sumber dan Bahaya Gempa Indonesia Tahun 2017*.
- PUTRA, R. R., KIYONO, J., ONO, Y., & PARAJULI, H. R. (2012). SEISMIC HAZARD ANALYSIS FOR INDONESIA. *Journal of Natural Disaster Science*, 33(2), 59–70. <https://doi.org/10.2328/jnds.33.59>
- Rossetto, T., & Elnashai, A. (2003). Derivation of vulnerability functions for European-type RC structures based on observational data. *Engineering Structures*, 25(10), 1241–1263. [https://doi.org/10.1016/S0141-0296\(03\)00060-9](https://doi.org/10.1016/S0141-0296(03)00060-9)
- Sadiq Bhanbhro. (2017). Indonesia’s Minangkabau culture promotes empowered Muslim women. *The Conversation* .

- Sieh, K. (2006). Sumatran megathrust earthquakes: from science to saving lives. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 364(1845), 1947–1963. <https://doi.org/10.1098/rsta.2006.1807>
- Sieh, K., Natawidjaja, D. H., Meltzner, A. J., Shen, C. C., Cheng, H., Li, K. S., ... Edwards, R. L. (2008). Earthquake supercycles inferred from sea-level changes recorded in the corals of west Sumatra. *Science*, 322(5908), 1674–1678. <https://doi.org/10.1126/science.1163589>
- SNI 2847. (2013). Persyaratan Beton Struktural untuk Bangunan Gedung. *Bandung: Badan Standardisasi Indonesia*, 1–265.
- Tagel-Din, H., & Meguro, K. (2000). Analysis of a small scale RCbuilding subjected to shaking table tests using applied element method. *12WCEE. New Zealand:[Sn]*, (January 2000), 1–8. Retrieved from <http://www.iitk.ac.in/nicee/wcee/article/0464.pdf>
- Tegnan, H. (2015). Legal pluralism and land administration in west Sumatra: The implementation of the regulations of both local and Nagari governments on communal land tenure. *Journal of Legal Pluralism and Unofficial Law*, 47(2), 312–323. <https://doi.org/10.1080/07329113.2015.1072386>
- UN General Assembly. (2015). A/CONF.224/L.1 Sendai Declaration, 04878(March), 1504878. Retrieved from http://www.preventionweb.net/files/43300_sendaideclaration.pdf.
- UNISDR. (2015). Sendai Framework for Disaster Risk Reduction 2015 - 2030. *Third World Conference on Disaster Risk Reduction, Sendai, Japan, 14-18 March 2015.*, (March), 1–25. <https://doi.org/A/CONF.224/CRP.1>
- Vamvatsikos, D., & Allin Cornell, C. (2002). Incremental dynamic analysis. *Earthquake Engineering and Structural Dynamics*, 31(3), 491–514. <https://doi.org/10.1002/eqe.141>
- Vamvatsikos, D., & Cornell, C. A. (2005). Direct Estimation of Seismic Demand and Capacity of Multidegree-of-Freedom Systems through Incremental Dynamic Analysis of Single Degree of Freedom Approximation. *Journal of Structural Engineering*, 131(4), 589–599. [https://doi.org/10.1061/\(ASCE\)0733-9445\(2005\)131:4\(589\)](https://doi.org/10.1061/(ASCE)0733-9445(2005)131:4(589))
- Wahab, S. N. A., & Hamid, M. Y. (2011). A review factors affecting building defects of structural steel construction. Case study: Student accommodation in UiTM Perak.

Procedia Engineering, 20, 174–179. <https://doi.org/10.1016/j.proeng.2011.11.153>

Wibowo Kismiyati El; Haykal, Achmad, S. K. A. K. (2012). Konflik Pengetahuan Kepemilikan Tanah di Minangkabau. *Student E-Journal*, (Vol 1, No 1 (2012): Wisuda Agustus 2012), 18. Retrieved from <http://jurnal.unpad.ac.id/ejournal/article/view/1161>

Wilkinson, S. M., Alarcon, J. E., Mulyani, R., Whittle, J., & Chian, S. C. (2012). Observations of damage to buildings from Mw7.6 Padang earthquake of 30 September 2009. *Natural Hazards*, 63(2), 521–547. <https://doi.org/10.1007/s11069-012-0164-y>

Zachariassen, J. (2001). Paleoseismicity of the northern Horohoro Fault , Taupo Volcanic Zone , New Zealand Australian plate. *New Zealand Journal of Geology and Geophysics*, 44(January 2000), 391–400. <https://doi.org/10.1080/00288306.2001.9514946>

Neville, A.M., Properties of Concrete, Pitman Books Limited, London, 1981.

Mindess, S.and Young J.F., Concrete, Prentice-Hall, Inc, New Jersey, 1981.

Abidin.Z., 2016, Statistik Daerah Kota Padang 2016: Badan Pusat Statistik Kota Padang, ISBN 978-602-0919-60-7 (in Indonesian)

<http://tourism.padang.go.id>

CHAPTER 2

ENVIRONMENTAL SYSTEM OF RC BUILDING IN PADANG CITY

2.1.Introduction

This chapter discusses the study on the environmental system of Reinforced Concrete (RC) building in Padang City, West Sumatra. This study is important to identify the variables that affect the process of development of the actual condition of fragility function for predominant building in Padang City and find the local situation and structure of the community to develop an effective and unique mechanism to disseminate the risk knowledge of buildings under earthquake load. By doing so, the earthquake disaster can be reduced effectively based on a local condition in Padang City.

2.1.1. Cutting the chain of the disaster of RC Building

The experience of earthquake reveals that even developed urban area is quite vulnerable, although the provisions against seismic hazards have been considerably improved. This condition is due to the complexity of the environment that exists in the area which is affected by each other, both physical and non-physic, e.g., policy and local socio-system.

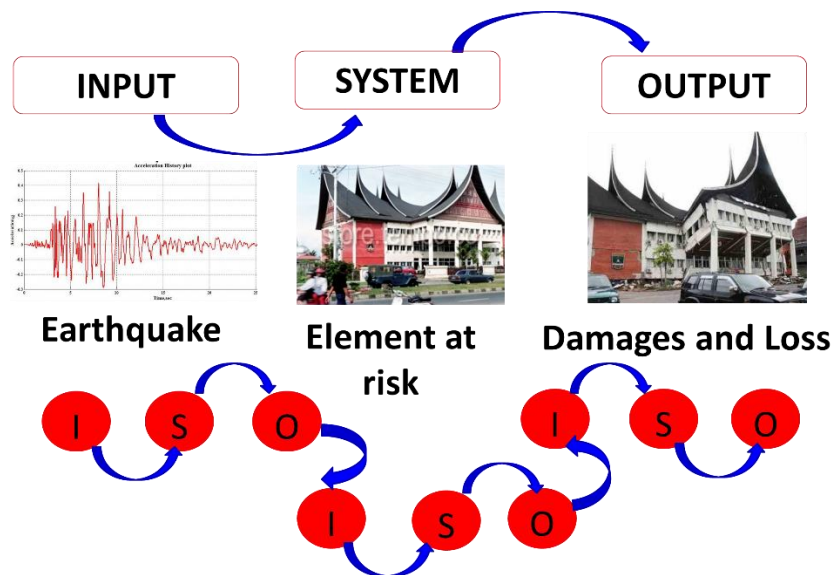


Figure 2.1. The Chain of Disaster

Earthquake disaster reduction on a regional level relies on the integrated strategy that can cut the chain of the disaster that is created when the action from earthquake load is subjected to a system resulted in the reaction of the system (see Fig.2.1). The

system can be any element at risk located on the earthquake hazard-prone area, including building, infrastructure, community, and so on. If the system has enough capacity to accept the action, the damage can be minimized. That is called resilience, but if the system is damaged due to the earthquake, that is called vulnerable. In case of that, there should be a strategy to strengthened/enhanced the system to increase its capacity which can reduce the damage experienced by it.

2.1.2 The Understanding of Environmental System

As earthquake hazards of RC buildings in the specified area are influenced by the system which is supporting the buildings stock condition, it is necessary to understand the system which is then called an environmental system. We used some methodologies, e.g., using interview, literature, and building code review, document inspections, google maps survey and the street survey. We also discuss with some government staff, experts and local people in Padang City and asking advice from related earthquake department head officers.

In this research, we include three general categories of environmental systems, which are:

- 1) Building typology
- 2) Construction methods
- 3) Indigenous Community System

Each of this system will be discussed in the next part of this chapter.

2.2 Building Typology

2.2.1 The Importance of Building Typology Understanding for developing Fragility Function

Most important step in the derivation of fragility function as a part of the assessment of building vulnerability is defining building typology. It is important that structures and component on the system, having similar structural characteristics, and being in a similar geotechnical condition, so they are expected to show the same performance for a given seismic excitation. Within this context, the damage is related to the structural properties of the buildings directly.

Building typology can be defined by doing an inventory of each building on the

system. Parameters which can describe the typology includes geometry, material properties, dimension, age, seismic design level, soil condition and foundation details, etc. This is the main challenge when conducting a seismic risk assessment on a city scale, where practice will be impossible to assess the building level. It is necessary to classify the buildings and defines building classes which then can present similar response characteristic of the building under seismic excitation (Amit, 1998; Fotopoulou & Pitilakis, 2013)

2.2.2 The Methodologies to get Building Typology in Padang City

Methodologies were used to obtain the building typology in Padang City includes an interview with experts from building offices in Padang City, to collect reliable information regards to the situation of buildings and the system supported the buildings, e.g., regulation, inspection system, and construction method. Google earth street view has been utilized to get images of the building`s types which are distributed in Padang City which then has been confirmed with a street survey by taking many pictures of the building. Almost 300 building`s documents also have been collected and analyzed to get the detail information about the building, regards to its structural types, storey, materials and occupation types JULIAFAD, E., MEGURO, K., & GOKON, H. (2017). Study on The Environmental System towards The Development of Assessment Tools for Disaster Reduction of Reinforced Concrete Building due to Future Mega-Earthquake in Padang City, Indonesia. SEISAN KENKYU, 69(6), 351-355.

2.2.3 Building Typology in Padang City

To develop a fragility function that represents the condition of the existing building, the first critical step is examining the building typology in Padang city.

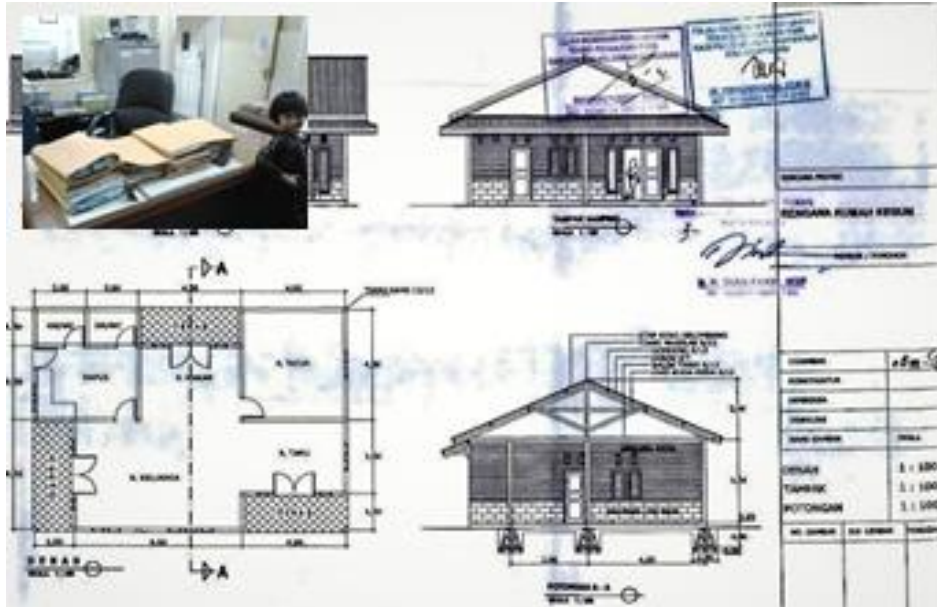


Figure 2.2. Building Document Sample

Figure 2.2 is a sample of Building Document that has been submitted to Building and City Planning office. We collected 300 documents includes residential buildings, commercial buildings, public and government buildings and some special buildings. Sample documents in the Fig.2.2 have been signed by the head office and got a legal stamp, which indicated that together with other legal complementary documents, the buildings are permitted to be constructed. Detail procedure regards to the building permit procedure will be discussed in Chapter 3 as a part of regulations discussion.

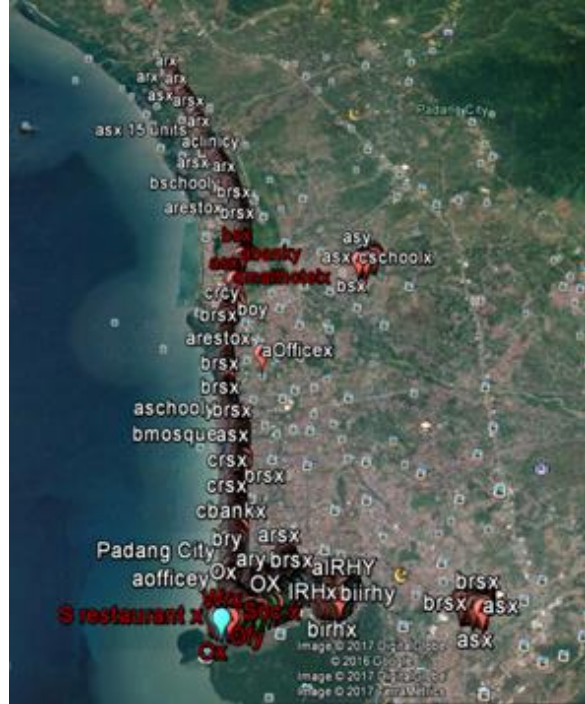
Figure 2.3. shows the results of the street survey and google street survey. The street survey was conducted to cover all of Padang city by taking many pictures. The type of the buildings is indicated based on the storey, the shape and some of the wall part still uncovered, so it is possible to indicate the wall material. For google street survey, the survey conducted by using google street application and checked the building on the main street in Padang City.



(a) Typical Low Storey Buildings



(b) Typical Mid- Storey Buildings



(c) Google Street Survey

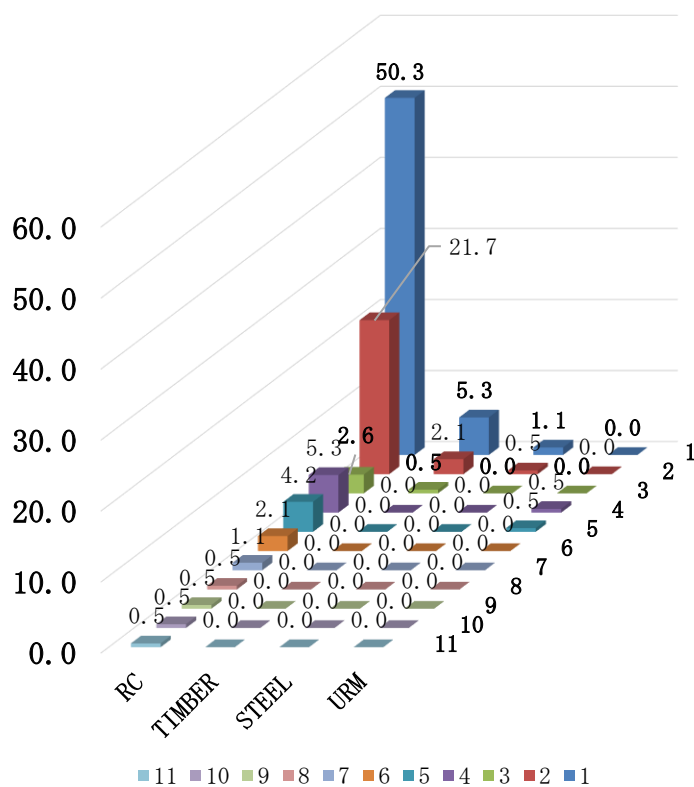
using Google Street View

Figure 2.3. Google Street Survey and Street Survey for Building Typology in Padang City

In Figure 2.3.a, the type of the buildings is a hybrid building as a combination of a shop on the first floor and residential in the second or the third floor. The main frame is the RC frame and the wall made from infill red masonry wall. The first storey has a big opening due to the inexistence of wall. This building is called “Ruko.” As the commercial city, this type of building is widespread in Padang City. In the September 2009, “Ruko” type suffered many types of damages, from light to collapse.

Using interview, document analysis, google street survey and street survey, (see Fig.2.2 and Fig.2.3) has been concluded that Reinforced Concrete (RC) building with low-mid storey is the most populated building compared to another type of building, e.g., Steel building, timber building and Unreinforced Masonry (URM), (see Figure 2.4.).

Building Typology In Padang City



Type	RC	Steel	Timber	URM
%	89.4	7.9	1.6	1.1

Figure 2.4. Building Typology in Padang City

A total number of buildings in Padang City is 200,112 buildings per 2015. Overall, the distribution of buildings in each district is shown in Figure 2.5. an Table 2.1. below. The figure 2.5. show that highest distribution of RC buildings in the area of Koto Tengah sub-district, followed by Kuranji, Lubuk Begalung dan Padang Timur sub-district.

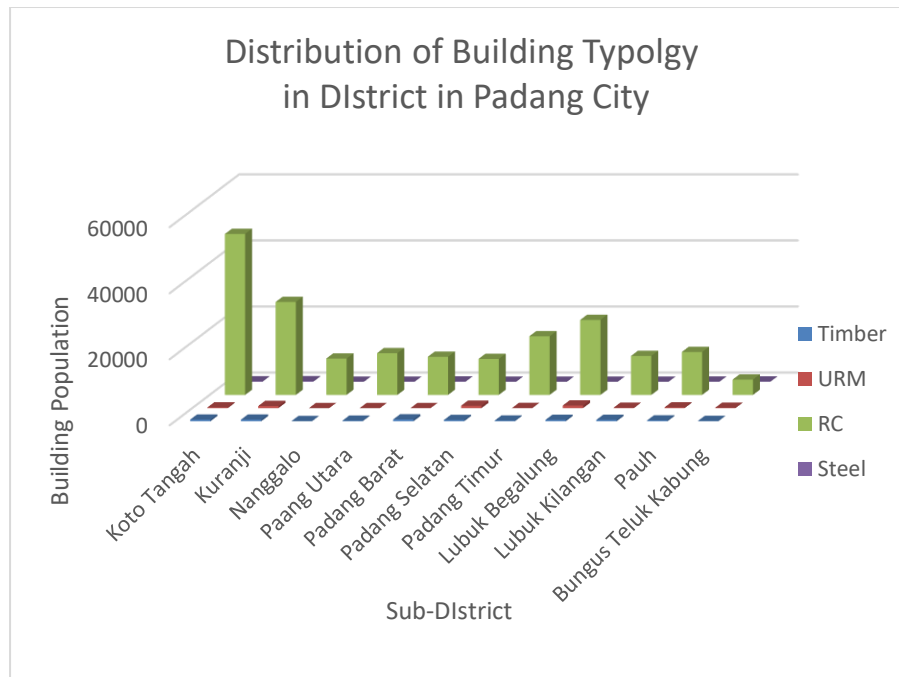


Figure 2.5. Distribution of Building Typology in 11 Sub-districts in Padang City

Table 2.1. Building Population per Sub-District in Padang City

	Timber	URM	RC	Steel	Total
Koto Tengah	498	213	48738	100	9959349
Kuranji	492	625	28143	147	5910807
Nanggalo	65	3	11016	2	2228286
Paang Utara	165	0	12646	15	2578026
Padang Barat	548	5	11553	70	2447376
Padang Selatan	377	729	10906	1	2414613
Padang Timur	187	29	17755	10	3614181
Lubuk Begalung	401	796	22717	3	4807317
Lubuk Kilangan	408	111	11805	8	2478732
Pauh	253	215	12990	20	2709078
B.Teluk Kabung	75	112	4654	65	986106
	3469	2838	193364	441	200112

Projection of residential houses in the future will be a 6% rate per year to be increased, and in 2032 there will be 336.614 residential houses in Padang.

We investigated one area in Padang City which is called as “Kota Tua/Kampung Cina” or “The Old City/ Chinese Village.” This area is famous for many unreinforced masonry buildings (Intarti et al., 2014). In 2009 Earthquake, there was many buildings damaged, mostly heavy and collapse, which can be seen in Figure 2.6 below.

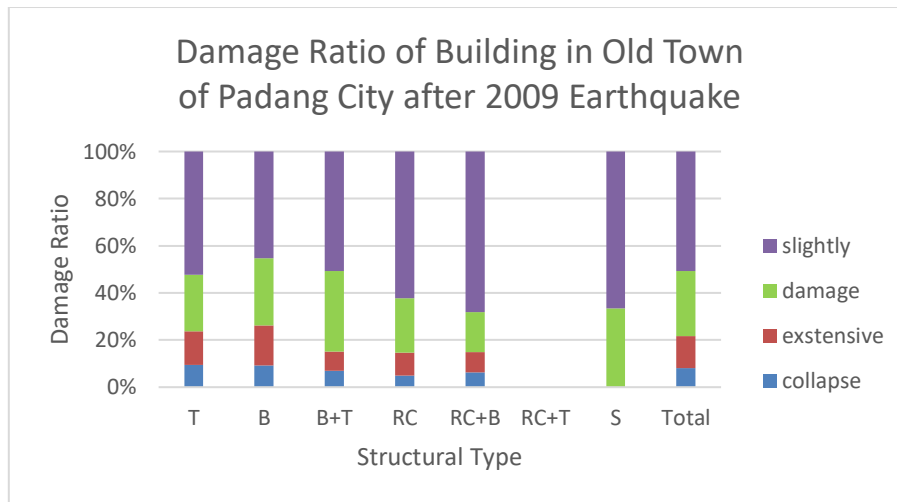


Figure 2.6. Damage ratio of Building in Old Town of Padang City

Figure 2.6 shows that buildings made from unreinforced masonry (B) and unreinforced masonry composite with timber (B+T) was the most damaged compared to another type of buildings. RC building also suffered a collapse and extensive damages. In total, almost 50% of the buildings in this area suffered significant damages (moderate, extensive and collapse).

To focus on the building typology discussion, we compared the building typology in this area due to the reconstruction or rehabilitation activities after the earthquake. Through the quantifying the number of the building which had been surveyed during this research in 2016 and compare it with the data from 2009.

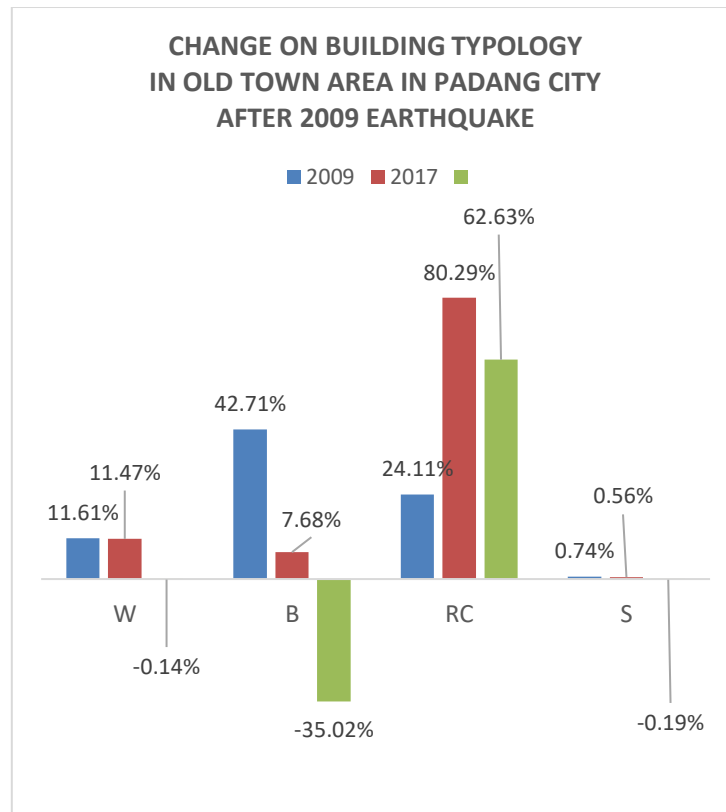


Figure 2.7. The Change on Building Typology in the Old Town area in Padang City after the 2009 Earthquake

Figure 2.7 presents the comparison percentage of the population of some types of buildings in the old town area in Padang City. The blue color indicated the building type population before the 2009 earthquake; the red one represented the building population after 2009 September Earthquake. Finally, the green graph shows the increasing or decreasing population of some building type.

Wood (W) or Timber (T) structures do not have a significant change in population due to small damage ratio in this type of building. However, the population of unreinforced masonry building is significantly decreased (35.02%), while the population of RC building is significantly increasing (62.63%). This data shows that after the earthquake, many people chose the RC building type which shows us the trend of RC building construction in Padang also increase. This data also shows that the building typology of Old Town which used to be a historical area due to a massive number of historical unreinforced masonry building has been changed to be populated more with RC building types.

Meanwhile, if we observed the quality of RC building construction method as will be

discussed in part 2.3 below, the potential damage due to the future earthquake of RC buildings type seems to be necessary to be assessed.

2.3 Construction Methods of RC Building

2.3.1 Interview and Survey of RC Building Builders in Padang City Activity.

This research used interview method and field observation to collect the information about the workmanship of RC building in Padang City. We interview 100 builders including the head of builder and builder. The questions involve items related to the milestone of RC building construction work. Since the number of the interviewee is significant, we use a structured interview sheet to keep the timing and the quality of the answers.

This interview and site observation visit was conducted in November 2017 in 65 construction sites in Padang City, West Sumatra, Indonesia. The interviewee works in RC building projects of low to mid-rise buildings



Figure 2.8. Builder Interview Activities in Padang City

We categorized the questions into six categories which are:

1. Builder profile, aiming to understand the profile of the builder in Padang City. The information can be gathered including their educational background, experience, type of buildings they used to build, and their recent knowledge of building construction.
2. Concrete mixing practice. This part emphasizes the practice of concrete mixing in the construction site.

3. Concreting workmanship. This category is aimed to find the problem mostly occurs during the construction process in the field and the probability of concrete and construction defect that might occur due to that practice.
4. Steelwork. This category is aimed at finding the method of steel arrangement used by the builder while installing longitudinal reinforcement, stirrups, and anchor at the structural joint.
5. Brickwork. This category has objective to understand how the builders/masons prepare the bricks, laying technique, mortar thickness for vertical and horizontal bed joint and whether they install the anchor between column and wall as required by Indonesia Building Code for infill masonry RC building.
6. Building quality perception. The perception of the builders regards to their construction methods and material selection.

Table 2.1 presents some sample of questions and sub-questions regards to the aim of the interview.

Table 2. 1. Milestone of Interview Questions

Questions	No	Sub-questions
A. Builders Profile	1	Name
	2	Position (head of the builder, builder, labor)
	3	Education background
	4	Construction work experience
	5	Seminar or construction training has been joined
B. Concreting mixing	1	Concrete workability (dilution)
	2	Do you measure slump
	3	How do you learn to mix the concrete
	4	How do you measure water to cement ratio
C. Concreting Workmanship	1	Compaction practice
	2	Curing Methods
	3	Compaction methods
	4	Construction joint treatment

2.3.2 Reinforcing and Concreting Workmanship

Engineering codes of practice and specifications provide guidance and regulation aimed at ensuring the satisfaction of workability and strength criteria of the concrete

mix. This specification includes the choice of constituents in the concrete mix, mix design, manufacture of the mix, transport, and placement of the mix and curing of the freshly placed concrete [8].

Water Cement ratio is one of the critical factors that influence the strength of the concrete and other desirable properties of concrete under job conditions [9]. Propovics 2009 mentioned fundamental assumptions for the strength versus water-cement ratio relationship. Where'

- 1) The strength of structural concrete is controlled by the strength of the cement paste in it
- 2) Cement paste strength depends strongly on the condition of porous in it
- 3) The porosity (capillary) is a function of the water-cement ratio. As the results also show that too much water or too much cement both affect the decreasing of concrete strength [9].

Water-cement ratio influences the workability of concrete which leads the builders in the field to increase the water content to increase concrete mix flowability/dilution.

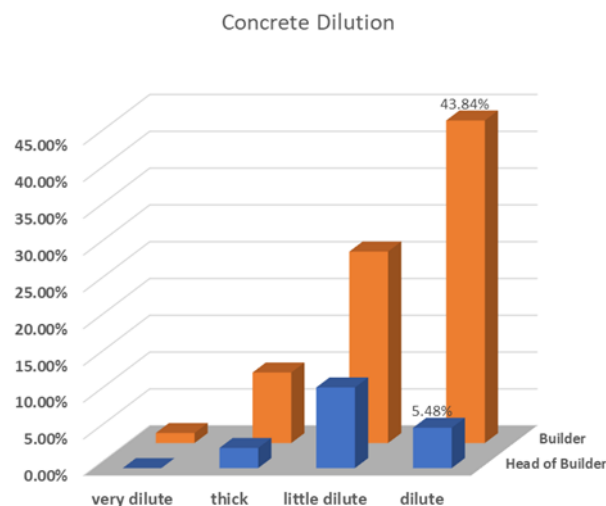


Figure 2.9. Concrete Dilution produced in RC Building Projects

Figure 2.9 shows the practice of builders who likely to produce high water content in concrete caused by the high workability of placed concrete. The practice to not measuring the slump of concrete mix, weather condition and inadequate mixing tools also become the reasons for their difficulties in controlling the water content. This research found 87.8% of the builders do not measure the slump. They visually

observe their concrete mix workability and adjust it till reach the dilution that they want without considering the final concrete strength.

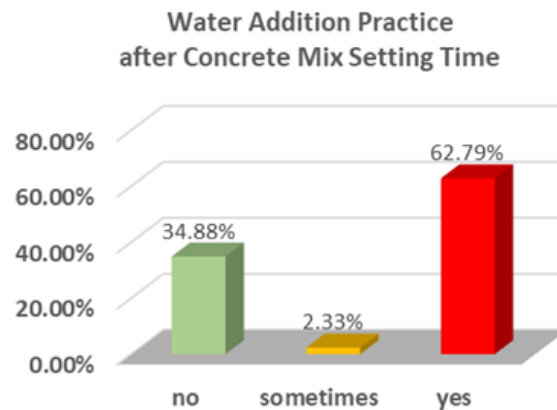


Figure 2.10. Water addition practice in RC Building Projects

Figure 2.10. presents the finding of water addition practice quantitatively. Water addition is a practice that is conducted by the builders who find their concrete mix has been dry after a couple time counted since the concrete setting time is finish. Almost 65% of the builders said they add more water after the concrete setting time over. Some of the respondents admit that they add more water after 4-5 hours, even one day after the first mix of the concrete. The builders explain that when they add water, they also add cement. However, this practice will result in increasing of un-homogeneity of concrete mix and decreasing of concrete strength.

Poor concreting workmanship reduced concrete serviceability reliability by reducing the permeability of the concrete. Proper compaction ensures the proper shield around the reinforcement and tendons and helps to achieve the higher ultimate strength, abrasion resistance and improves the bond strength between the reinforcement and concrete [10,11]. Figure 2.12. shows the reduction in cube strength due to different compaction techniques. The specimens have the least strength without compaction and improved strength if compacted by rodding whereas maximum strength when compacted with a vibrator. Suleiman and Kevern (2003) study the effect of improper compaction on the strength of the concrete as shown in Figure 2.13. [12,13].

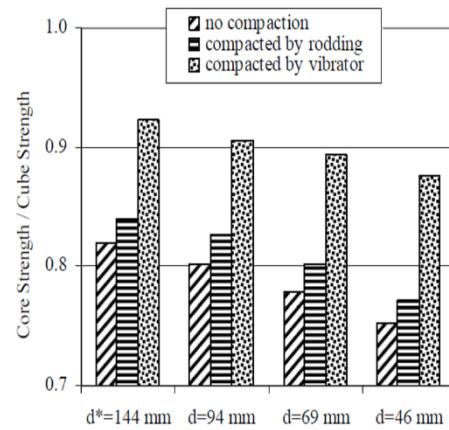


Figure 2.11. Effects of compaction [11]

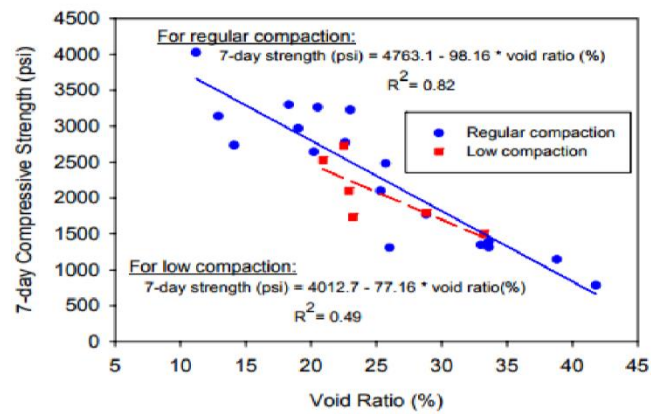


Figure 2.12. Effect of improper compaction on concrete strength [12]

This research found the real practice of concrete compaction which is conducted in an RC construction project in Padang City.

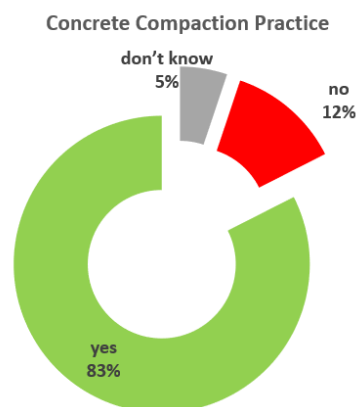


Figure 2.13. Concrete Compaction Practice among the Builders

Figure 2.14 shows that 83% of the builders answered that they conduct concrete compaction, the rest 12% do not compact the concrete. However while we asked the compaction method they conduct, only 6% answered that they use a vibrator which is on previous research conducted by Tuncan and Suleiman show the best performance of concrete compared to other compaction methods, e.g., rodding.

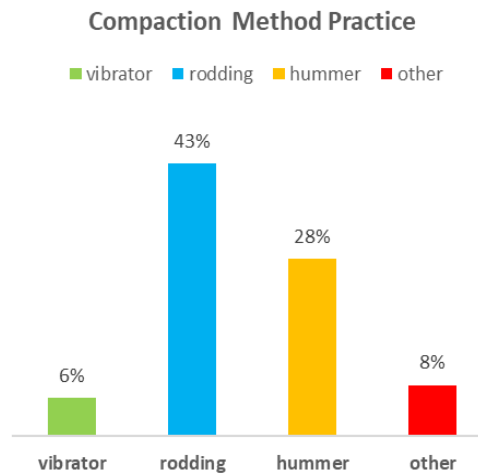


Figure 2.14. Concrete Compaction Method among the Builders

Figure 2.15. shows that dominant compaction methods that are used by builders in Padang City are rodding (43%) and give external vibration by using hummer stone (28%). Other methods (8%) are by shaking the structural element after concrete placement which aimed at moving the concrete mix downward for column element; or by adding more water directly inside the column element to increase the flowability of the placed concrete mix (based on the opinion of the builder).

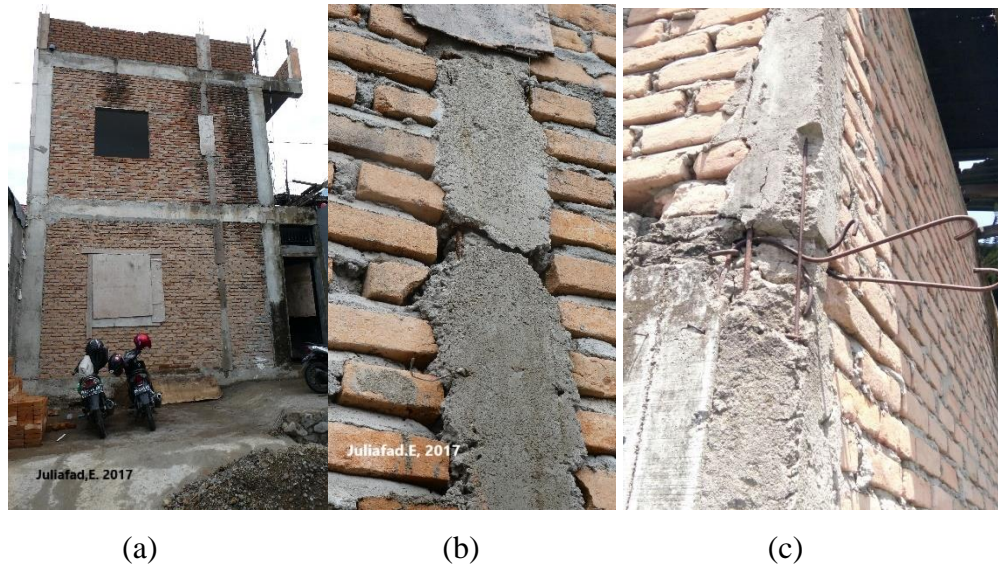


Figure 2.15. A sample of Improper Casting Results of Concrete at Axial Member from some construction sites

Figure 2.16. shows the observation in the field found defects in concrete that could be a sign of improper compaction. In figure 11, we can see hardened concrete in the axial member is poor, indicated by inhomogeneity of the casting, the concrete parts are separated due to improper casting sequence and compaction. We also can identify the segregation of aggregate. The reinforcement obviously uncovers by the concrete, and the concrete cover seems to be inadequate. This finding is typical and easily finds in many RC building infill walls in Padang City.

Curing Method

Improper curing of concrete can have the following effects.

1. Increase the reduction of compressive strength of concrete. Figure 2.17 shows an increase in compressive strength with different curing conditions. It shows that the compressive strength of concrete can increase even after 28 days in case of moist curing.
2. Due to less curing, the cracks are formed.
3. The durability of concrete decreases due to improper curing.
4. Improper curing also leads to the reduction of abrasion resistance of concrete as the sand is coated on the surface [14].

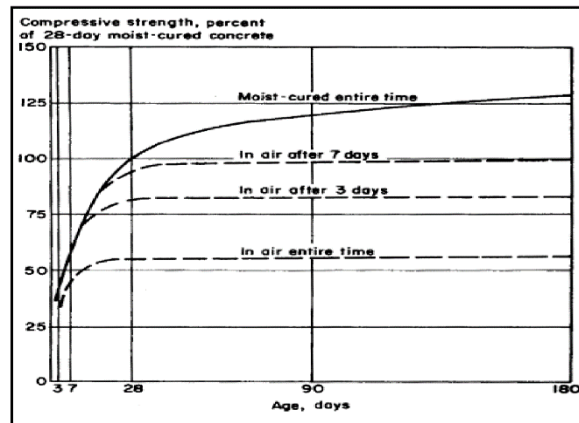


Figure 2.16. Effects of curing conditions on f_c' [14]

Figure 2.18. shows the results of interview regards to concrete curing practice in RC building projects in Padang City. Only 34% of the builders who conduct concrete curing. The method that they use is by watering the placed concrete surface for a couple days or covering it with wet materials. However, 65% of the builders answered that they do not conduct the curing due to the opinion that the concrete does not need to be cured since it will dry by the time.

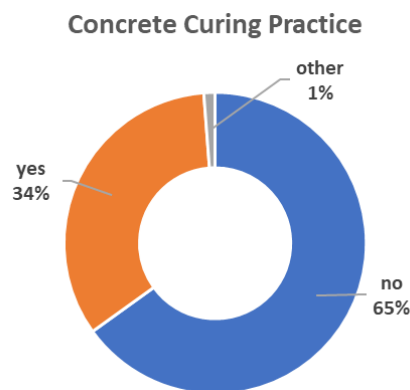


Figure 2.17. Concrete Curing Practice

This finding shows the lack of understanding of the builder about the basic knowledge of concrete characteristic and its effects on building performance and durability.

Builder Perception of RC Building

Slovic (1987) in Messner and Meyer (2005) described risk perception as “intuitive risk judgments of individual and social groups in the context of limited and uncertain information.” He described it from different sources: geography, sociology, political science, anthropology, and psychology

Plapp and Werner (2006) proposed that risk perception can be defined “as an everyday subjective assessment process that is based on experience and on available information without referring to reliable data, series, and complex models.” They showed that the study of risk perception has been a subject of many researchers, and a number of approaches and concepts have been proposed, such as psychometric paradigm and similar concepts, the cultural theory of risk perception, trust-oriented concepts, the mental models’ approach, concepts to include associations and effect, demographic variables, gender and others. They also argued that risk perception is one of the important determinants in the decision-making process for technical risk reduction. Based on knowledge of risk perception of people living in risk-prone areas, effective risk communication strategies on protective measures can be designed. Peoples’ perception of risk is subject to many influencing cognitive, personal, situational and contextual factors (Pribadi, Kusumastuti, & Utami, 2008)

Figure 2.18 show the answer of the builders. In the survey of the builder in Padang City, the builder has been asked for their self-work assessment and their perception of the RC building that they have been built. Their perception about the effect of RC building material constituent also has been asked. In this part of this thesis, the results can be shown below.

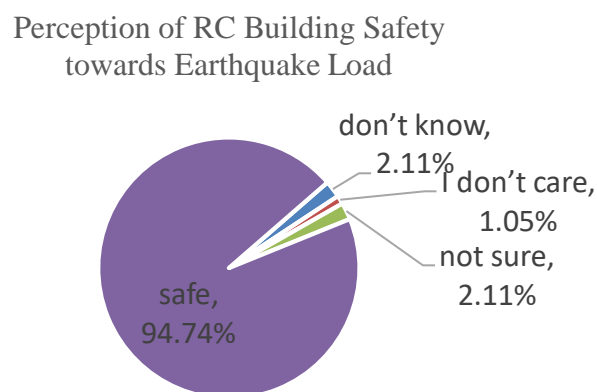


Figure 2.18. Perception of The Builder for RC Building Safety
towards Earthquake Load

Figure 2.18 shows that mostly the builder assumed that the building that has been built are safe from earthquake load. Their perception is needed to be proved since when the assessment of their practice is not fulfilling the standard construction method.

2.4 Indigenous Land System

More than 85% of West Sumatra, including Padang City, is habited by MINANGKABAU PEOPLE (Blackwood, 1993; Wibowo Kismiyati El; Haykal, Achmad, 2012). Their village management systems known as Nagari (before the 14th century), established based on adat (custom) principles and the center of the system is women (matriakhat) which is the only one in Indonesia and the largest one in the world. The objective is to protect the rights of a community member, including the right of communal land/tribe land 6). Therefore, the land cannot be sold because must be inherited from generation to generation for a woman in the communal/tribe. The tribe may pawn their tribe land just for finance should meet these four objectives:

1. To arouse the soaked stem
2. The old virgin without a husband
3. The human`s corps is stretched out in the middle of the house (death in the family)
4. The traditional house gets wet from a leak (need to repair the house)

By the time the land area becomes not clear and complicated for the government to manage including to control building construction causing the low quality of building construction (Chadwick, 1991; Tegnan, 2015).

This finding has been supported by previous research (JICA) which interview building officers in City and district levels to understand the building construction process and their experience regards to the problems on covering their responsibility to ensure the building quality, which seem to be considered as one of the roots of the problem of poor building construction.

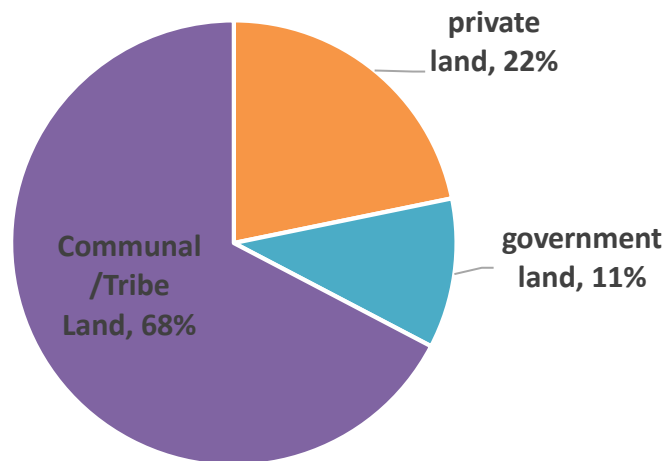


Figure 2.19. Distribution of Land Ownership in Padang City

Figure 2.19 presents the percentage of Land ownership in Padang City. In general, the system of Land in Padang City can be categorized into three kinds, which are:

1. Private Land

Private land is the land that owns privately by person/company. The private ownership used to be the tribe lands which had been sold by the tribes caused by the families of the tribe does not have any born daughters.

2. Government Land

Government land is the land own by the government. The government bought these lands from tribe leaders or can come from the percentage of “Prona” Land, which is the land that distributed as a gift-land of some percentage of Private land when the owner need to legalized their land and gets legal land certificates.

3. Communal/Tribe land

As aforementioned above, the tribe land is the land that inherited from generation to generation following motherly name so-called matriakhat system.

The land percentage is reduced since the influence of government policy in Soeharto President era that eliminates the Minangkabau system and also some tribes had to sell or gave their land to the community since they do not have a daughter was born in the tribes.

In the figure, the percentage of tribal land is 67%, followed by government land 11% and private land 22%.

2.5 Reference

- ACI. (2008). *Building code requirements for structural concrete (ACI 318M-08) and Commentary*. American Concrete Institute (Vol. 2007). [https://doi.org/10.1016/0262-5075\(85\)90032-6](https://doi.org/10.1016/0262-5075(85)90032-6)
- Amit, K. (1998). Economic Assessment of Seismic Retrofitting of Non-Engineered Buildings - Case Study from India.
- Andaya, L. Y. (2000). Unravelling Minangkabau Ethnicity. *Itinerario*, 24(2), 20–43. <https://doi.org/10.1017/S0165115300013000>
- ASCE 41-06. (2007). *Seismic rehabilitation of existing buildings*. <https://doi.org/10.1061/9780784408841>
- ASTM C311-04 C512-02. (2002). Standard Test Method for Creep of Concrete in Compression. *Annual Book of ASTM Standards*, 1–4. https://doi.org/10.1520/C0512_C0512M-15
- ASTM C823. (2016). Standard Practice for Examination and Sampling of Hardened Concrete in Constructions. *American Society for Testing and Materials*, 1–7. <https://doi.org/10.1520/C0823>
- Aydan, Ö. (2009). a Reconnaissance Report on the Pariaman-Padang Earthquake of September 30, 2009. *Earthquake*, (October), 1–36. Retrieved from http://www.jsce.or.jp/library/eq_repo/Vol3/12/20090930report.pdf
- Blackwood, E. (1993). *The politics of daily life: Gender, kinship and identity in a Minangkabau village, West Sumatra, Indonesia*. ProQuest Dissertations and Theses. Retrieved from <http://search.proquest.com/docview/304063843?accountid=13771>
- Carlberg, C. (2011). *Statistical analysis - Microsoft Excel 2010*. Pearson.
- Chadwick, R. J. (1991). Matrilineal Inheritance and Migration in a Minangkabau. *Indonesia*, 50, 47–81. <https://doi.org/10.2307/3351065>
- Coleman, A., & Karagedikli, Ö. (2018). Residential construction and population growth in New Zealand : 1996-2016, (January), 1–59. Retrieved from www.rbnz.govt.nz/research/discusspapers
- Dardiri, A., Sutrisno, Kuncoro, T., Ichwanto, M. A., & Suparji. (2017). Enhancing the competitiveness of skilled construction workers through collaborative education and training. *AIP Conference Proceedings*, 1887. <https://doi.org/10.1063/1.5003488>
- Education, P. (2017). Dynamics of Structures 5th Edition Chopra Solutions Manual Full clear download (no formatting errors) at : Solution :
- Fotopoulou, S. D., & Pitilakis, K. D. (2013). Fragility curves for reinforced concrete buildings

- to seismically triggered slow-moving slides. *Soil Dynamics and Earthquake Engineering*, 48, 143–161. <https://doi.org/10.1016/j.soildyn.2013.01.004>
- Fraser, I. A. N. (1983). a New Draft Code for Seismic Design of Buildings in Indonesia, (3), 247–254.
- Guragain, R. (2015). Development of Earthquake Risk Assessment System for Nepal (ネパールを対象とした地震リスク評価システムの開発), (February).
- Hanifa, R., Gunawan, E., Irsyam, M., & Abidin, H. Z. (2016). Outline Earthquake risk reduction strategy in Indonesia after the 2004 tsunami disaster Irwan Meilano Earthquake disaster in Indonesia Earthquake sources : slip-rate and maximum magnitude PSHA map of Indonesia Earthquake risk analysis Building code Conclu.
- Hazus-MH_2.1. (2015). Hazus–MH 2.1: Technical Manual. *Department of Homeland Security Federal Emergency Management Agency Mitigation Division Washington, D.C.*, 718. Retrieved from www.fema.gov/plan/prevent/hazus
- Intarti, Y. R., Damayanti, S., Rahmayanti, H., Rahmat Widyanto, M., Wahyudi, D., & Nadera, M. M. (2014). Development of Minangkabau Women ' s Roles as an Effort to Reduce Risk in Disaster - prone Cities in Indonesia A Case Study of Western District of Padang , Padang City , West Sumatra , Indonesia 1. *International Journal of Disaster Recovery and Business Continuity*, 5(November 2013), 29–42. <https://doi.org/10.14257/ijdrbc.2014.5.03>
- Irsyam, M., Dangkoa, D. T., Hendriyawan, Hoedajanto, D., Hutapea, B. M., Kertapati, E. K., ... Petersen, M. D. (2008). Proposed seismic hazard maps of Sumatra and Java islands and microzonation study of Jakarta city, Indonesia. *Journal of Earth System Science*, 117(SUPPL.2), 865–878. <https://doi.org/10.1007/s12040-008-0073-3>
- Irsyam, M., Hutabarat, D., Asrurifak, M., Imran, I., Widiyantoro, S., Sadisun, I., ... Pandhu, R. (2014). Development of seismic risk microzonation maps of Jakarta city. In *Geotechnics for Catastrophic Flooding Events* (pp. 35–47). <https://doi.org/10.1201/b17438-6>
- ISDR. (2015). Chart of the Sendai Framework for Disaster Risk Reduction, 2030.
- Juliafad, E., & Andayono, T. (2018). BUILDING OFFICIAL ` S AWARENESS IN TERM OF BUILDING PERMIT SYSTEM IN INDONESIA.
- Kaushik, H. B., Rai, D. C., & Jain, S. K. (2006). Code approaches to seismic design of masonry-infilled reinforced concrete frames: A state-of-the-art review. *Earthquake Spectra*, 22(4), 961–983. <https://doi.org/10.1193/1.2360907>

- Megawati, Kusnowidjaja. (2012). Shear-Wave Velocity Structure underneath the City of Padang, Indonesia. *15th World Conference on Earthquake Engineering (15WCEE)*.
- Megawati, K., & Pan, T. C. (2010). Ground-motion attenuation relationship for the Sumatran megathrust earthquakes. *Earthquake Engineering and Structural Dynamics*, 39(8), 827–845. <https://doi.org/10.1002/eqe.967>
- Meguro, K., & Tagel-Din, H. S. (2002). Applied Element Method Used for Large Displacement Structural Analysis. *Journal of Natural Disaster Science*, 24(1), 25–34.
- Nur, O F. (2012). Earthquake Damage – Intensity Relationship Based on Sumatran 30 September Earthquake. *15th World Conference on Earthquake Engineering (15WCEE)*.
- Porter, K., Hamburger, R., & Kennedy, R. (2005). Practical Development and Application of Fragility Functions.
- Porter, K., Hamburger, R., & Kennedy, R. (2007). Practical Development and Application of Fragility Functions. *Structural Engineering Research Frontiers*, 1–16. [https://doi.org/10.1061/40944\(249\)23](https://doi.org/10.1061/40944(249)23)
- Porter, K., Kennedy, R., & Bachman, R. (2007). Creating fragility functions for performance-based earthquake engineering. *Earthquake Spectra*, 23(2), 471–489. <https://doi.org/10.1193/1.2720892>
- Pribadi, K. S., Kusumastuti, D., & Utami, A. (2008). Earthquake Risk Perception in Indonesia : Government Officers and Builders View, (2007), 259–267.
- PusGen. (2017). *Peta Sumber dan Bahaya Gempa Indonesia Tahun 2017*.
- PUTRA, R. R., KIYONO, J., ONO, Y., & PARAJULI, H. R. (2012). SEISMIC HAZARD ANALYSIS FOR INDONESIA. *Journal of Natural Disaster Science*, 33(2), 59–70. <https://doi.org/10.2328/jnds.33.59>
- Rossetto, T., & Elnashai, A. (2003). Derivation of vulnerability functions for European-type RC structures based on observational data. *Engineering Structures*, 25(10), 1241–1263. [https://doi.org/10.1016/S0141-0296\(03\)00060-9](https://doi.org/10.1016/S0141-0296(03)00060-9)
- Sadiq Bhanbhro. (2017). Indonesia’s Minangkabau culture promotes empowered Muslim women. *The Conversation* .
- Sieh, K. (2006). Sumatran megathrust earthquakes: from science to saving lives. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 364(1845), 1947–1963. <https://doi.org/10.1098/rsta.2006.1807>
- Sieh, K., Natawidjaja, D. H., Meltzner, A. J., Shen, C. C., Cheng, H., Li, K. S., ... Edwards, R. L. (2008). Earthquake supercycles inferred from sea-level changes recorded in the corals of west Sumatra. *Science*, 322(5908), 1674–1678.

- <https://doi.org/10.1126/science.1163589>
- SNI 2847. (2013). Persyaratan Beton Struktural untuk Bangunan Gedung. *Bandung: Badan Standardisasi Indonesia*, 1–265.
- Tagel-Din, H., & Meguro, K. (2000). Analysis of a small scale RCbuilding subjected to shaking table tests using applied element method. *12WCEE. New Zealand:[Sn]*, (January 2000), 1–8. Retrieved from <http://www.iitk.ac.in/nicee/wcee/article/0464.pdf>
- Tegnan, H. (2015). Legal pluralism and land administration in west Sumatra: The implementation of the regulations of both local and Nagari governments on communal land tenure. *Journal of Legal Pluralism and Unofficial Law*, 47(2), 312–323. <https://doi.org/10.1080/07329113.2015.1072386>
- UN General Assembly. (2015). A/CONF.224/L.1 Sendai Declaration, 04878(March), 1504878. Retrieved from http://www.preventionweb.net/files/43300_sendaideclaration.pdf.
- UNISDR. (2015). Sendai Framework for Disaster Risk Reduction 2015 - 2030. *Third World Conference on Disaster Risk Reduction, Sendai, Japan, 14-18 March 2015.*, (March), 1–25. <https://doi.org/A/CONF.224/CRP.1>
- Vamvatsikos, D., & Allin Cornell, C. (2002). Incremental dynamic analysis. *Earthquake Engineering and Structural Dynamics*, 31(3), 491–514. <https://doi.org/10.1002/eqe.141>
- Vamvatsikos, D., & Cornell, C. A. (2005). Direct Estimation of Seismic Demand and Capacity of Multidegree-of-Freedom Systems through Incremental Dynamic Analysis of Single Degree of Freedom Approximation. *Journal of Structural Engineering*, 131(4), 589–599. [https://doi.org/10.1061/\(ASCE\)0733-9445\(2005\)131:4\(589\)](https://doi.org/10.1061/(ASCE)0733-9445(2005)131:4(589))
- Wahab, S. N. A., & Hamid, M. Y. (2011). A review factors affecting building defects of structural steel construction. Case study: Student accommodation in UiTM Perak. *Procedia Engineering*, 20, 174–179. <https://doi.org/10.1016/j.proeng.2011.11.153>
- Wibowo Kismiyati El; Haykal, Achmad, S. K. A. K. (2012). Konflik Pengetahuan Kepemilikan Tanah di Minangkabau. *Student E-Journal*, (Vol 1, No 1 (2012): Wisuda Agustus 2012), 18. Retrieved from <http://jurnal.unpad.ac.id/ejournal/article/view/1161>
- Wilkinson, S. M., Alarcon, J. E., Mulyani, R., Whittle, J., & Chian, S. C. (2012). Observations of damage to buildings from Mw7.6 Padang earthquake of 30 September 2009. *Natural Hazards*, 63(2), 521–547. <https://doi.org/10.1007/s11069-012-0164-y>
- Zachariassen, J. (2001). Paleoseismicity of the northern Horohoro Fault , Taupo Volcanic Zone , New Zealand Australian plate. *New Zealand Journal of Geology and Geophysics*, 44(January 2000), 391–400. <https://doi.org/10.1080/00288306.2001.9514946>

CHAPTER 3

A REVIEW OF EARTHQUAKE DISASTER REDUCTION ACTS FOR REINFORCED CONCRETE BUILDING IN INDONESIA

3.1 Introduction

Firstly, disaster risk reduction acts can be defined as the concept and practice of reducing disaster risks using systematic efforts to analyze and reduce the causal factors of disasters. Some of the example of disaster reduction is by reducing exposure to hazards, lessening the vulnerability of people, management of land and the environment, and improving preparedness and early warning for events are all examples of disaster risk

3.2 Time Frame of Indonesia Disaster Reduction Strategy

Figure 1.3. shows the time frame of disaster reduction acts for RC building in Indonesia which is started from the 1950`s to 2017 was made. This time frame is based on the review of related RC building code, law, and regulations supporting the code and the activities conducted by government agency or community. Every milestone of the acts will be discussed on sub-categories below.

3.2.1 RC Building Regulations and Codes in Indonesia

a. The Indonesian Building Code 1954

Even though concrete as a construction material has been used in Indonesia before 1950`s, the boom of its use is in the mid 80`s which was signed by the construction of many high-rise buildings especially in Jakarta (Irsyam et al., 2008) (Hoedajanto,--).

The design procedure adopted for most concrete structures at that time is based on Indonesia Concrete Code 1954 (Peraturan Beton Indonesia-PBI) which required the allowable stress design concrete. The targeted concrete cube strength was around 22.5 MPa for ordinary concrete. The steel reinforcement used were mild steel reinforcement with a yield strength of 240 MPa.

b. The Indonesian Building Code 1971

The ultimate strength design method was brought into practice as the Indonesia Concrete Code 1971 was introduced. However, the allowable stress design was admissible also in The Code 1971. In Fraser, 1983, He emphasized that the PBI 1971 contain a formula for the calculation of the horizontal earthquake load and its distribution. The formula included a parameter for the zone, soil type, structural material and importance factor. Even the concrete material included some seismic provision similar to ACI but excluding the ductility aspects. Hence, the design procedure was essentially elastic (Fraser, 1983)

The steel bars diameter used for column generally contain 4 – 10 mm in diameter, with 300mm space for stirrups. The dominant features of the wall were the use of locally made red bricks without reinforcement. The beam and column width practically is the same as the width of brick with additional thickness of mortar plaster. The design rule for wall area is no greater than 12m² between column and beam (Fraser, 1983).

c. The 1992 Indonesia Concrete Building Code (SNI-03-2847-1992)

The revised version of Indonesia Concrete Code 1971, the 1992 Indonesia Concrete Building Code (*Standard Nasional Indonesia-Tata Cara Perhitungan Struktur Beton untuk Gedung-1992, SNI-03-2847-1992*) introduce some significant change. The changes were the adoption of ACI-318-86 and the concept of ductile earthquake resistance concrete structures adopted from New Zealand Standard Code of Practice for General Structural Design and Design Loadings for Buildings (NZS 4203-1984).

The factor to consider the lower capability of local contractor also introduced by requires the use of the capacity reduction factor, adopted from ACI 318-86, while the load factor followed ASCE-7-76 (ASCE 41-06, 2007).

d. The 2002 Indonesia Concrete Building Code (SNI-03-2847-2002).

The 2002 Indonesia Concrete Building Code is a revision from 1992 version. This standard referred to previous standard and American Concrete Institute (ACI) 318M-1999 and American Concrete Institute (ACI) 318-2002.

e. The 2013 Indonesia Concrete Building Code (SNI-03-2847-2013)

After more than 13 years and considered a crucial amendment of the building code after some devastating earthquake in Padang (2009) and Yogyakarta (2006), in 2013

new version of the code for the concrete building was issued named as SNI-2847-2013. SNI-2847-2013 which is refers to ACI 318-08 and ACI 318-11 which has some fundamental revision to accommodate some new material specification, material testing method, detailing of reinforcement and concrete durability.

In detail, compared to its previous version, on SNI 03-2847-2013 has been established some fundamental amendment which are:

1. Establish more comprehensive durability requirement for concrete.
2. Establish a more comprehensive requirement for light concrete.
3. Accommodate new materials and systems, for example, high strength steel with yield stress (f_y) ≥ 550 MPa, Fibre Reinforced Concrete (FRP).
4. Accommodate concrete testing for high strength concrete.
5. Loading combination follows the seismic code SNI 1726-2012.
6. Simplification of reinforced concrete detailing with accommodating the use of high strength spiral reinforcement.

3.2.2 *Review of Guide to Residential Concrete Construction (Panduan Untuk Konstruksi Beton Perumahan-RSNI 2)*

This part explains the design process of the earthquake resistance residential concrete building construction process based on Indonesia Building Code. It is started from foundation, column, wall, beam and roof construction.

The frame of building codes that are used for the design can be seen in the following Table 3.1.

Table 3. 1. The frame of building codes that are used for the design

Design step	Code	Code title
Building layout	Pt-T-02-2000-C	Earthquake resistance building construction
The position of the opening (window and door)	Pd-T-14-2004-C	Earthquake resistance building
Concrete	SNI-03-1734-1989	Reinforced concrete and reinforced wall
	SNI 03-2847-2002	Concrete structure for building
	SNI 03-3976-1995	Concrete mixing and casting

Steel reinforcement	SNI 03-6814-2002 SNI 03-6816-2002	Mechanical joint for reinforcement Reinforcement detailing
Wall	SNI 03-6883-2002	Mortar for wall
Timber	SNI 03-2445-1991	Timber dimension for housing and building
Foundation and tie beam	SNI 03-2449-1991	Truss member dimension type 15/6
Column		Truss member dimension type 30/6
Beam		
Roof frame	SNI 03-2450-1991	

The material quality requirement in Indonesia Building Code

Material quality requirement refers to the technical requirement on SNI 03-2847-1992 calculation requirement for the building.

1. Concrete

Concrete material for earthquake design must follow SNI 03-2847-2002 article 3.14.2. as follows'

- 1) Concrete for structural component requires compressive strength not least than 20MPa
- 2) If the structural component uses a lightweight aggregate, the design compressive strength should not exceed 30 MPa.

2. Steel reinforcement

Steel reinforcement requirements as stated in SNI 03-2847-2002 must follow these below requirements:

- 1) Article 3.14.2 verse 5 about flexural and axial reinforcement states that reinforcement for the earthquake designed frame and masonry wall frame must fulfill the ASTM A706. Reinforcement that fulfills ASTM A 615M 300 and 400 can be used if:
 - a) Yield stress based on the tensile stress should not exceed 120 MPa
 - b) The ratio of ultimate stress to yield stress should not exceed 1.25.
- 2) Article 3.5. States tensile and compression reinforcement should be well connected at every side of the cross-section.
- 3) Article 3.16.1 state that 180-degree hook should add 4db or minimum 60mm at the free end. If the hook is 90-degree, the designer must add 12db at the free end,

and for stirrup, reinforcement with a diameter less than D-25 must have 135-degree hook and elongation 6db.

- 4) Article 3.6.2 regulate the minimum hook diameter for reinforcement (see table 3.2).

Table 3. 2. Hook diameter minimum

Reinforcement diameter	Minimum hook diameter
D10 – D14	4db
D16 – D25	6db
D29 – D36	8db
D44 – D56	10db

All of the reinforcement should be bent in cold treatment, and the installed reinforcement is prohibited to be bent.

3. Concrete Cover

SNI Verses 3.16.5 require minimum concrete cover is 10 mm and 12 if cross section effective depth $d \leq 200\text{mm}$ and $d \geq 200\text{ mm}$ respectively. Meanwhile, effective space between main reinforcement should not less than 25mm. Concrete cover for the structural member which exposed to environmental condition should have at least 40mm depth. While the unexposed members are required 20mm depth for concrete cover.

For column or axial member, minimum diameter for stirrups must not less than 10mm, and the stirrups space is 16 times the diameter of longitudinal reinforcement.

4. Building Layout or horizontal plan

Building plan design must follow regularity concept, symmetry, simple. If the design has to be asymmetric, SNI 03-1734-1989 verses 3.1.12 requires separation at least 0.004 times the total height of buildings or 7,5 cm (following the which one is greater). If one of plan direction is longer than the other, the longer direction should not be bigger than three times the perpendicular side. The arrangement of the wall should be symmetric with the main coordinate of the building plan.

5. Wall

Provision of the wall structure in Indonesia building code S-CI 03-1734-1989 and Pt-T-02-2000C regulates the brick material requirement.

1. The requirement for red brick material that is used for masonry wall should have at least 30kg/cm² for its compression strength and 9 cm width. If the masonry wall is plastered, the compression strength of the mortar is 30 kg/cm². The thickness of the bed joint should not less than 1 cm and should be positioned parallel to the frame. The wall should be plastered with the minimum thickness is 1 cm.

2. Material characteristic of red bricks

Typical masonry wall in Indonesia consists of red brick which is traditionally produced by local manufacturers. Hence, the production of red bricks does not follow standards which cause the dimension and strength of the bricks vary greatly.

Indonesia Industrial Standard SII.0021-78 classifies standard unit size for Indonesian red brick as follows:

Table 3. 3. Red Bricks Size (SII.0021-78)

Type	Size (mm)		
	Height	Width	Length
M-5a	65	90	190
M-5b	65	140	190
M-6	55	110	230

However, many red bricks available in the market (and thus used broadly in construction sites) do not follow this dimension standard. The dimensions vary from one construction site, and the bricks physical appearance (color, texture) also vary from one location to others.

SII classifies the compressive strength of red brick in Indonesia into six classes:

Table 3. 4. Red Bricks Classification (SII.0021-78)

Class	The average minimum compressive strength of 30 tested bricks (MPa)	The varied allowable coefficient of the average compressive strength (%)
25	2.5	25
50	5	22
100	10	22
150	15	15
200	20	15
250	25	15

If the class label is unknown, SII.0021-78 requires compression strength test, as described in the following

The compressive strength f_m can be calculated using this equation

$$f_m = \frac{P + W}{A}$$

Where,

P: maximum compressive force

W: weight of the specimen

A: area of loading

Eurocode 6 also adopt the same method above.

Modulus Elasticity

In general, the modulus elasticity of red bricks can be determined by using the same procedure as determining the modulus elasticity of concrete, i.e., by drawing a straight line from 0 (initial point) up to 1/3 of the top of the stress-strain relationship curve of red brick, which is considered as the proportional limit.

3. Material characteristic of mortar

Indonesian Earthquake Study recommends that mortar materials on masonry prism must have a minimum compressive strength of 3 MPa and the mix ratio of cement: sand supposed to be 1:6. The recommended mortar thickness is 8-15 mm.

Another standard, Eurocode 6, stated that the minimum compressive strength of

the mortar should be 5 MPa for unreinforced and confined masonry. However, UNDP on its publication, titled “Second Progress on Improved Brickwork, 1978” summarized that the smaller characteristic differences between masonry brick and mortar, the better quality of the prism produced. The reason is that the degree of homogeneity of the prism increases. Therefore, to provide the wall with better lateral resisting capacity, the mortar should have adequate strength.

6. Wall and Column Connection

The provision of safer housing from the earthquake produced by public work department requires the connection between columns and wall. The steel with diameter 10 mm with 400mm length should be installed as an anchor at every six layers of brick, as shown in Figure 3.1.

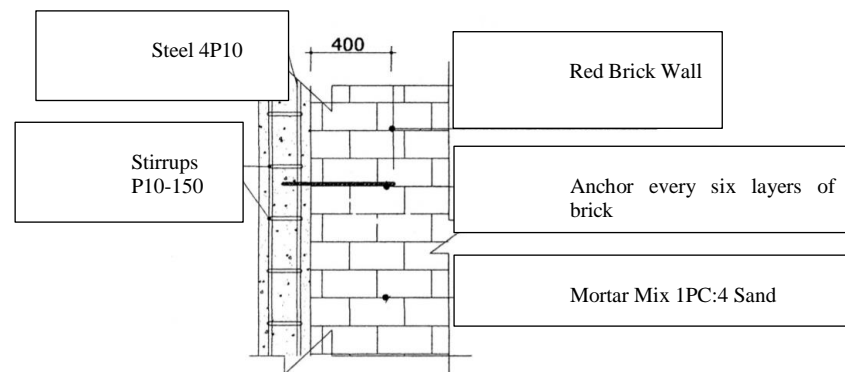


Figure 3. 1. Wall and Column Connection

7. Building Serviceability Certification

Reliability building inspection should be done for every building according to law and regulations. The inspection focuses on four criteria, safety, health, comfort and convenience(4K). Indonesia Building Law regulates this program.

Structural reliability assessment is aimed at understanding the existing condition of the building to withstand the existing loading and future loading based on building occupancy in the design lifetime.

Table 3. 5. Indonesia assessment procedure

Assessment Procedure					
qualitative	quantitative				
	Direct measurement	Numerical Simulation			
Level 0 Subjective based on visual inspection	Level 1 Based on the loading effects calculation	Level 2 Using simple modeling Data from building document	Level 3 Detail model Based on inspection	Level 4 Calculate modification and safety factor	Level 5 Capacity assessment based on probabilistic loading Data from inspection

Some normative reference regulates the assessment procedure in Indonesia. The codes are normal design procedure code for building since Indonesia yet has a structural evaluation code. In this case, the activity is based on American Standard for building Assessment in ASCE code.

Table 3. 6. Evaluation procedure

Technical Document Check <ol style="list-style-type: none"> 1. The building owner, designer, supervisor, contractor data 2. Technical specification 3. Design drawing 4. Shop drawing 5. As built drawing 6. Control document of building construction 	
Visual Inspection <ol style="list-style-type: none"> 1. Concrete cover 2. Crack and other damages 	
Is detail inspection needed?	
Yes	No
Detail inspection <ol style="list-style-type: none"> 1. Existing material testing using non-destructive (rebound number) or destructive test 2. Numerical simulation 	No need detail inspection
Structural Reliability Judgement Building failure defined as a condition of a building that does not agree with minimum requirement/limitation of performance based on the codes to fulfill the strength, stability, and serviceability required	
Recommendation	

Building inspection program has been scheduled to check elements for some particular range of time. Consider the structural elements only, foundation and shear wall must be checked after three years, plate every six months and roof structure every one year. Persons who are involved in this program are building owner, government staff and experts from university and a private company. The inspector is a certified engineer that will be trained by Trainer. Buildings on target are divided into two categories:

1. Simple building is building with the 1-3 storey (low-story building), which designed and constructed planning is organized by the owner. This building will be inspected
2. The complex building is building with more than three storey (mid-high rise) buildings, which designed by a professional designer, constructed by a professional engineer and inspected by a certified engineer.

The method that is used in this Inspection including visual observation using inspection form for building and its elements, testing Material to check strength and quality of building material using appropriate equipment and structural analysis if needed.

Structural Analysis using static analysis for simple building with height less than 40m and using dynamic analysis for complex building with height more than 40m. This model analysis aimed at structural resistance testing, for all of the buildings or/and its elements. Especially for buildings which:

- a. Changing on the occupancy level
- b. Changing on loading configuration
- c. After natural hazards

3.2.3 Building Expert Team

Building Expert Team is a team which is involved the experts from university, government; engineer association must supervise and provide professional engineer advice for the building construction activities. The establishment of Building Expert Team is aimed to fulfill the principals of Building Construction based on Laws of the building, Laws of Traffic and Roads, Laws of spatial planning, and Laws of engineer profession.

This team is regulated by Public Work Minister Regulation no 26/PRT/M/2007 the year 2007 and PP no.36 Year 2005 about Implementation Regulation of Law no 28 the Year 2002. The responsibility of the team is providing advice, opinion, and professional considerations to assist local government or national government in building construction activity.

The team responsibility is limited to the building's activities related to unique and public buildings which are required for their technical consideration. They will coordinate with the government, the public and the owner. Sometimes, while there are problem regards to construction, the team has a responsibility to give testimony at the court.

The timeline of the act of building quality enhancement

	PP 36/2005 About the implementation of UU no 28/2002		1. Permen PU 24/PRT/M/2007 about Technical Guidance of Building Permit 2. Permen PU 25/PRT/M/2007 about Building Serviceability Certification Guidance 3. Permen PU 26/PRT/2007 about Building Expert Team Guidance.		Perpres 73/2011 about building	
	↑		↑		↑	
2002	2005	2006	2007	2008	2011	2016
↓		↓		↓		↓
UU no 28/2002		Permen PU 29/PRT/M/2006 about Guidance of Technical Requirements of Building		Permen PU no 24/PRT/M/2008 about Guidance maintenance and rehabilitation of the building		Permen PUPR 05/PRT/M/2016 about Technical Guidance of Building Permit

Figure 3. 2. Timeline of building quality enhancement

The criteria for building under the responsibility of building an expert team which are special building and public building. A public building is a building which functions for public activities and needs. The technical aspect can be simple or complicated, e.g., school, government office. A special building is a building which is used or special usage and has a special requirement and constructed by using some special technology approach. The regulation requires the team to finish the technical requirements fulfillment of public building up to 8 stories is eight workdays, and more than eight storey is 25 workdays.

In local level, the responsibility of this team is regulated in Local Regulation no seven the Year 2015 for Padang City. Hence, for unique and public building, the technical documents must follow the advice of the team. The local regulation also states

that building with an area less than 150 m², single residential building, un-single/row buildings, semi-permanent building do not need the technical documents designed by a certified designer.

The frame of cooperation of the team involves the roles of engineer/builder association, university, and community with the basic rules is ad-hoc, independent, objective and without interest.

Source: Meeting and discussion with Eko Alvarez, Expert, and Professor from Bung Hatta University, Padang West Sumatra and Dr.Eng.Jon Affi, ST.MT, West Sumatra Provincial Expert Team.

3.2.4. The Builder Certification

Standardization is required to facilitate Indonesian workers to able to compete with foreign workers. SKKNI is the only standard that should be used by competency test/certification developers. However, there has been a lack of awareness of the importance of competency certification among stakeholders and construction workers, resulting in a low motivation to participate in the certification. The failure of training programs is due to low awareness of the importance of the training process, work culture, organizational structure, the financial and physical condition of participants, policy, and technology support.

The organizations involved in collaborative training are universities, professional associations institution, the government namely the Department of Labour Resources (Disnaker), the Ministry of Public Works and Housing (Kemen PUPR) at the district or provincial level, the construction business entities (BUJK) such as Gappensi/Gapeksindo/Gapeknas and others. Universities and professional associations board have expertise in developing curricula, training materials, and assessment instruments. The government, in this case, the Ministry of Public Works and Housing, the Ministry of Manpower, and the Ministry of Industry hold the authority to manage the certification and construction services. The construction business entity is the employer of skilled construction workers. These three stakeholder elements undertake the collaborative training program in an attempt to improve the skills of construction workers. The construction industry plays a significant role in providing training places (internships or apprenticeship) for the participants. Skilled workers will be motivated to participate in the certified collaborative training program, and the expected outcome

is an increased quality of skilled construction workers (Dardiri, Sutrisno, Kuncoro, Ichwanto, & Suparji, 2017; Wahab & Hamid, 2011)

3.2.4 Building Permit System

a. Introduction

Building Permit System is regulated upon Law no.28-year 2002 about Building, Law no.26 year 2007 about spatial planning and Government Regulation no.36 the year 2007 about the implementation of Law no.28 year 2002. As a countermeasure for disaster and improvement of building resilience, IMB system also implements Law no.24-year 2007 about disaster countermeasure action and Indonesian National Building Standard (SNI).

The Building law and regulation structure in Indonesia is described in Figure 3.3 as below:

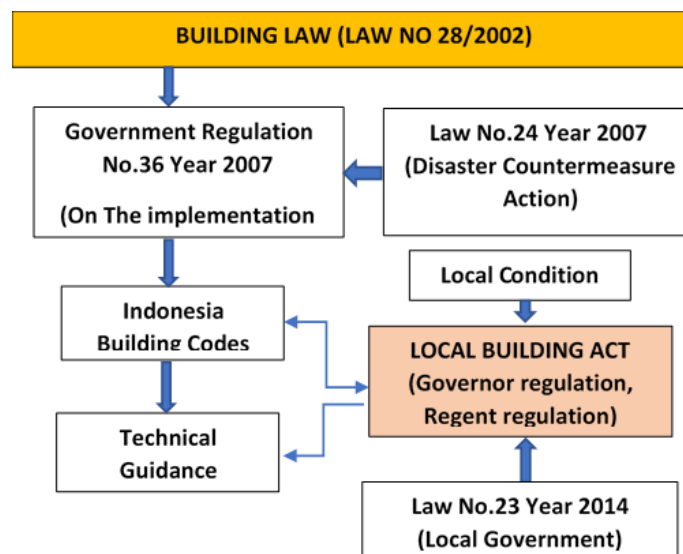


Figure 3. 3. Structure of Building Law in Indonesia [2,3,4]

Figure 3.3., mainly informed that building regulation in Indonesia is derived from Building Law no.28 year 2002, then every detail which is supported the law will discuss more on Government regulation (PP), Minister Decree (PerMen) from related ministry. Every province and cities can implement all of the regulation at the national level regards to local condition using local regulation which is stipulated by Governor or Major.

In case of local building act, according to the database from Public Work Department, till November 2015, there are 329 districts/cities (64,89%) which are

already regulated the Local Building Regulation including Padang city, West Sumatra province, which is becoming research area on this study.

Padang city had suffered much damages due to earthquake load. Many types of buildings in this area, such as unreinforced masonry building, timber building, steel structure and the most damaged one is reinforced concrete building both of low-rise and medium-rise. There was no high-rise building at that time.

Since after earthquake many high-rise buildings are starting from 8 storeys in Padang city, this fact becomes our concern to make sure that they are provided with the adequate seismic capacity to avoid possible damage due to seismic load. One of the ways to achieve its performance is to make sure the building permit system and the process of building construction can guarantee the resilience of every building in Padang city, Indonesia.

Responding to some amendments on Local Regulation, this study explains about the new system on building construction process compared to the previous one and scoring the related parameter that will show that the system can provide adequate building performance.

b. Stages of Building Permit System

In general, building construction process in Indonesia can be divided into five steps

1. Step 1: Pre-application

During this pre-application, there are three main players are involved in this step, which is building owner as an applicant, TRTB officer, and building designer. The main purpose of this step is to complete the basic document of owners and the building.

2. Step 2: Design

After clarification of the personal information of the owner, land ownership document and other supporting documents, the owner can submit the building related document and get a review from a building officer. The review process will be repeated a couple times until all of the aspects of reliability and safety are fulfilled.

3. Step 3: Construction

After verification of building and spatial requirements, Spatial and Building Planning Office (TRTB) will issue building permit document that officially signed as a statement that government agree and approve the owner's data including land certificate and reliability of building's design and construction planning.

4. Step 4: Utilization

As the construction process is finished, TRTB will inspect the building serviceability level and decide whether the building can be operated or not by giving SLF certificate

5. Step 5: Demolition

In case of building need to be demolished partly or all of the buildings, due to some particular reason, the owner need to ask recommendation from TABG which will investigate and study about building condition from structural aspect and the importance level of the building regarding safety and preservation issue

Process	Documents	Building Up to 2 nd Stories (Housing)	Building > 2 nd Stories
Document Administration	Land Owner/User Certificate	O Apply to the village municipality or regional government (mayor level). The designer is an uncertified engineer	Apply to Public Work Dept.at Mayor Level. The designer is certificated, engineer
	Architectural	O	
	Technical	X	
Design State	Land status and architectural doc	O	Public Work Dept.
	Technical doc	X	
Building Permit Issued		O	
Construction process with supervision		X	Constructed by the certified construction company. Supervised by TABG
Post Supervision		O Inspected by regional municipalities construction association or	Serviceability supervision, doing by professional technical building inspector from company/individual/owner
Utilization with periodic review	Inspection documents	X	After getting SLF certificate The building owner must have an insurance certificate

Technical Review	X	for structural failure possibility Need to do a technical review after 20 years
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O = required
X = not required

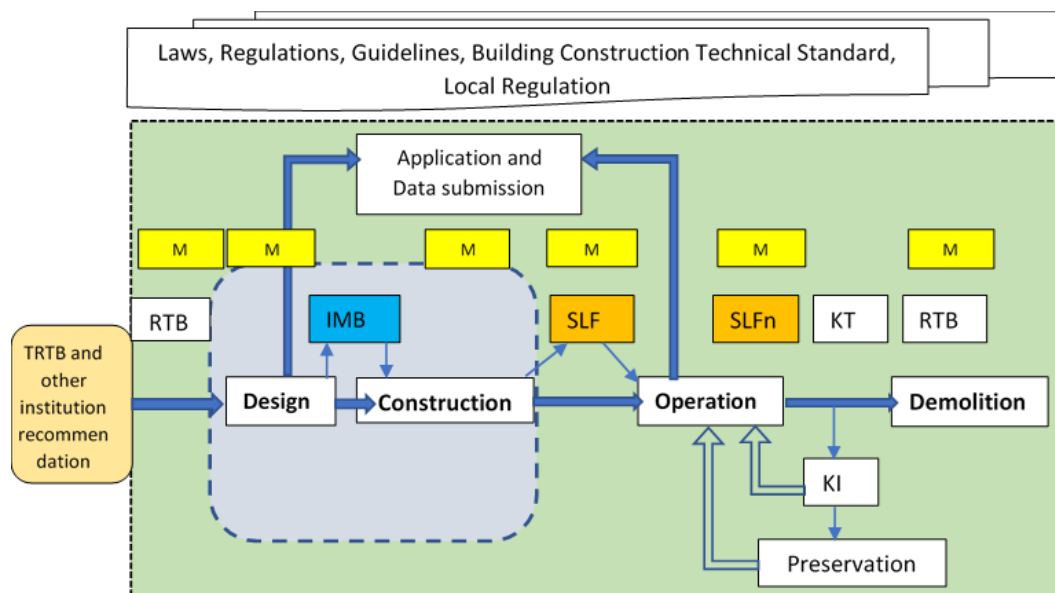
Figure 3. 4. Building Permit Process and Requirements

c. *Structure of Building Permit System*

Implementation of new building permit system is divided into two (2) schemes according to a significant degree of building occupancy.

1. Common building scheme where are buildings that are used for housing and private occupancies such as for a residential building, shop, industry and private office as shown in figure 2.
2. A particular building is used for public function and life-line function such as school and other important building which contribute numerous impacts if damaged due to low-code design or due to natural/environment load as shown in figure 3.5.

The structure of building construction process implementation is shown in the figures below.



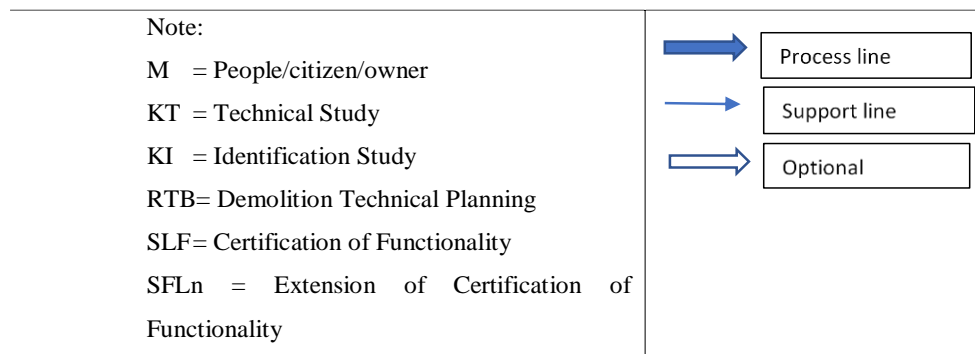


Figure 3. 5. Structure of Normal Building Construction Process in Padang City, Indonesia

4. Reference

- ACI. (2008). *Building code requirements for structural concrete (ACI 318M-08) and Commentary*. American Concrete Institute (Vol. 2007). [https://doi.org/10.1016/0262-5075\(85\)90032-6](https://doi.org/10.1016/0262-5075(85)90032-6)
- Amit, K. (1998). Economic Assessment of Seismic Retrofitting of Non-Engineered Buildings - Case Study from India.
- Andaya, L. Y. (2000). Unravelling Minangkabau Ethnicity. *Itinerario*, 24(2), 20–43. <https://doi.org/10.1017/S0165115300013000>
- ASCE 41-06. (2007). *Seismic rehabilitation of existing buildings*. <https://doi.org/10.1061/9780784408841>
- ASTM C311-04 C512-02. (2002). Standard Test Method for Creep of Concrete in Compression. *Annual Book of ASTM Standards*, 1–4. https://doi.org/10.1520/C0512_C0512M-15
- ASTM C823. (2016). Standard Practice for Examination and Sampling of Hardened Concrete in Constructions. *American Society for Testing and Materials*, 1–7. <https://doi.org/10.1520/C0823>
- Aydan, Ö. (2009). a Reconnaissance Report on the Pariaman-Padang Earthquake of September 30, 2009. *Earthquake*, (October), 1–36. Retrieved from http://www.jsce.or.jp/library/eq_repo/Vol3/12/20090930report.pdf
- Blackwood, E. (1993). *The politics of daily life: Gender, kinship and identity in a Minangkabau village, West Sumatra, Indonesia*. ProQuest Dissertations and Theses. Retrieved from <http://search.proquest.com/docview/304063843?accountid=13771>
- Carlberg, C. (2011). *Statistical analysis - Microsoft Excel 2010*. Pearson.
- Chadwick, R. J. (1991). Matrilineal Inheritance and Migration in a Minangkabau. *Indonesia*,

- 50, 47–81. <https://doi.org/10.2307/3351065>
- Coleman, A., & Karagedikli, Ö. (2018). Residential construction and population growth in New Zealand : 1996-2016, (January), 1–59. Retrieved from www.rbnz.govt.nz/research/discusspapers
- Dardiri, A., Sutrisno, Kuncoro, T., Ichwanto, M. A., & Suparji. (2017). Enhancing the competitiveness of skilled construction workers through collaborative education and training. *AIP Conference Proceedings*, 1887. <https://doi.org/10.1063/1.5003488>
- Education, P. (2017). Dynamics of Structures 5th Edition Chopra Solutions Manual Full clear download (no formatting errors) at : Solution :
- Fotopoulou, S. D., & Pitilakis, K. D. (2013). Fragility curves for reinforced concrete buildings to seismically triggered slow-moving slides. *Soil Dynamics and Earthquake Engineering*, 48, 143–161. <https://doi.org/10.1016/j.soildyn.2013.01.004>
- Fraser, I. A. N. (1983). a New Draft Code for Seismic Design of Buildings in Indonesia, (3), 247–254.
- Guragain, R. (2015). Development of Earthquake Risk Assessment System for Nepal (ネパールを対象とした地震リスク評価システムの開発), (February).
- Hanifa, R., Gunawan, E., Irsyam, M., & Abidin, H. Z. (2016). Outline Earthquake risk reduction strategy in Indonesia after the 2004 tsunami disaster Irwan Meilano Earthquake disaster in Indonesia Earthquake sources : slip-rate and maximum magnitude PSHA map of Indonesia Earthquake risk analysis Building code Conclu.
- Hazus-MH_2.1. (2015). Hazus–MH 2.1: Technical Manual. *Department of Homeland Security Federal Emergency Management Agency Mitigation Division Washington, D.C.*, 718. Retrieved from www.fema.gov/plan/prevent/hazus
- Intarti, Y. R., Damayanti, S., Rahmayanti, H., Rahmat Widyanto, M., Wahyudi, D., & Nadera, M. M. (2014). Development of Minangkabau Women ' s Roles as an Effort to Reduce Risk in Disaster - prone Cities in Indonesia A Case Study of Western District of Padang , Padang City , West Sumatra , Indonesia 1. *International Journal of Disaster Recovery and Business Continuity*, 5(November 2013), 29–42. <https://doi.org/10.14257/ijdrbc.2014.5.03>
- Irsyam, M., Dangkoa, D. T., Hendriyawan, Hoedajanto, D., Hutapea, B. M., Kertapati, E. K., ... Petersen, M. D. (2008). Proposed seismic hazard maps of Sumatra and Java islands and microzonation study of Jakarta city, Indonesia. *Journal of Earth System Science*, 117(SUPPL.2), 865–878. <https://doi.org/10.1007/s12040-008-0073-3>

- Irsyam, M., Hutabarat, D., Asrurifak, M., Imran, I., Widiyantoro, S., Sadisun, I., ... Pandhu, R. (2014). Development of seismic risk microzonation maps of Jakarta city. In *Geotechnics for Catastrophic Flooding Events* (pp. 35–47). <https://doi.org/10.1201/b17438-6>
- ISDR. (2015). Chart of the Sendai Framework for Disaster Risk Reduction, 2030.
- Juliafad, E., & Andayono, T. (2018). BUILDING OFFICIAL `S AWARENESS IN TERM OF BUILDING PERMIT SYSTEM IN INDONESIA.
- Kaushik, H. B., Rai, D. C., & Jain, S. K. (2006). Code approaches to seismic design of masonry-infilled reinforced concrete frames: A state-of-the-art review. *Earthquake Spectra*, 22(4), 961–983. <https://doi.org/10.1193/1.2360907>
- Megawati, Kusnowidjaja. (2012). Shear-Wave Velocity Structure underneath the City of Padang, Indonesia. *15th World Conference on Earthquake Engineering (15WCEE)*.
- Megawati, K., & Pan, T. C. (2010). Ground-motion attenuation relationship for the Sumatran megathrust earthquakes. *Earthquake Engineering and Structural Dynamics*, 39(8), 827–845. <https://doi.org/10.1002/eqe.967>
- Meguro, K., & Tagel-Din, H. S. (2002). Applied Element Method Used for Large Displacement Structural Analysis. *Journal of Natural Disaster Science*, 24(1), 25–34.
- Nur, O F. (2012). Earthquake Damage – Intensity Relationship Based on Sumatran 30 September Earthquake. *15th World Conference on Earthquake Engineering (15WCEE)*.
- Porter, K., Hamburger, R., & Kennedy, R. (2005). Practical Development and Application of Fragility Functions.
- Porter, K., Hamburger, R., & Kennedy, R. (2007). Practical Development and Application of Fragility Functions. *Structural Engineering Research Frontiers*, 1–16. [https://doi.org/10.1061/40944\(249\)23](https://doi.org/10.1061/40944(249)23)
- Porter, K., Kennedy, R., & Bachman, R. (2007). Creating fragility functions for performance-based earthquake engineering. *Earthquake Spectra*, 23(2), 471–489. <https://doi.org/10.1193/1.2720892>
- Pribadi, K. S., Kusumastuti, D., & Utami, A. (2008). Earthquake Risk Perception in Indonesia : Government Officers and Builders View, (2007), 259–267.
- PusGen. (2017). *Peta Sumber dan Bahaya Gempa Indonesia Tahun 2017*.
- PUTRA, R. R., KIYONO, J., ONO, Y., & PARAJULI, H. R. (2012). SEISMIC HAZARD ANALYSIS FOR INDONESIA. *Journal of Natural Disaster Science*, 33(2), 59–70. <https://doi.org/10.2328/jnds.33.59>
- Rossetto, T., & Elnashai, A. (2003). Derivation of vulnerability functions for European-type

- RC structures based on observational data. *Engineering Structures*, 25(10), 1241–1263. [https://doi.org/10.1016/S0141-0296\(03\)00060-9](https://doi.org/10.1016/S0141-0296(03)00060-9)
- Sadiq Bhanbhro. (2017). Indonesia's Minangkabau culture promotes empowered Muslim women. *The Conversation* .
- Sieh, K. (2006). Sumatran megathrust earthquakes: from science to saving lives. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 364(1845), 1947–1963. <https://doi.org/10.1098/rsta.2006.1807>
- Sieh, K., Natawidjaja, D. H., Meltzner, A. J., Shen, C. C., Cheng, H., Li, K. S., ... Edwards, R. L. (2008). Earthquake supercycles inferred from sea-level changes recorded in the corals of west Sumatra. *Science*, 322(5908), 1674–1678. <https://doi.org/10.1126/science.1163589>
- SNI 2847. (2013). Persyaratan Beton Struktural untuk Bangunan Gedung. *Bandung: Badan Standardisasi Indonesia*, 1–265.
- Tagel-Din, H., & Meguro, K. (2000). Analysis of a small scale RC building subjected to shaking table tests using applied element method. *12WCEE. New Zealand:[Sn]*, (January 2000), 1–8. Retrieved from <http://www.iitk.ac.in/nicee/wcee/article/0464.pdf>
- Tegnan, H. (2015). Legal pluralism and land administration in west Sumatra: The implementation of the regulations of both local and Nagari governments on communal land tenure. *Journal of Legal Pluralism and Unofficial Law*, 47(2), 312–323. <https://doi.org/10.1080/07329113.2015.1072386>
- UN General Assembly. (2015). A/CONF.224/L.1 Sendai Declaration, 04878(March), 1504878. Retrieved from http://www.preventionweb.net/files/43300_sendaideclaration.pdf.
- UNISDR. (2015). Sendai Framework for Disaster Risk Reduction 2015 - 2030. *Third World Conference on Disaster Risk Reduction, Sendai, Japan, 14-18 March 2015.*, (March), 1–25. <https://doi.org/A/CONF.224/CRP.1>
- Vamvatsikos, D., & Allin Cornell, C. (2002). Incremental dynamic analysis. *Earthquake Engineering and Structural Dynamics*, 31(3), 491–514. <https://doi.org/10.1002/eqe.141>
- Vamvatsikos, D., & Cornell, C. A. (2005). Direct Estimation of Seismic Demand and Capacity of Multidegree-of-Freedom Systems through Incremental Dynamic Analysis of Single Degree of Freedom Approximation. *Journal of Structural Engineering*, 131(4), 589–599. [https://doi.org/10.1061/\(ASCE\)0733-9445\(2005\)131:4\(589\)](https://doi.org/10.1061/(ASCE)0733-9445(2005)131:4(589))
- Wahab, S. N. A., & Hamid, M. Y. (2011). A review factors affecting building defects of structural steel construction. Case study: Student accommodation in UiTM Perak.

- Procedia Engineering*, 20, 174–179. <https://doi.org/10.1016/j.proeng.2011.11.153>
- Wibowo Kismiyati El; Haykal, Achmad, S. K. A. K. (2012). Konflik Pengetahuan Kepemilikan Tanah di Minangkabau. *Student E-Journal*, (Vol 1, No 1 (2012): Wisuda Agustus 2012), 18. Retrieved from <http://jurnal.unpad.ac.id/ejournal/article/view/1161>
- Wilkinson, S. M., Alarcon, J. E., Mulyani, R., Whittle, J., & Chian, S. C. (2012). Observations of damage to buildings from Mw7.6 Padang earthquake of 30 September 2009. *Natural Hazards*, 63(2), 521–547. <https://doi.org/10.1007/s11069-012-0164-y>
- Zachariasen, J. (2001). Paleoseismicity of the northern Horohoro Fault , Taupo Volcanic Zone , New Zealand Australian plate. *New Zealand Journal of Geology and Geophysics*, 44(January 2000), 391–400. <https://doi.org/10.1080/00288306.2001.9514946>
- Andayono, T., & Juliafad, E. (2015). Pemahaman Masyarakat Tentang Bangunan yang Aman Terhadap Gempa dan Izin Mendirikan Bangunan di Kabupaten Padang Pariaman. *proceedingfptk*, 440.

Time frame of disaster reduction acts for RC buildings in Indonesia																			
			Aceh Earthquake (9.3Mw)		Yogya Earthquake (6.4 Mw)	West Sumatra Earthquake (8.4 Mw)		West Sumatra Earthquake (7.6 Mw)		West Sumatra Earthquake (7.8 Mw)							EQ. EVENT		
1978	1992	2002	2004	2005	2006	2007	2008	2009	2010	2011	2011	2012	2013	2016	2017	TIME			
Red Brick Quality Standard		Indonesian Building Code for RC (based on Ultimate Design) and Seismic Code 2002		Indonesian Building Code for RC (based on Ultimate Design) and Seismic Code 2002								New Seismic Code 2012		New Seismic Map of Indonesia		RELATED RC BUILDING CODE			
UU no 28/2002 Laws about Building		PP 36/2005 About the implementation of UU no 28/2002		Permen PU 29/PRT/M/2006 about Guidance of Technical Requirements of Building		Achieving safer housing through effective dissemination of building code (HESI)		Permen PU no 24/PRT/M/2008 about Guidance of maintenance and rehabilitation of the building		Minimum Requirement of earthquake safer house Manual (PU-JICA) Guidelines on building back better for reconstruction Rumah Instant Sehat Aman (RISHA) \ Instant Health Modest House, designed by Public Work Dept.		Perpres 73/2011 about building		Training on damage and assessment Module for training in rehabilitation and reconstruction Decision Support System for Post Disaster Need Assessment		Permen PUPR 05/PRT/M/2016 about Technical Guidance of Building Permit		National Earthquake Center Establishment Builder Certification and workshop	RELATED LAWS AND REGULATION SUPPORTING RC BUILDING CODE AND AGENCY PRODUCTS

CHAPTER 4

FIELD STUDY ON EXISTING BUILDINGS, MATERIAL PROPERTIES AND WORKMANSHIP OF REINFORCED CONCRETE BUILDING; STUDY AREA: PADANG CITY, WEST SUMATRA, INDONESIA

4.1 Introduction

This chapter explains the field study activities which was conducted in Padang City to understand the RC building masonry wall structures actual condition. The studies cover the investigation of 100 existing RC buildings, investigation of existing concrete material, testing on existing red brick material, testing on marketed available steel reinforcement. This study also covers the interview of 100 RC building builders, interview with ten building officers, and the interview with the tribe leaders.

4.1.1 The Objective of Field Study

The objective of the field study, in general, is to achieve a comprehensive understanding of the actual condition of RC buildings in Padang City including the systems that supported or influenced the RC building's quality. The data which is obtained in this study can be used to provide information for further researches regards to RC building with masonry wall in Indonesia and the disaster reduction activities. The information also can be valuable for the related stakeholders (government, construction practitioners, and the community). In detail, the objective of each study can be derived as follows:

1. To measure the quantitative measurements of existing RC buildings in Padang City which covers the buildings from early 1970 to 2017.
2. To obtain the strength parameter of main materials which are used for RC Buildings with a masonry wall, including concrete, steel reinforcement, red bricks, and mortar.
3. To understand the construction practice that is used by the builders in Padang City to construct RC building construction, this study could be

used to understand the cause of some defects that might be found in the surveyed existing RC buildings.

4. To understand the awareness of the building officers regards to their tasks to process the building planning, construction, and supervision.
5. To understand the knowledge and the roles of the tribe leaders in constructing the RC buildings in tribe lands. The information about the tribe land was reviewed in Chapter 2.

4.1.2 The Methodology

This study used quantitative and qualitative approaches which cover the measurement of a quantitative parameter of existing building, testing on RC building materials, interviewing the owners, the builders, the building officers and the tribe leaders. Table 4.1. explains the activities in this study, the applied methodology and the number of surveyed items.

Table 4. 1. Activities in this study, the applied methodology and the number of surveyed items

No	Activities	Methodology	Number of Targets
1	Existing RC Building with a masonry wall	Quantitatively measure the building parameters	100 buildings
2	Concrete material	Compression test of concrete from demolished buildings Collecting data of concrete core drill from existing buildings Collecting data of concrete cylinder testing from the certified laboratory	25 concrete cubes 34 buildings 300 data set
3	Steel reinforcement	The tensile strength of common steel reinforcement which is used for RC construction in Padang City	

4	Red Brick	Compression Test of bricks from demolished buildings	30 red bricks
5	RC buildings builder's construction methods	Interview	100 builders
6	The building officers	Interview	15 officers
7	The experts and head of the office	interview	Five persons
8	The tribe leaders	Interview	Ten leaders

Figure 4.1. shows the frame of the field stud towards the development of assessment tools for disaster reduction of RC buildings in Padang City, Indonesia.

4.2 Existing RC Building Investigation

4.2.1 Target Building and Survey Area

The building criteria in this study are existing RC buildings with masonry wall as the most populated building population as described in building typology research that explained in chapter 2. RC building in Figure 2.1. covers more than 80% of the total building population, where around 70% of this population consists of low and mid-rise buildings.

To ensure that the building samples will represent the building population, the surveyed RC buildings have to consider:

1. Building age; This information was gathered from the information of the owner and verified with the building document permit (if available).
2. Building storey; The low and mid-rise RC buildings were investigated to cover the structural behavior of building population towards the seismic loads.

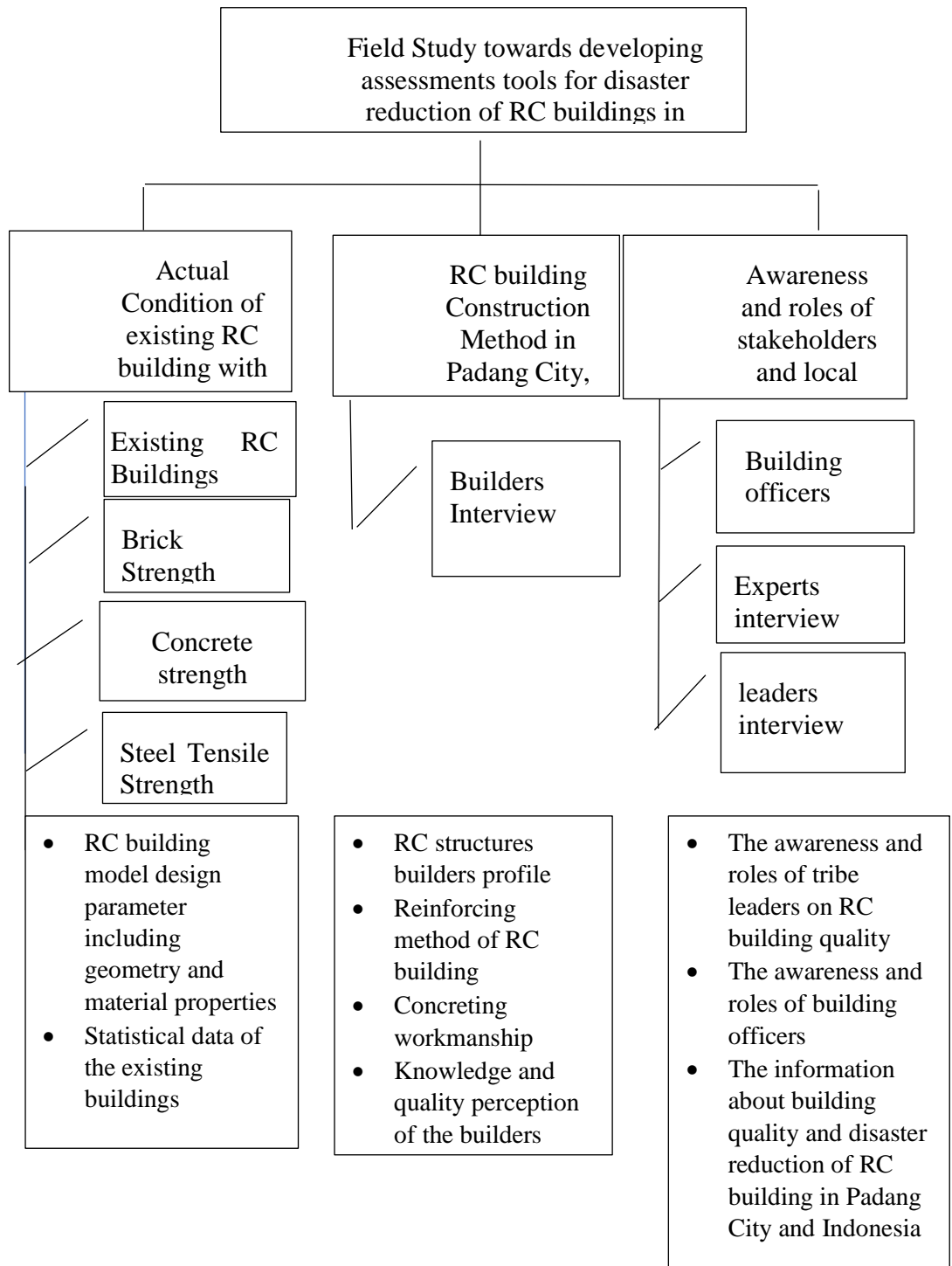


Figure 4. 1. The framework of Field Study

3. Masonry wall; the buildings that surveyed should be confirmed first as RC buildings with masonry wall by checking the visualization of the outer wall from the street.
4. The investigation was conducted using structured survey sheets to ensure the investigation covers the quantitative parameters that would be needed to build the RC buildings model. The survey sheets that were used in the investigation can be found in appendix 1 of this chapter.

Table 4.2. explained the obtained parameters and information that was collected during the existing RC building investigation. Due to

Table 4. 2. The parameters information of existing RC buildings

No	Information	Tools
1	Building owner information, including names and occupations	Interview the owner or the occupants
2	General data of the buildings, including the type of occupancy, construction year and the prediction of construction cost.	Interview with the owner
3	Building plan design	Building documents (If available)
4	Building layout	Laser measurement or measurement tape
5	Building height and inter-story height	Laser measurement
6	Structural elements position and effective length/height	Measurement tape
7	Structural elements cross-section, including columns, beams, and slab. The measured parameters cover dimension, concrete cover, main-bars position and diameter, and stirrups position and diameter	Measurement tape Rebar scanner Caliper

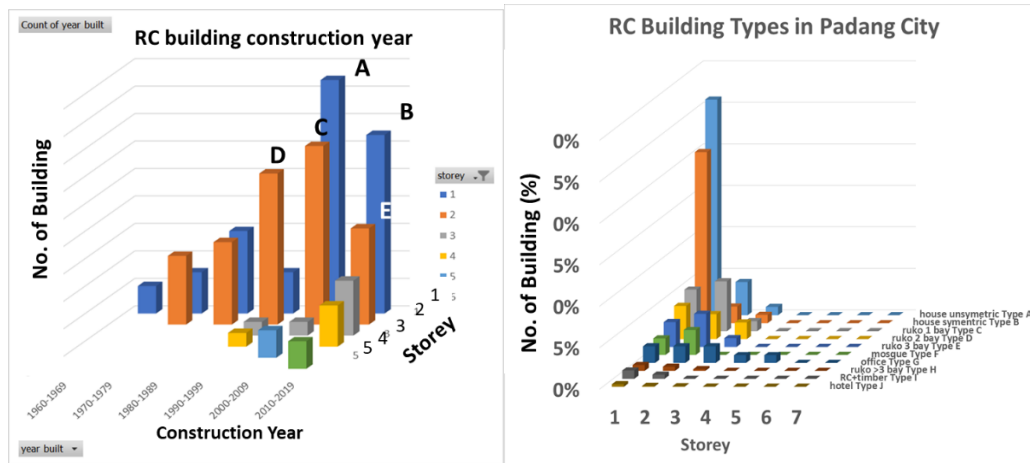
8	Masonry wall position and dimension	Measurement
9	Opening position and dimensions	
10	Wall confinement or lintel beam	Rebar scanner

The survey area in Padang city covers the Padang City from South to North and West to East (see Figure 4.2.) The population of buildings in the area also consider the number of investigated buildings.



Figure 4. 2. The Field Study Plan

There were ten types of RC building masonry buildings which cover 70% of building a population that investigated in this study.






	house unsymetric	house symmetric	ruko 1 bay	ruko 2 bay	ruko 3 bay	mosque	office	ruko >3 bay	RC+timber	hotel
storey	Type A	Type B	Type C	Type D	Type E	Type F	Type G	Type H	Type I	Type J
1	26%	21%	5%	4%	3%	2%	2%	1%	1%	0%
2	4%	2%	6%	3%	4%	3%	2%	1%	1%	0%
3	1%	1%	1%	2%	1%	0%	2%	0%	0%	0%
4	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%
5	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%
6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Figure 4. 3. The Field Study Data of Predominant RC Building

To categorize the RC Buildings based on its construction year, we consulted with a senior architect about the characteristic of buildings in Padang, together with asking the owner of investigated buildings about their building construction year. Regards to the information from the expert interview and investigation of the buildings, we can recognize the buildings based on its construction year based on its characteristic. We divide the construction year into four categories:

1. RC Building 1970`s
2. RC Building 1980`s
3. RC Building 1990`s
4. RC Building 2000
5. RC Building 2010

Table 4. 3. Description of Reinforced Concrete based on Its Construction Year

Construction Year	Characteristic
<p>1970`s</p> 	<p>RC buildings which were constructed during 1970`s have a high roof with 30-45 degree in angle. Usually the height of the roof almost same with the height of the storey. The windows are wide and made from timber. That is are due to the need for natural air circulation at that time</p>
<p>1980`s</p> 	<p>RC Buildings which were constructed during 1980`s have a short roof with an angle of 15 degrees. The opening such us window are made from timber, but the ventilation above the window made of iron and have an arch-shaped following the architecture trend at that time</p>
<p>1990</p> 	<p>RC Buildings of 1990`s can be recognized from the angle of the roof are 30 degrees, but the size of the opening is smaller than the buildings from the 1970`s. The type of window cover is “nako” style using horizontal rotated glass grid.</p>







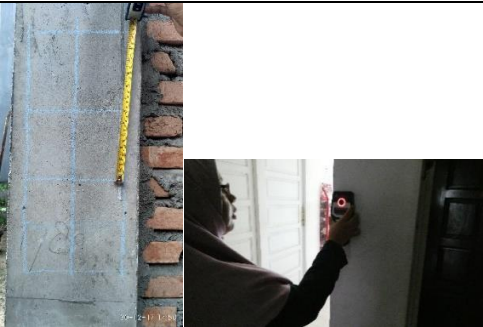

<p>2000</p> 	<p>Due to the increasing of the air conditioner of popularity and increase of daily temperature, the buildings from 2000 have smaller window and ventilation. The use of aluminum frame for window also gain its popularities</p>
<p>2010</p> 	<p>After 2009 earthquakes, there are many discussions in regards to the weight of the buildings especially roof frame. The use of light steel frame for truss structure gains its popularity. The opening also becomes small due to air conditioner utilization.</p>

Figure 4. 4. Identification of existing building for its construction year

After recognized the building from the street, the year of construction was confirmed with the owner/occupant/the neighbor. In Fig.4.4., comparison of the height of the roof for each construction year era based on the measurement of existing building shows that buildings that were constructed during 1970`s era have around 3.4 m of height, buildings from 1980`s era have a low roof with height is 1 m. Started from 1990`s the height of the roof become higher again and vary, but as the information from the senior architect interview, the style of the opening can be used as the reference for classifying the buildings based on its construction year while conducting a field study.

No	Main Parameter	Sub-parameters	Pictures
1	Building dimensions. Tools: 1) laser measurement, Bosch brand with accuracy 1-2 mm and can be used for outside and inside the room. 2)tape measurement		
	1.vertical	a. total height	
		b. inter-story height	
		c. the height of the roof	
	2.horizontal	a. total length for x and y directions	
		b. distance between column	
2	Structural Element Tools: 1) laser measurement 2) tape measurement 3) rebar locator (HILTI and BOSCH) to find the detect the rebar inside structural elements or wall 4) Digital Vernier Caliper Accuracy 0.01mm		
	1.Dimension	a. Height of column	
		b. Length of the beam	
		c. Thickness of slab	

	2. Cross section	a. Cross section dimension	
		b. Concrete cover thickness	
		c. Number and position of the longitudinal rebar	
		d. The position of the stirrups at the middle of the span and near joint	



		e. Rebar diameter of column, beam, and slab	 
3	Opening (doors, windows, garage gate, wide opening)	a. Opening position b. Opening dimension	
4	Additional confinement	a. Confinement above window/ or doors	

Figure 4. 5. Existing RC Building Study in Padang City

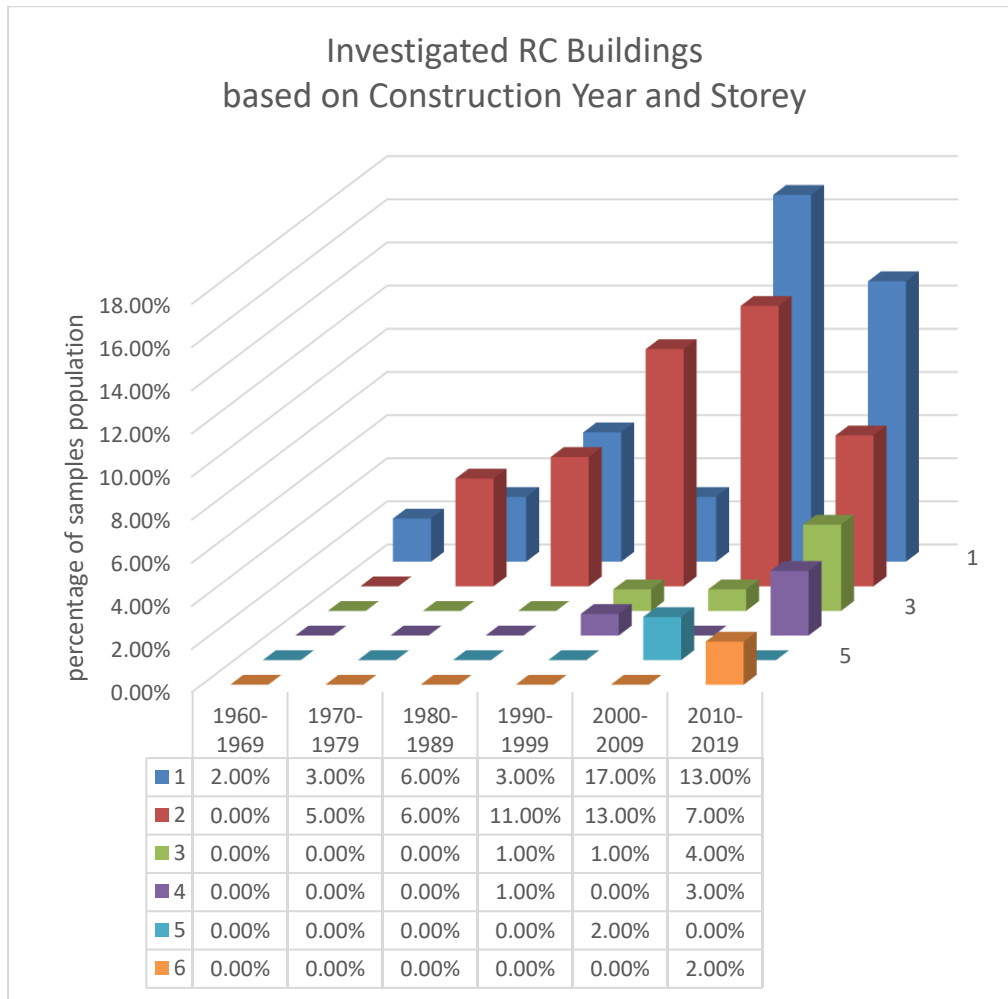


Figure 4. 6. Surveyed Existing RC Building by year built (construction year)

Based on Fig 4.7 for Column mostly the buildings of 1 storey used 6 to 12 mm diameter of rebar. Started from the second storey, the buildings used 10mm till 16 mm in diameter and a 3rd storey that has been surveyed use 12-16 mm of diameter. Some of the buildings, the diameters are unknown due to the limitation of the rebar locator and all of part of the column are covered by plasters.

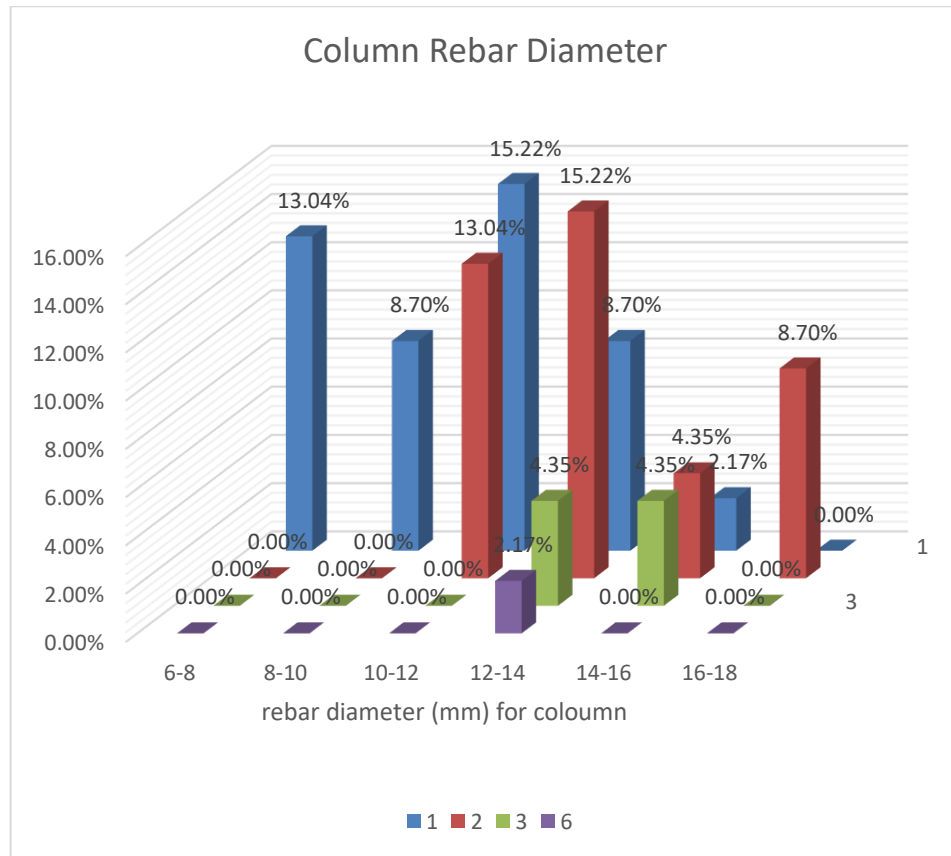


Figure 4. 7. Column Rebar Diameter

For Confinement above or near the opening, the number of surveyed building that has confinement is insufficient. Only three buildings have confinement, 97 others are not. Using rebar locator, we checked the existence of rebar from column to column between opening as an indicator of confinement beam for the opening.

4.3 RC Building with Masonry Wall Material Property Investigation

The sound evaluation criteria for RC Structures include the compressive strength of concrete in the structure. To understand the reinforced concrete material properties has been conducted 4 activities, as follows.'

- 1) Taking samples of concrete and brick from demolished buildings
- 2) Taking samples of steel and conducting a tensile stress test.
- 3) Collect data from the certified laboratory that conducted testing regards to material based on the request of the construction project

- 4) The experiment of the effect of local compaction method using local material. The information about the local compaction method was gathered from an interview of 100 builders which also conducted to understand the reinforced concrete building workmanship in the local area, in this case, Padang City as the study area in this research.

4.3.1 Concrete

To get understand the performance of existing buildings under evaluation, represent material properties is important. There are many methods that both destructive of non-destructive to extract the information about concrete strength from existing buildings. ASTM stated that the most reliable results to know the concrete strength is by coring the structural elements of inspected buildings. There is no non-destructive method can be conducted alone without taking a sample of the concrete core. The most common method used is using Schmidt hammer as one of the non-destructive methods (ASTM C311-04 C512-02, 2002; ASTM C823, 2016) .

However, based on expert opinion, the accuracy of this method is less than 50%, where the core drill itself is found to be difficult to be conducted at existing buildings especially in developing country, regards to the limitation of the tools and the level of understanding of the community.

Regards to this fact, sampling concrete from some demolished buildings is used to get concrete properties.

For the minimum requirement of concrete strength, Indonesia National Standard for reinforced concrete buildings required minimum compressive strength is 17 MPa

- a) The demolished building location and building condition explanation
As aforementioned, one of a method that used in this research to get the material properties of concrete of RC buildings in Padang City is by sampling concrete from building that just demolished.



We cut the concrete using a concrete cutter and try to get a

The compression standard procedure used the Indonesian

based on the actual input cross-section. So, here we assume that we can neglect the size effect of the sample.



Figure 4. 9. The process of Concrete Cube Sampling from Demolished Buildings

Instead of the data from demolished buildings, we also obtained data of concrete core drill samples from 25 existing RC buildings. A total number of core samples is 360 concrete core cylinders. Type of target buildings is moment resisting frame RC buildings. The core samples were taken from columns, beams, and slabs.

The results of the existing concrete core drill and concrete from the demolished building were plotted on the graph below (Fig.) Form Figure 4.8. the concrete compression strength from existing concrete from 38 buildings has a median value of 18,2 MPa with standard deviation 9,48 MPa. The Coefficient Variant (CV) of existing concrete is 0,51 which is greater than 0,35. These mean that the concrete

compression strength from the inspected building has considerable variation and many of the buildings have low strength concrete.

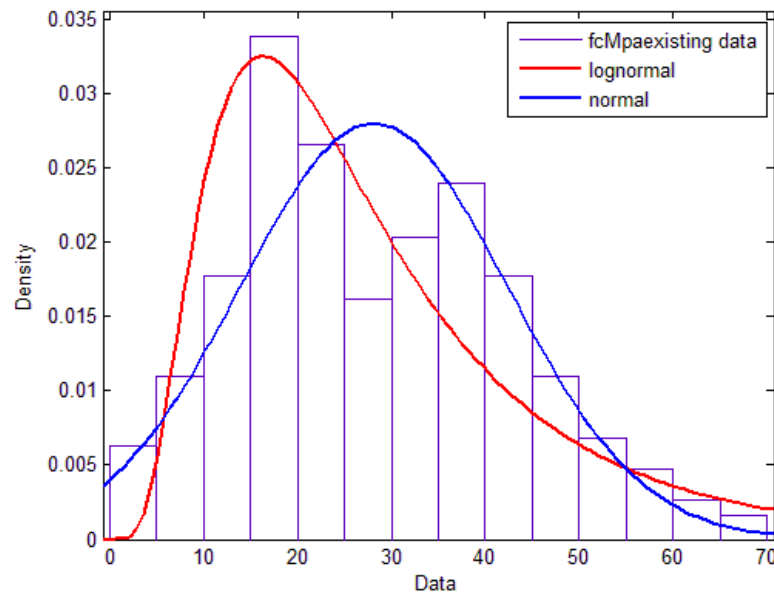


Figure 4. 10. Concrete Compressive Strength form existing RC buildings in Indonesia

- b) The concrete compression strength data from Public Work Department and Laboratory Testing.

Another data source is from concrete cylinder compression testing data which were obtained from a certified laboratory in Padang City. This concrete cylinder was the tested concrete by request from many construction projects in Padang City and surrounding areas.

From figure 4.11. The mean concrete strength is 17 MPa; the standard deviation is 8,11 MPa, and CV is 0,47 which is higher than 0,35.

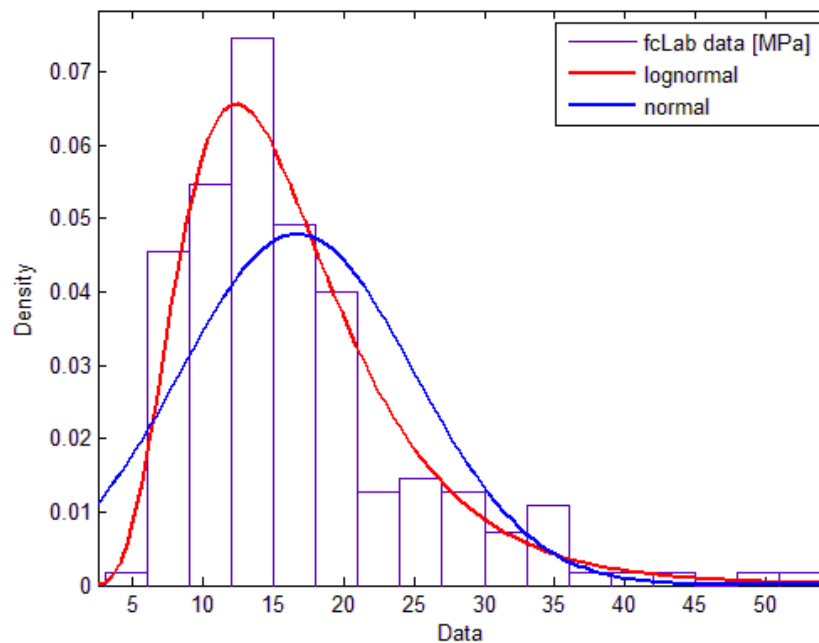


Figure 4. 11. Concrete Compressive Strength of Laboratory data

c) Compression Strength of Concrete from Housing Project

New concrete was taken from 10 housing projects in many areas in Padang City. New concrete was casting into cylinder mold (diameter 150mm, height 300mm) , compacted and keep on the protected place and container till hardened. After 24 hours, hardened concrete was transported to Laboratory for compression strength testing. In total there were 30 data of concrete cylinder. The compressing test used compression strength concrete testing machine ELLE. Figure 4.11 show the process of sampling new concrete from housing projects in Indonesia.

Compression strength value from the test were compiled and statistical analysis to get the distribution of the strength were conducted.

Figure 4.12. show the concrete compression strength test value from housing project. The mean value is around 7 MPa.



a. New Concrete in Housing Construction Project



b. Process of Compaction for Casted New Concrete



c. Hardened Concrete Cylinder



d. Concrete Cylinder after Compression Strength Test

Figure 4.11. The Process of Obtaining the Concrete Compression Strength of Housing Project in Indonesia.

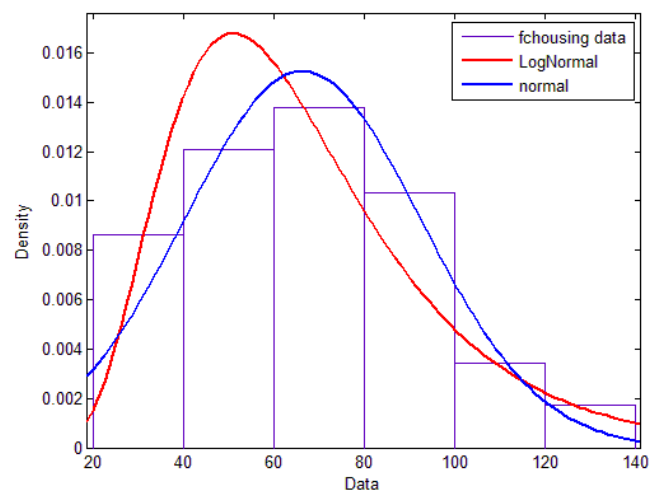


Figure 4. 12. Concrete Compressive Strength from Housing Project

4.3.2 Steel Reinforcement Properties

a. Tensile Test

To understand the steel reinforcement properties available in Padang City,

a series of tensile test was conducted. The steel was purchased from the material shop. The testing used tensile test procedure from Indonesia building code for steel testing (SNI. 07-2052-2002).

The sample that were used is the KSTI-SNI type with diameter 8mm, 10mm, 12mm, 16mm, and 19mm. The diameter was chosen based on the predominant steel diameter and type that is used in construction site based on the information from under construction building observation and the builder`s interview study. The length of each sample is 8d plus 20cm.



Figure 4. 13. Sample for Tensile Test



Figure 4. 14. Sample Measurement



Tensile Testing Machine



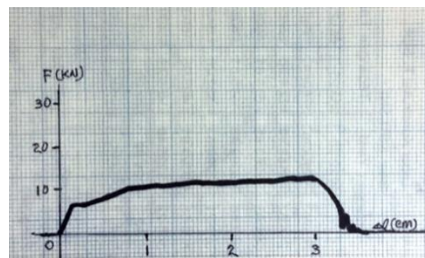
Sample Condition before Testing



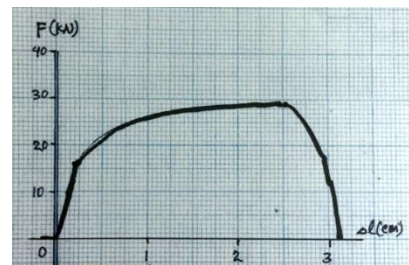
Sample Condition after testing

Figure 4.15. Tensile Strength Test in Universitas Negeri Padang Laboratory

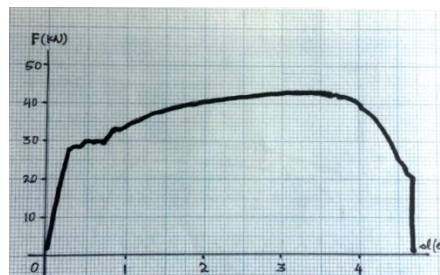
Figure 4.12 shows the obtained graph from the tensile test. The tensile testing machine that were used in this test is the manual type, where the deformation of the sample was measured by using the string that is connected from the tensile grip body to the rotated metal rod in the measurement part of the machine. As the steel elongated, the steel rod will be rotated, and a pen that is attached to the millimeter block paper will draw the steel length deformation vs. loading.



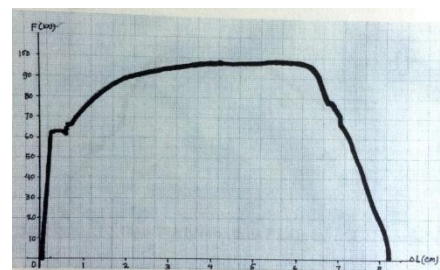
Steel diameter 8mm



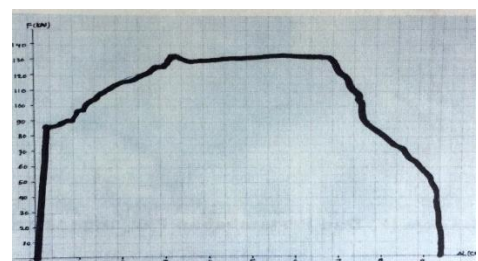
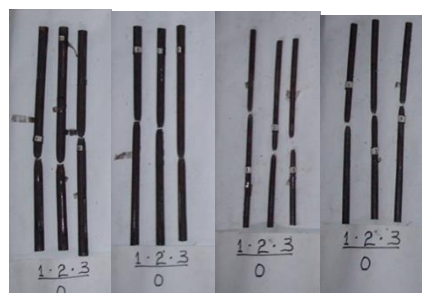
Steel diameter 10mm



Steel diameter 12mm



Steel diameter 16mm



Steel diameter 19mm

Figure 4. 16. Tensile Strength Test Results in Universitas Negeri Padang Laboratory

Table 4.2. show the recap of tensile strength data of market steel reinforcement in Padang City.

Table 4. 4. show the recap of tensile strength data of market steel reinforcement in Padang City

Diameter	Actual Diameter	Area	Actual Area	ϵ_y	ϵ_f	σ_y	σ_f	E	fu/fy
(mm)	(mm)	(mm²)	(mm)	-	-	N/mm²	N/mm²	kg/cm²	
8-0-1	7.70	46.54	75.00	0.02	0.40	139.66	268.57	89031.24	1.92
8-0-2	7.70	46.54	72.00	0.01	0.41	139.66	292.21	102563.99	2.09
8-0-3	7.70	46.54	73.00	0.01	0.41	146.10	279.31	108787.96	1.91
	7.70	46.54	73.33	0.01	0.41	141.81	280.03	100127.73	1.97
10-0-1	9.90	76.94	99.00	0.02	0.36	207.96	363.93	104999.03	1.75
10-0-2	9.90	76.94	99.00	0.02	0.33	214.46	367.83	108280.25	1.72
10-0-3	9.90	76.94	100.00	0.02	0.37	220.96	369.13	112688.36	1.67
	9.90	76.94	99.33	0.02	0.35	207.96	363.93	108655.88	1.71
12-0-1	11.80	109.30	116.00	0.02	0.35	247.02	388.83	116909.08	1.57
12-0-2	11.80	109.30	116.00	0.02	0.34	247.02	393.40	116909.08	1.59
12-0-3	11.80	109.30	116.00	0.02	0.32	256.17	388.83	116576.01	1.52
	11.80	109.30	116.00	0.02	0.34	247.02	388.83	116798.06	1.56
16-0-1	15.65	192.26	148.00	0.02	0.19	330.27	509.72	199433.11	1.54
16-0-2	15.65	192.26	148.00	0.02	0.41	332.08	509.72	201003.45	1.53
16-0-3	15.65	192.26	148.00	0.02	0.37	332.47	512.32	194722.09	1.59
	15.65	192.26	148.00	0.02	0.32	330.27	509.72	198386.22	1.55
19-0-1	18.70	274.51	178.00	0.02	0.38	316.93	480.86	191807.38	1.52
19-0-2	18.70	274.51	179.00	0.02	0.35	316.93	480.86	192884.94	1.52
19-0-3	18.70	274.51	180.00	0.02	0.42	320.58	477.95	183929.97	1.49
	18.70	274.51	178.00	0.02	0.38	316.93	480.86	189540.76	1.51

4.3.3 Red Brick Material Properties

The sample was taken from 10 locations. Five bricks were taken from each location, so entirely there are 50 bricks.



Figure 4. 17. A sample of Brick from Demolished Buildings

Each brick then will be measured for the size, absorption rate, and its compressive strength. Indonesia Industrial Standard, SII-0021-78.



Figure 4. 18. A sample of Brick from Demolished Buildings under Compression Load

The result of the compressive strength can be shown as follow

Table 4. 5. Brick compression strength data of market steel reinforcement in Padang City

	Sample Number	Area	Maximum Force	fc _b	fc _b ` (kg/cm ²)	fc _b ` (Mpa)	fc _b ` (kg/mm ²)
A	1	92.16	1340	14.53993	14.53993	1.323134	0.13492
	2	92.16	1470	15.95052	8.079788	0.735261	0.074975

	3	92.16	2960	32.11806	6.059841	0.551446	0.056231
B	1	81	1270	15.67901	15.95052	1.451497	0.148009
	2	81	1110	13.7037	13.7037	1.247037	0.12716
	3	81	940	11.60494	11.60494	1.056049	0.107685
C	1	86.49	2230	25.78333	25.78333	2.346283	0.23925
	2	86.49	500	5.781015	32.11806	2.922743	0.298032
	3	86.49	1800	20.81165	5.781015	0.526072	0.053644
D	1	79.21	480	6.059841	20.81165	1.893861	0.193117
	2	79.21	490	6.186088	20.45196	1.861129	0.189779
	3	79.21	640	8.079788	15.67901	1.42679	0.14549
E	1	79.21	1620	20.45196	12.37218	1.125868	0.114805
	2	79.21	980	12.37218	6.186088	0.562934	0.057402
	3	79.21	1300	16.41207	16.41207	1.493498	0.152292
F	1	96.04	500	5.206164	5.206164	0.473761	0.048309
	2	96.04	1340	13.95252	13.95252	1.269679	0.129469
	3	96.04	410	4.269055	4.269055	0.388484	0.039614
G	1	92.16	2440	26.47569	26.47569	2.409288	0.245675
	2	92.16	2480	26.90972	26.90972	2.448785	0.249703
	3	92.16	2390	25.93316	25.93316	2.359918	0.240641
H	1	96.04	1710	17.80508	17.80508	1.620262	0.165218
	2	96.04	1540	16.03499	16.03499	1.459184	0.148793
	3	96.04	1660	17.28446	17.28446	1.572886	0.160387
I	1	75.69	670	8.851896	8.851896	0.805523	0.082139
	2	75.69	390	5.152596	5.152596	0.468886	0.047812
	3	75.69	2080	27.48051	27.48051	2.500727	0.254999
J	1	90.25	1590	17.61773	17.61773	1.603213	0.16348
	2	90.25	1010	11.19114	11.19114	1.018393	0.103846
	3	90.25	700	7.756233	7.756233	0.705817	0.071972

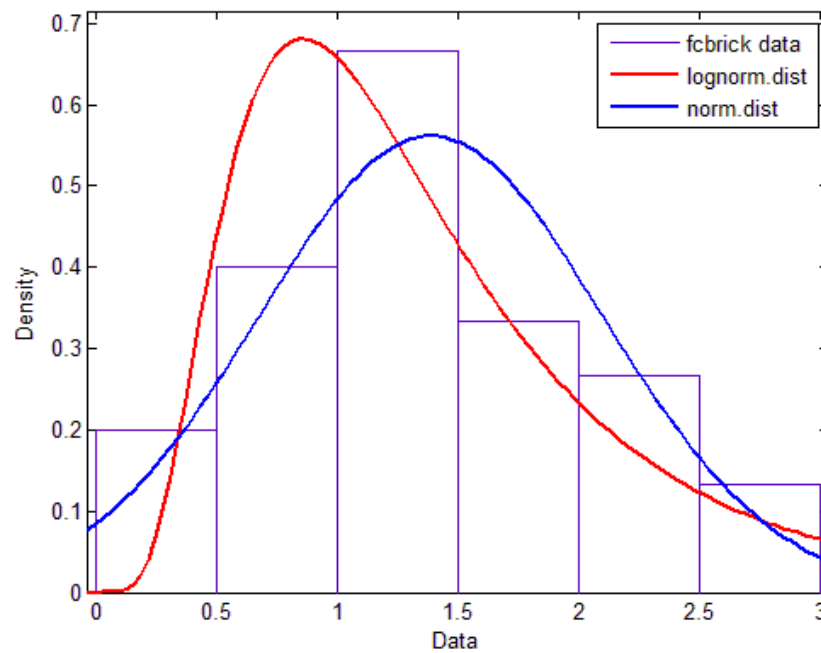


Figure 4. 19. Compression Strength of Brick from Demolished Building

Figure 4.19. shows the compression strength of brick from demolished buildings in Padang. The graph shows that the main compression strength of the brick available is 0.9 kg/mm^2 , which will be used for building the structural mode

4.4 Interview with the building officers

The building offices in this research are defined as the officer in government office from village to city level. The officer should have a responsibility to manage building permit system and the surveys on after earthquake event and reconstruction phase also indicated that building quality seems still not fulfill the minimum standard of construction quality. While as stated on Indonesian Building Law no 28/2002, every building must have a building permit before the construction phase, which means theoretically, construction defect must be minimized. However, the evidence seems to be different. Building officials as the person in charge of controlling building quality, from the design phase to the completion phase are expected to have good knowledge on building quality and

administration process. However, there is a need to assess the awareness of building's officials.

This study aims to understand the level of awareness and competency of building construction officers in Indonesia regards to building resistance to seismic load and implementation of building permit system as part of their duty. The study area is Padang-Pariaman district, West Sumatra province in Indonesia.

The method used in this study is interviewing building officer in 6 sub-districts in the target district. Interview conducted using question and answer sheet, as well as collecting related building permit document to support the results and improve the understanding of building construction process.

Minimum three parameters were measured on this study; 1) general data of the building official to understand their background which can be related with the answer 2) awareness and understanding level about earthquake disaster and technical knowledge about building resistance to earthquake 3) awareness about their main responsibility as building officer. The last one is to collect information about building construction in the area.

a) Respondent Profile

Figure 4.21 shows that building officials who were interviewed are 90% male and 10% female, with 80% of them are 31-50 years old which indicate that the officers are on their productive age (see Fig.4.20). The rest, 20% are above 50 years old. Highest education is bachelor degree for 70%, while 30% only reached Senior High School. However, officials that graduated with a bachelor degree generally did not expertise on civil engineering course (see Fig,4.22).

b) Awareness Level

Based on the interview, generally, the officers were trained to conduct administrative tasks but claimed that they could supervise structure and inspect construction based on Building Permits Documents. However, when we compare their information with their knowledge based on their study on building technical expertise, only 10% of building officers who trained on technical workshop for building's construction (see Fig.4). This finding needs to follow up by conducting training for building officers on the sub-district and village level as the central

player on building supervision.

As the basis of building regulation in Indonesia, it is necessary for the building officials to understand Building Law no 28/2002 about building and Technical Guidance, Government Regulation about Building (PP 36/2005) as the basis for building permit issues [5,6].

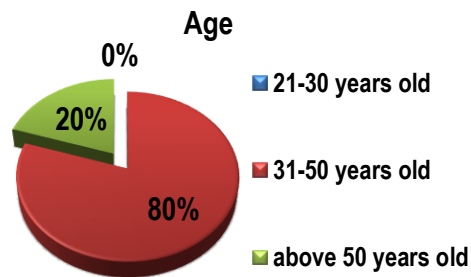


Figure 4. 20. Age of Officials

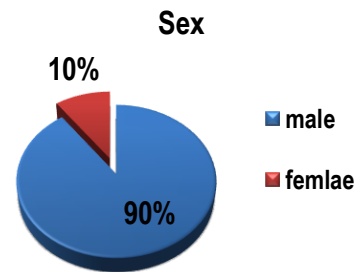


Figure 4. 21. Sex Profile of Officials

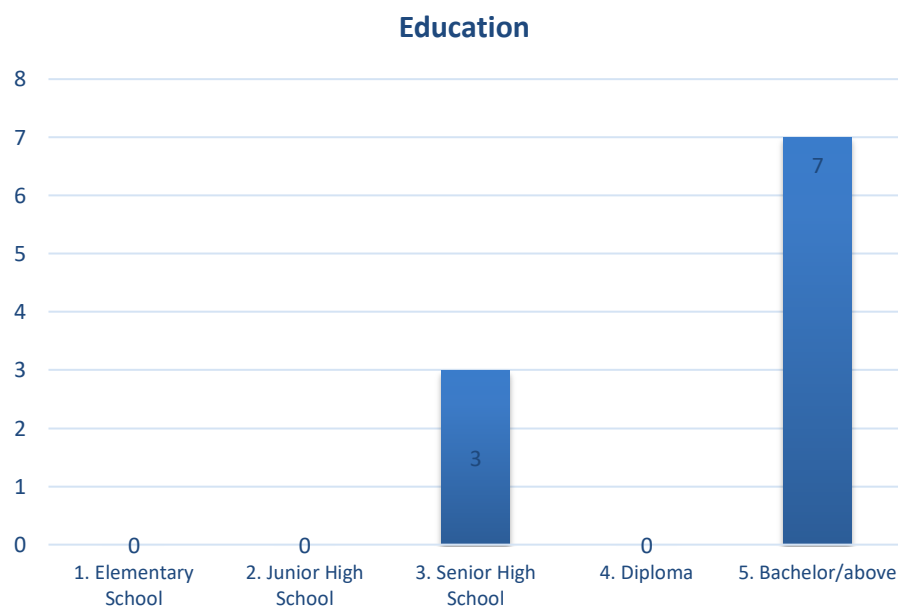


Figure 4. 22. Education of Officials

4.5.2 Supervision and Administration Skill

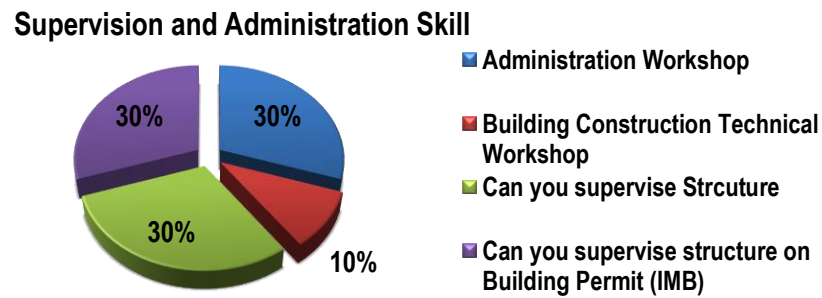


Figure 4. 23. Supervision and Administration Skill

Unfortunately, the results find that 80% of the officials never read the book of Law since they never get/have the book. The rest read once time only. The same fact also found for PP 36/2005. 60% of officials never read but 40% had read the book at least one time. The reason also same, that they do not have the book (see Fig.4.24 and 4.25)

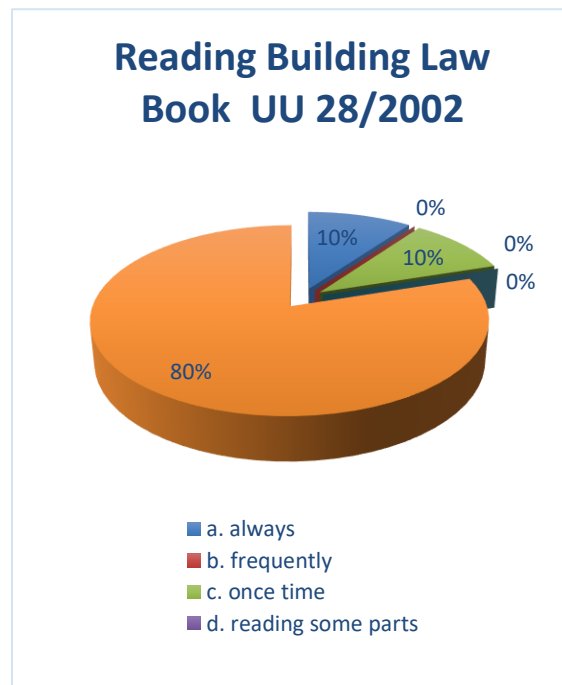


Figure 4. 24. Knowledge about Building Law

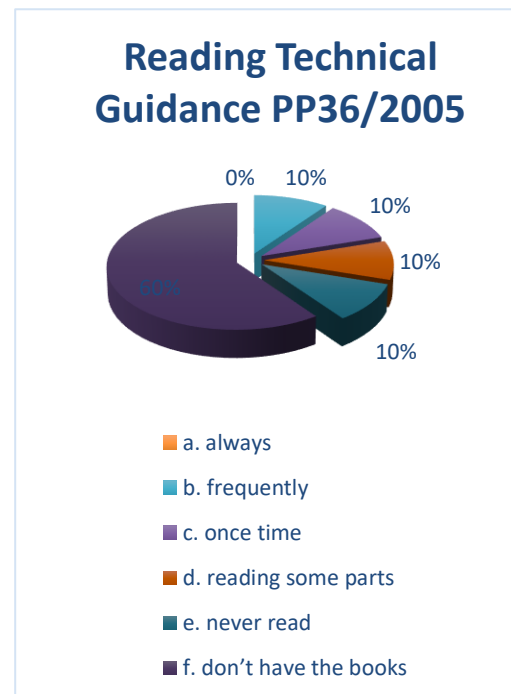


Figure 4. 25. Knowledge about Technical Guidance for Building Law

This study also seeks the information about the perception of building official about the implementation of local regulation of building permit system and its effectiveness. In Fig.4.26 almost 100% agree that the regulation is effective on building permit system implementation. While the officials think so, they admit that many people were less awareness on register their building construction and get building permits

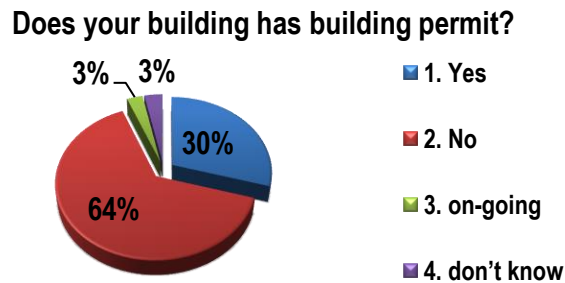


Figure 4. 26. Number of Registered Building Permits

Figure 4.26 shows that 64% of building in the study area do not have a building permit . While we confirm the possible reason, building officials think that it is due to lack of awareness of people for applying for the building permits (70%) and the retribution for building permits application is not affordable for people (20%). The rest of think that it is due to people do not know about building permit system, which means that intensive socialization for people is needed (see Fig.4.27)

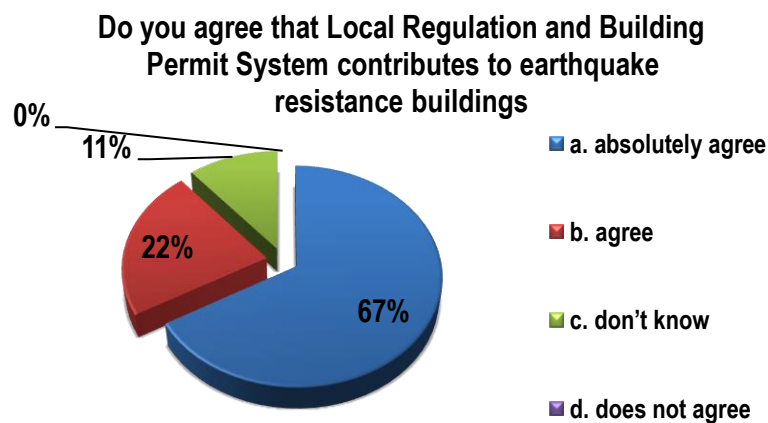


Figure 4. 27. Perception of Official about the effectiveness of Building Permit System

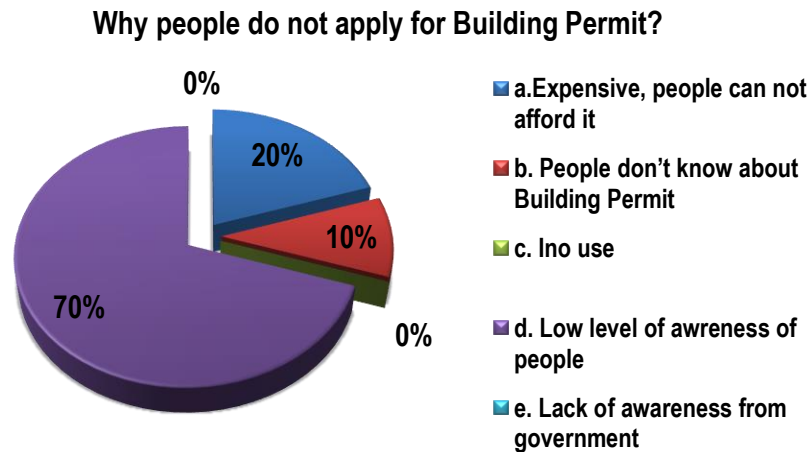


Figure 4. 28. Perception of Official about the reasons for less number of building permit's ownership

The interview also finds that the problem of land acquisition also triggers the unclear status of land ownership that put people and building owner about their situation on applying for building permit. The situation of interview activity can be seen in Figure 4.20.

Finally, this study provided information about the profile of building official of building permit division on the sub-district level of local administration in Indonesia, especially in West Sumatra region. It seems that government needs to evaluate the recruitment system that can improve the input of official's quality in term of their competency in carrying on their duty. The lack of understanding of Building Law also indicated that their knowledge about how to implement the regulation is low. The government on the higher level should give attention about the understanding of the law itself as the basis of building permit system implementation.



Figure 4. 29. Interview Situation at Officials Office

4.5 Tribe leaders Interview

The objective of the interview is

1. To understand the leadership based on the tribe system
2. To understand the structure of the indigenous community in Padang City
3. To understand the responsibility of the leader on managing the family in regards to their safety, the economic situation

As the information of government officers in Padang and the interview of tribe leaders, there are 20 tribes in Padang City. The tribes are distributed in every subdistrict in Padang City. The whole tribes are in Lubuk Begalung sub-district which then named by Lubuk Begalung Nan XX, means the subdistrict which has 20 tribes on it.

As the interview with Datuak Kapatihan, who is the leader of Melayu tribes and also the head of Tribe Organization in village level, the tribe leaders in Padang City has the organizations from village level to City Level.

The organization at village level is named by Kerapatan Adat Nagari (KAN) or Village Tribe Organization (in English). The higher level is Lembaga Kerapatan Adat Alam Minangkabau (LKAAM) or Minangkabau Tribe Unity Organization, which organized all of the KAN in Padang City.

The roles of the tribe leaders in socio-politic in Padang City is significant which is admitted in Local Regulation of Padang City. The concept is called “Tungku Tigo Sajarangan” which is “three stone for cooking.” The philosophy is the food bowl to cook cannot be installed when there

are no at least three stoves (stone). The stones are government, tribe leaders, and religious leader. The discussion principal is the soul of this concept. Whenever, significant problems that affect the safety, security and wealth of the community in the city occurs, the government, religious leader, and tribe leader will discuss and work together to find the solution.

In the other interview with Mr.M.Giatman from Koto Piliang Tribe, he answered the questions regards to the responsibility of the tribe leaders in their family.

The leader has responsibility for taking care of their family members. Hence the tribe leader should be the wisest person, usually the oldest one. They are acknowledged for their influence on the community due to their charisma and broad knowledge about tribe system and community.

However, when we asked about their knowledge regards to the building quality, they admit that in general, not so many tribal leaders have appropriate knowledge about how to construct good quality of buildings. Their knowledge is limited mostly to the material of building especially where to get the good material based on the information from the builder that could be a friend of their family.

In the other question, one of the interviewees answered in regards to the question “how the tribe leader manages the family who wants to construct a building in the tribe land

Datuak Koto explained: *usually the leader will ask all the men in the tribe to gather and have a discussion. They will discuss the status of the land portion that will be used and ask either one of the family members has doubt and object the request from the other member. Then if nobody object, then the building can be constructed.*

However, Mr. Giatman give additional information

In case there is one of the family members knows how to construct a good building, the leader will ask the advises and disseminate that to the family. However, he also admitted that the person who knows the building is very less.

In case of that situation, we asked about their willingness to study about the basic knowledge on how to construct a building in a proper manner, mostly they would like to study since they considered that this is part of their duty and responsibility to keep their own big families (tribe members) safe from the disaster due to the damage of RC buildings.

However, two interviews said that might be difficult because they considered themselves have a low education level and they are getting very old, so they are not sure that they can learn more. But when we confirm that situation to another leader, they said that it should not be a problem, since there will be another young member that can learn and then the task of the leader is to back up and support the roles of the young one to convince the family member the need to choose the correct method to construct the building.

Based on the interview, the structure of the Minangkabau system in Padang City can be explained in the Figure 4.21. The tribe leader leads the families that join in one tribe. All of the tribe leaders and the head of the co-leaders join the Village Level Tribe Organizations or Kerapatan Adat Nagari (KAN). Each village in Padang city has the office of KAN. Each KAN can consult with the City Level Tribe Organization or Lembaga Kerapatan Adat Alam Minangkabau (LKAAM).

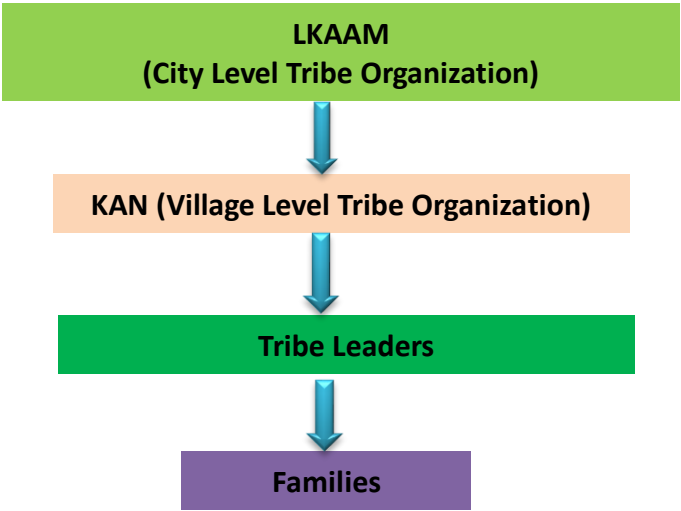


Figure 4. 30. The Structure of the indigenous community in Padang City.

CHAPTER 5

DEVELOPMENT OF ANALYTICAL FRAGILITY FUNCTION FOR RC BUILDING IN PADANG CITY, INDONESIA

5.1 Introduction

This chapter discusses the development of analytical fragility function for typical RC buildings in Padang City, Indonesia.

Figure 5.1. show the flowchart on developing the fragility function. The fundamental concept of each step will be discussed on the sub-chapter below.

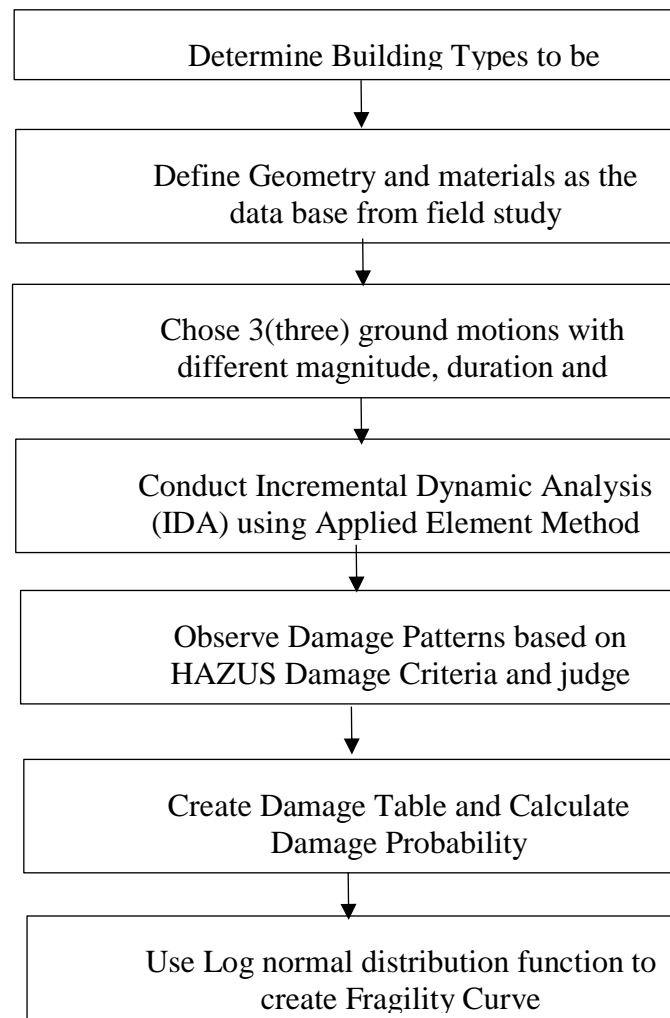


Figure 5. 1. Flowchart of development of Fragility Function for Typical RC Buildings in Padang City, Indonesia

5.2 Utilization of Incremental Dynamic Analysis

Incremental Dynamic Analysis (IDA) is a method to perform a series of nonlinear dynamic analysis of a structural model for multiple records by scaling each record to several levels of intensity that are selected to uncover the full range of model behavior ; from elastic to yielding and nonlinear elastic, finally leading to global dynamic stability (Dimitros Vamvatsikos,2005) (Vamvatsikos & Allin Cornell, 2002)(Vamvatsikos & Cornell, 2005)

Each analysis can be characterized by at least two parameters, an Intensity Measure (IM) and a Damage Parameter (DM)(Vamvatsikos & Allin Cornell, 2002). In this study, the IM is presented by Peak Ground Acceleration, and DM use damage patterns and damage level.

This research uses HAZUS damage criteria to judge damage level for each level of damage intensity. Elnashai 2003 develop a damage table which explains the damage patterns for each damage level for RC building infill wall based on the observation of thousands of damage patterns from actual earthquake damage.

5.3 Applied Element Method Utilization in ELS Software

Applied Element Method (AEM) is a developed method of structural analysis which can follow the structural behavior of a structural model from elastic range, crack initiation and propagation, separation of structural elements till total collapse in reasonable CPU time with reliable accuracy (Tagel-Din & Meguro, 2000)(Meguro & Tagel-Din, 2002).

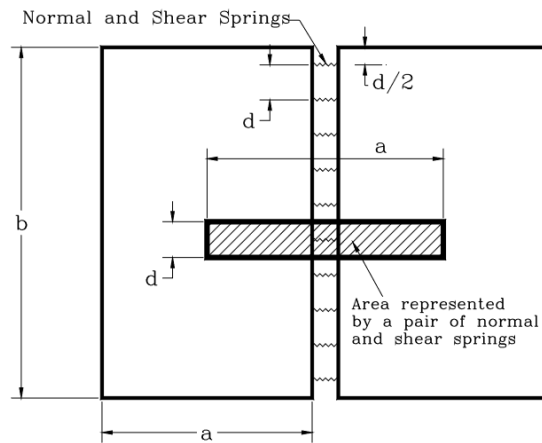


Figure 5. 2. Spring distribution and area of influence of each pair of springs in AEM

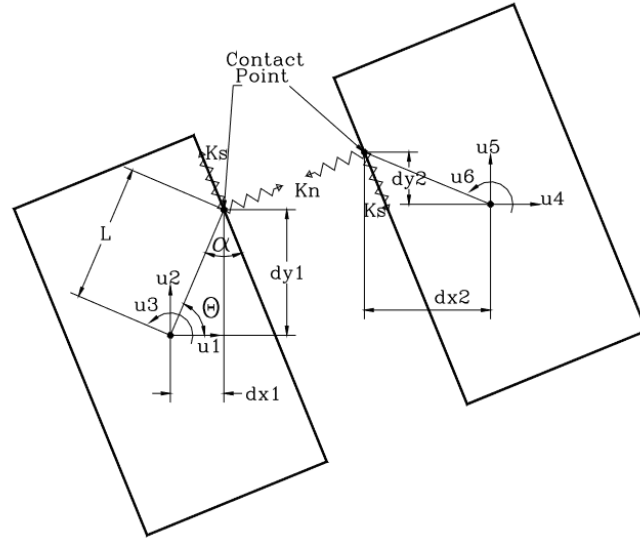


Figure 5. 3. Element Shape, contact point and degrees of freedom

The two elements are shown in Fig.5.2. are assumed to be connected by pairs of normal and shear springs located at contact points which are distributed around the element edges. Each pair of springs represents stresses and deformations of a specific area of the studied elements.

$$K_n = \frac{E * d * T}{a} \quad \text{and} \quad K_s = \frac{G * d * T}{a} \quad \dots\dots 1)$$

$$[K_G][\Delta] = [F] \quad \dots\dots 2)$$

$$F_q = \sum_{i=1}^N K_{qi} * \Delta_i \quad \dots\dots 3)$$

Spring of each element is defined in Eq.1 where d is the distance between springs, T is the thickness of the element, and "a" representative area's length, E, and G are the Young's and shear modulus of the material, respectively. The previous equation indicates that each spring represents the stiffness of an area (d*T) with length "a" of the studied material. In the case of reinforcement, this area is replaced by that of the reinforcement bar.

The global stiffness matrix KG for load and displacement control is mentioned in eq.2, and the applied load can be calculated by using the equation 3. For further

explanation are provided in Tagel and Meguro (Meguro & Tagel-Din, 2002; Tagel-Din & Meguro, 2000).

Reinforced concrete building with infill masonry wall has a very complex energy dissipation mechanism. Starting from the beam column joint mechanism where the energy dissipation occurs and the failure mechanism of masonry wall which its energy dissipation maintains through the crack formation and posterior frictional sliding of those cracked elements. Hence, a modeling technique able to simulate these phenomena is required to perform numerical analysis of masonry buildings accurately. For this reason, the Applied Element Method (AEM) is selected.

In this study, Extreme Loading for Structures (ELS) software is the tool selected to perform the AEM analysis of the RC building with a masonry wall, to get the damage patterns for each intensity measures applied to the structures.

5.4 The Selected Building Model Explanation

Based on the building typology, this research chooses five types of RC buildings in Padang City which represent the most populated types covering 64% of the total RC building population.

Figure 5.4- 5.8. shows the list of building a portfolio that was analyzed in this study.

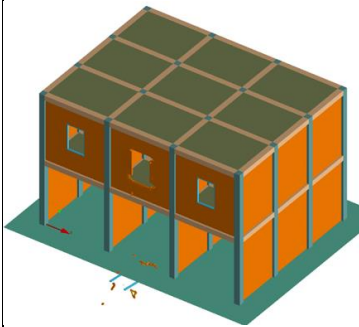
Type E	Cross Section	Column	Beam	Slab
	Dimension (mm)	330x330	330x300	140
	Longitudinal Steel	4P12 ;2 P12	3P12 ;2P12	P10-100
	Stirrups	P8-100	P8-100	
	Actual diameters (mm)	11.83	11.52	10.48
	fy[kg/mm ²]	33.62	33.62	47.55
	fu/fy	1.24	1.24	0.68

Figure 5. 4. RC Building Type E

Type E is a two storey shophouse RC building with infill masonry wall made from the local red brick material. It is symmetric on horizontal direction, but

the 1st storey has a wide opening in the front. It is a very common RC building type in Padang City where the shop is one of the main occupations of its residents. The 1st storey is used for shop and business, and the 2nd store is used for living/housing. The percentage of this

The column size is 330x330 cm, and the beam is 330x300 cm as the results from measurement of field study. Cross section of each structural element was assigned based on the rebar scanning and direct diameter measurement in the existing building.

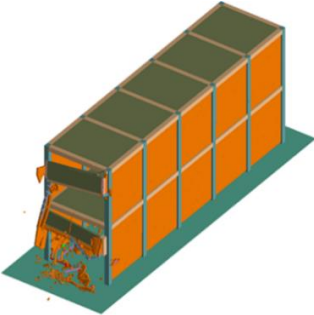
Type C	Cross Section	Column	Beam	Slab
	Dimension (mm)	300x300	300x300	t=125
	Longitudinal Steel	4P12	6P12	P10-200
	Stirrups	P10-100	P10-160	
	Actual diameters (mm)	9.17 9.75	11.52 9.75	9.95
	fy[kg/mm ²]	33.62	47.55	47.55
	fu/fy	1.24	0.68	0.68

Figure 5. 5. RC Building Type C

Steel reinforcement strength was defined based on the tensile strength test from the laboratory (see chapter 4). The material modeling based on the

This type C building cover 4% of RC building types in Padang City (based on the statistic data in Chapter 4)

For concrete material, each model was divided into three concrete strength, which is a median strength (m), lower (m-sd) and stronger (m+sd), where m is median value and sd is a standard deviation chapter 4. Considering the strength of the concrete parameter, for each type of building, a numerical model which were developed are three buildings.

Type C is two storey shop-office RC building infill wall, also very common in Padang City with a wide opening in the 1st storey and usually have heavy overhang in the front of 2nd storey for the balcony. This building model is 6m wide and 20 m in length. The inter-story height is 4.2m. The column size is 300x300mm

and the beam is 300x300mm. The concrete strength defined in the same method as the previous model.

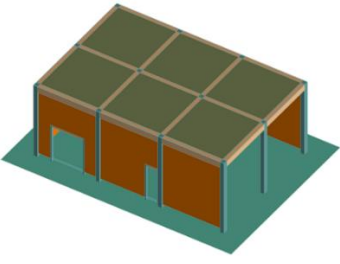
Type D	Cross Section	Column	Beam	Slab
	Dimension (mm)	260x260	260x330	t=120
	Longitudinal Steel	6P12	6P12	P10-200
	Stirrups	P8-110	P10-120	
	Actual diameters (mm)	11.83 7.6	11.83 7.6	9.1
	fy[kg/mm ²]	22.06	24.89	47.55
	fu/fy	1.76	1.4	0.68

Figure 5. 6. RC Building Type D

Type C is one storey housing RC building infill wall, the column size is 260x260mm, and the beam is 260x330mm

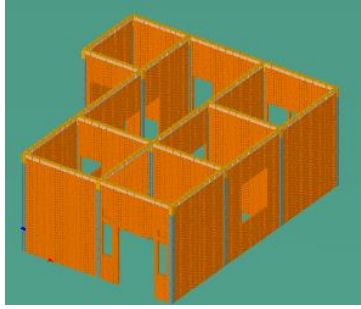
Type A	Cross Section	Column	Beam	Slab
	Dimension (mm)	150x150	150x180	-
	Longitudinal Steel	4P10	4P8	-
	Stirrups	P8-160	P8-160	-
	Actual diameters (mm)	9.67 7	7.42 7	-
	fy[kg/mm ²]	24.89	22.06	-
	fu/fy	1.4	1.76	-

Figure 5. 7. RC Building Type D

Type A is one storey single housing RC building infill wall which is the most common type of single RC building for housing in Padang City. The column size is 150x150mm and the beam is 150x180mm. The concrete strength defined in the same method as the previous model. This type of housing also represented the building which is constructed during 1985-2000. The characteristic is the wide window and door and high wall for natural circulation.

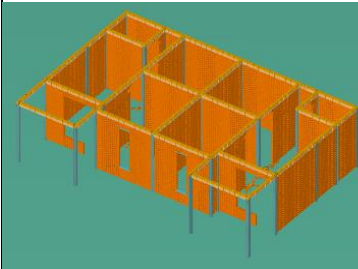
Type B	Cross Section	Column	Beam	Slab
	Dimension (mm)	140x140	140x170	-
	Longitudinal Steel	4P10	4P8	-
	Stirrups	P6-200	P6-200	-
	Actual diameters (mm)	9.17		-
	fy[kg/mm2]	21.47	24.9	-
	fu/fy	1.39	1.4	-

Figure 5. 8. RC Building Type B

Type B is one storey couple housing RC building infill wall. The column size is 140x140mm, and the beam is 140x170mm. The construction year of this building is during 2000- 2010. The characteristic is the size of its window is smaller due to the popularity of air conditioner circulation compare to an earlier year.

The buildings are analyzed for each different level of peak ground acceleration (PGA) by scaling down and scaling up the ground motion data from Fig. in Fig. The ground motion is scaled to 0.05g and increase step by step to 0.1g, 0.2g, 0.3g, 0.4g, 0.5g, 0.6g, 0.7g, 0.8g, 0.9g, 1g, 1.1g. Those ground motions were applied to the numerical models till the buildings are collapsed.

5.5 The Input Material

The input material for RC buildings numerical model were based on the compression strength of concrete material and brick material from demolished and existing RC buildings with masonry wall.

Figure 5.9 below present the point of concrete compression value used in numerical model. This study uses the log normal data distribution of concrete material from demolished and existing RC buildings data.

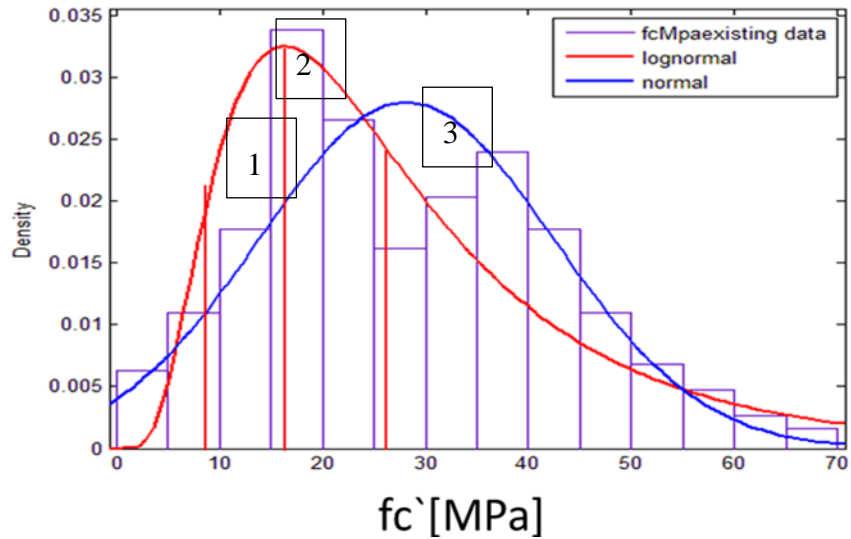


Figure 5. 9. Input Concrete Material

Table 5. 1. Input of Concrete Material

Concrete Input Material	Point 1	Point 2	Point 3	Formula based on Indonesia Building Code* and ACI 318M
f_c' [MPa]	8	17.2	27	Figure 5.9.
f_t [MPa]	1.98	2.9	3.64	$0.7\sqrt{f_c'}$
E [MPa]	13293.6	19492.3	24421.9	$4700\sqrt{f_c'}$
G [MPa]	5539.	8121.8	10175.8	$G = \frac{E}{2(1+\nu)}$
f_v [MPa]	1	2.236	3.5	$0.13\sqrt{f_c'}$

*SNI 03-2847-201

Input material were steel properties material based on the tensile strength test results that presented in Table 4.15 in chapter 4. While for brick material, the mean value on log normal distribution of red brick strength data of demolished building is used for all of the case.

Mortar for brick and pilaster of the wall uses the mortar strength data from

experimental of Public Work Department.

Table 5. 2. Input of Brick and Mortar Material

Masonry Wall Input Material	Mortar	Brick
f_c [kg/mm ²]	2.017	0.8
f_t [kg/mm ²]	0.0217	0.08
E [kg/mm ²]	79.74	13.14
G [kg/mm ²]	33.225	7.57
f_v [kg/mm ²]	0.504	0.019

5.6 The Input Ground Motion

Peak Ground Acceleration (PGA) is a good index to hazard for short buildings, up to about seven stories. To be a good index means that if you plot some measure of demand placed on a building, like inter-story displacement or base shear, against PGA, for a number of different buildings for a number of different earthquakes, you will get a strong correlation.

PGA is a natural, simple design parameter since it can be related to a force and for simple design one can design a building to resist a certain horizontal force. Peak ground velocity is a good index to hazard to taller buildings. However, it is not clear how to relate velocity to force to design a taller building.

SA would also be a good index to hazard to buildings, but ought to be more closely related to the building behavior than peak ground motion parameters. The design might also be easier, but the relation to design force is likely to be more complicated than with PGA because the value of the period comes into the picture.

In this research, three ground motion was applied to 5 types of numerical model of RC buildings with masonry wall in Padang City, Indonesia. Those three-ground motions are El-Centro, Kobe and Loma Puerta.

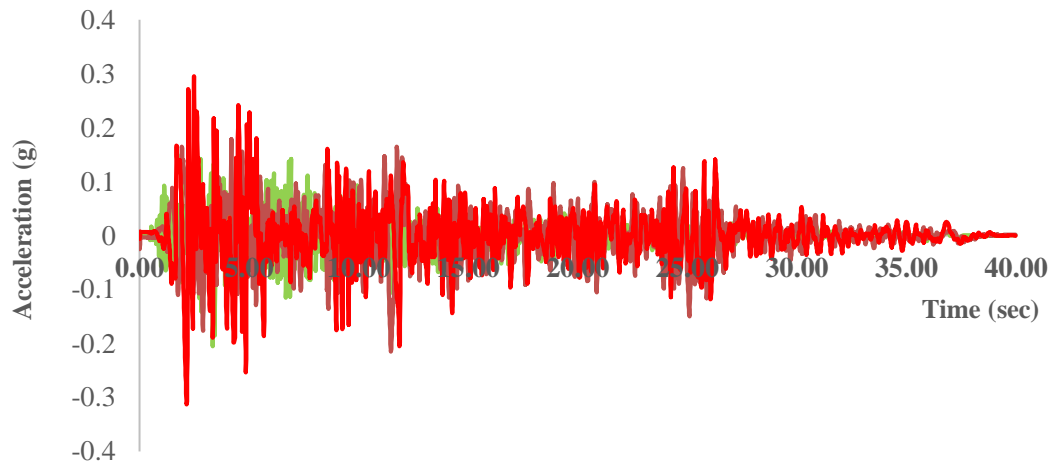


Figure 5. 10. Time history of the El Centro earthquake

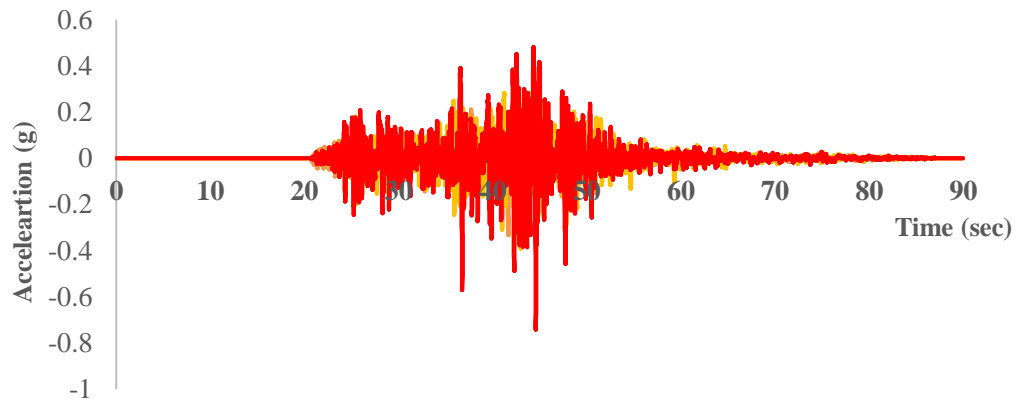


Figure 5. 11. Time history of Chi Chi earthquake

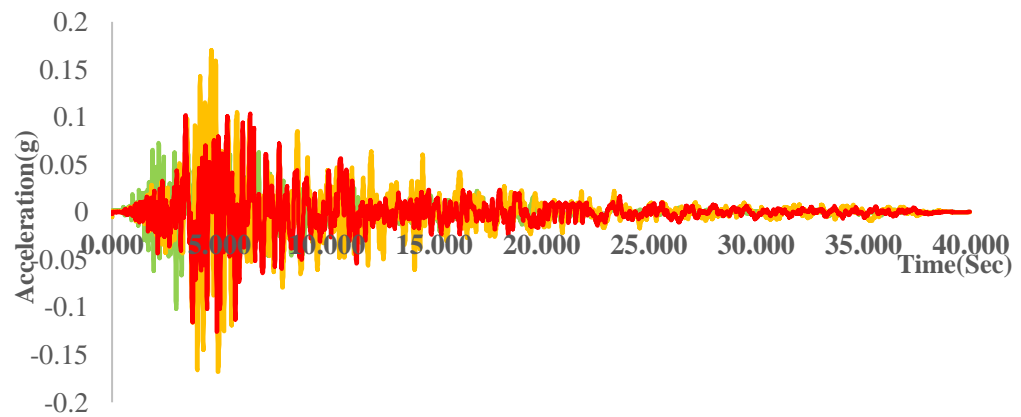


Figure 5. 12. Time history of Loma Prieta earthquake

Table 5. 3. Ground Motion Information

Ground motion	Duration (s)	Time Step		Main Period (s)	Frequency (Hz)
		Step (s)	Total data		
<i>Kobe</i>	40.96	0.01	4096	0.47	2.13
<i>El Centro</i>	50.0	0.01	4000	0.25	4
<i>Loma Prieta</i>	39.955	0.005	7991	0.15	6.67

The decision for selecting this suite of earthquake ground motions is based on their different main frequency component. The period of the structure to be analyzed is around 0.3s and 0.18s and the selected input motions' main period vary from 0.15s to 0.47s. As previously mentioned, the peak ground acceleration of each earthquake will be varied from 0.05g to 1.2g; With the total number of building types are five types and three different input of concrete material strength, followed by three input ground motion, there were 113 analyses will be conducted for each type.

5.7 Structural Modelling

The analytical models were created in such a way that the different structural components represent the buildings characteristic of mass, strength, stiffness, and deformability. The non-structural component was not model, the however total weight of the roof and roof frame were assigned as lumped mass (additional mass) to the top part of the structural model, in this case, is at the top of each ring beam and column. The variety of the primary structural component that was modeled are as follows,

1) Beams and Columns

Beams and columns were modeled as 3D solid elements. The parameters like the strength of concrete, detail of the main reinforcement and stirrups were assigned on each structural element.

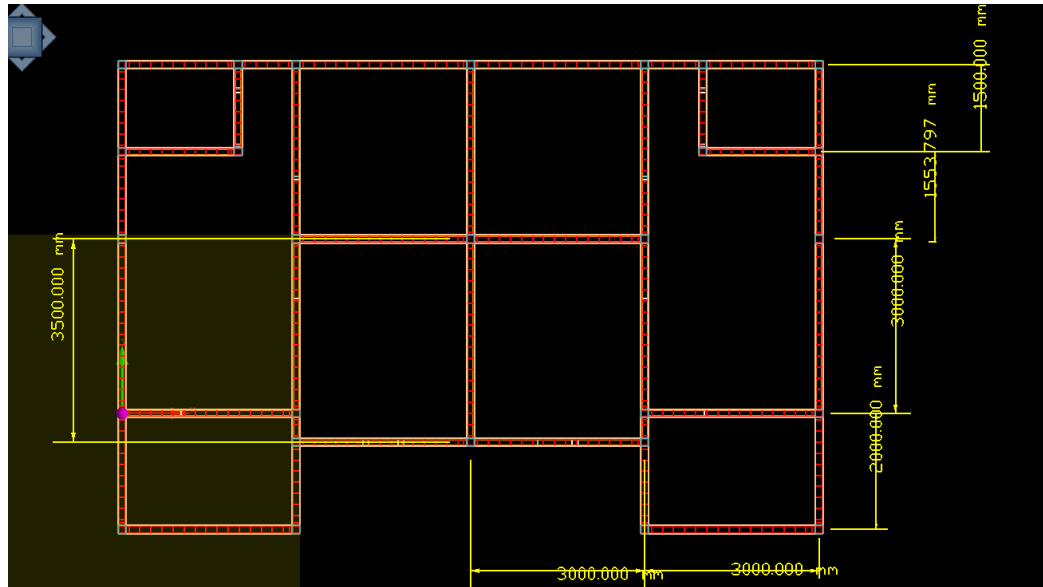


Figure 5. 13. Lay Out of One of RC Buildings Numerical Model

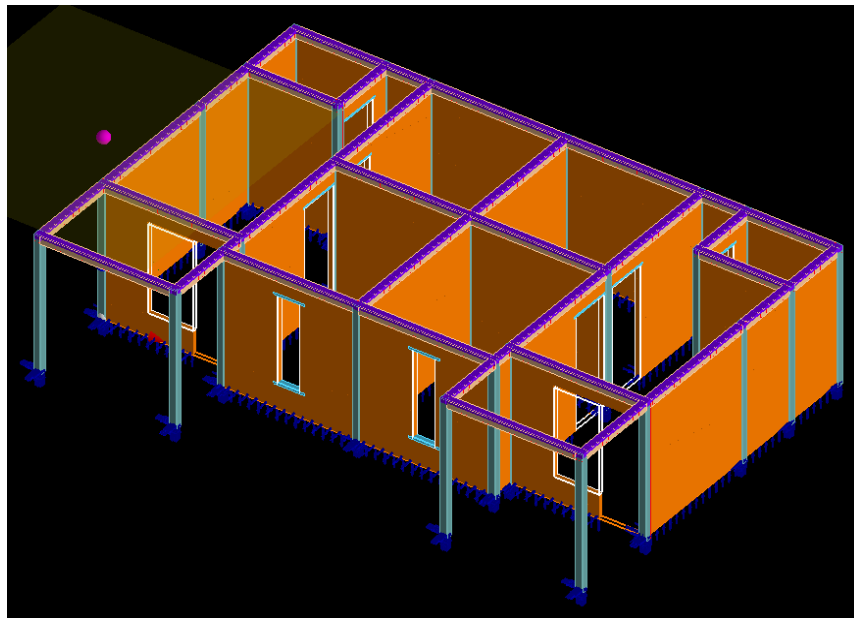


Figure 5. 14. 3D Model RC Buildings

2) Beam and Columns joint

The beam and column joint were modeled by assuming that reinforcement details including anchorage and reinforcement lap length follow Indonesia Building Standard.

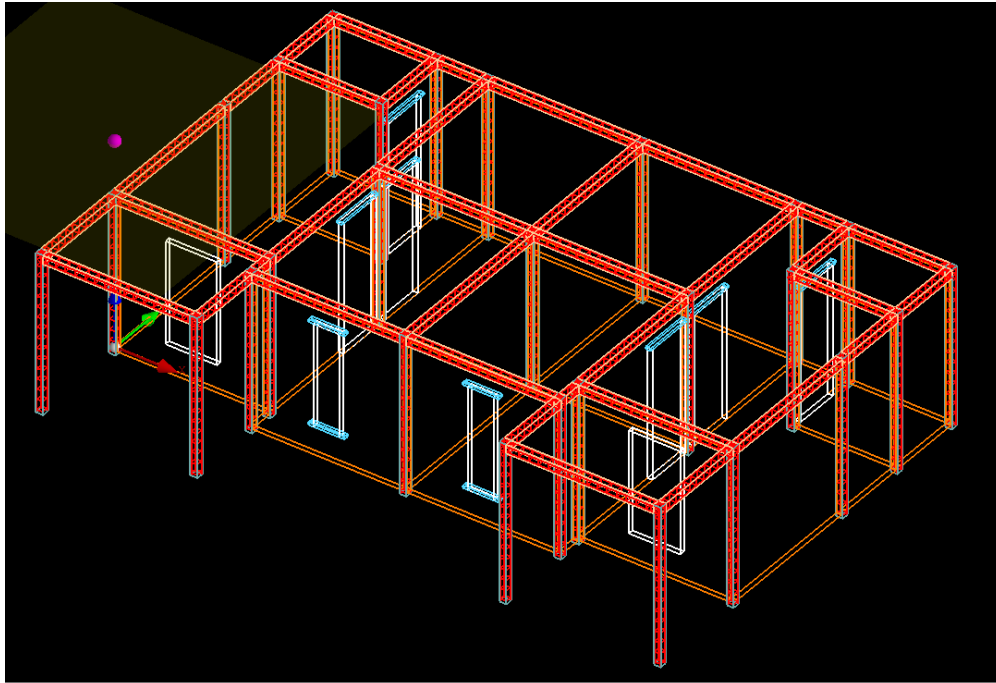


Figure 5. 15. Reinforcement of RC Buildings Numerical Model

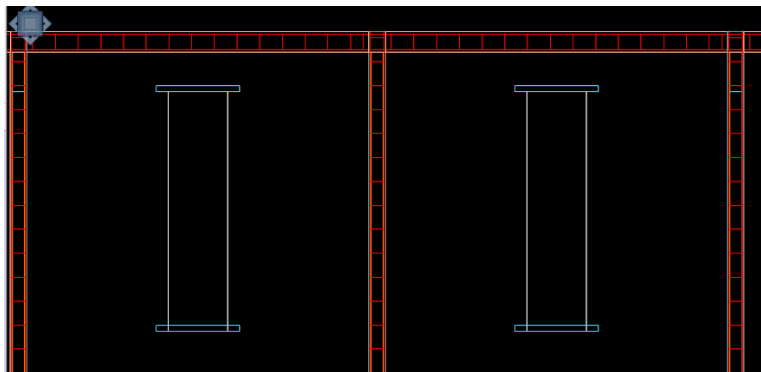


Figure 5. 16. Stirrups, Longitudinal and Joint Area Reinforcement of RC Buildings Numerical Model

3) Foundation modeling

The foundation was modeled based on the degree of fixity which is provided. The effect of soil structure interaction was ignored in the analysis. The structure support was assumed to be fixed at the column end and along the wall end in the bottom.

4) Wall and opening

The wall was modeled using 3D wall element which is provided in AEM. The size of each brick was assigned precisely and also its material properties. The mortar properties also assigned together in the 3D wall model. The infill wall was modeled by separating the wall from the column elements. Using this way, the deformability and out of plane failure can be modeled accurately. For the opening, the frame of the window which mainly made from timber also has been modeled by using eight nodes element. In this case, the damage in the slight damage level due to the opening can be modeled accurately.

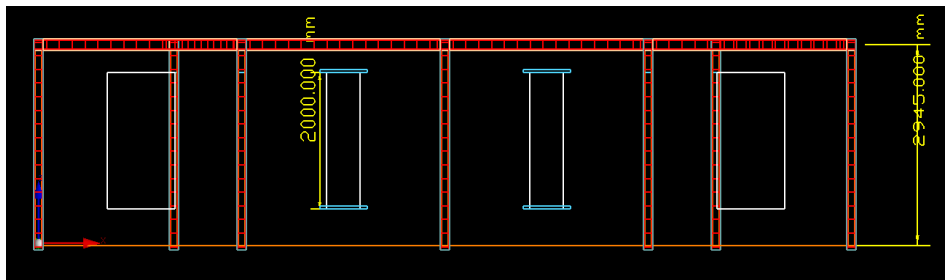


Figure 5. 17. Eight Node Elements for Opening Frame Modeling

- 5) Material property for concrete was used the actual concrete compression strength from existing building. Three values of compression strength based on the strength distribution of existing concrete were decided to be applied to the numerical model (see Chapter 4). By using the equation for concrete strength parameter based on Indonesia National Standard and American Concrete Institute, the value of modulus young, shear modulus, tensile and shear strength was obtained (ACI, 2008; SNI 2847, 2013).

5.8. Damage Patterns and Damage Level Criteria for RC Building with Masonry Wall

HAZUS 1999 which is adopted by Rosetto and Elnashai to derive fragility function for empirical damage building data that compiled from many earthquake events around the world is used in this study to observe damage pattern resulted from numerical analysis of RC buildings. Table 5.2. is criteria of damage level and damage patterns for RC with masonry wall resumed from Rosetto and Elnashai work in 2003 (Rosetto & Elnashai, 2003)

Table 5. 4. Damage Patterns and Damage Level based on HAZUS 1999 Criteria

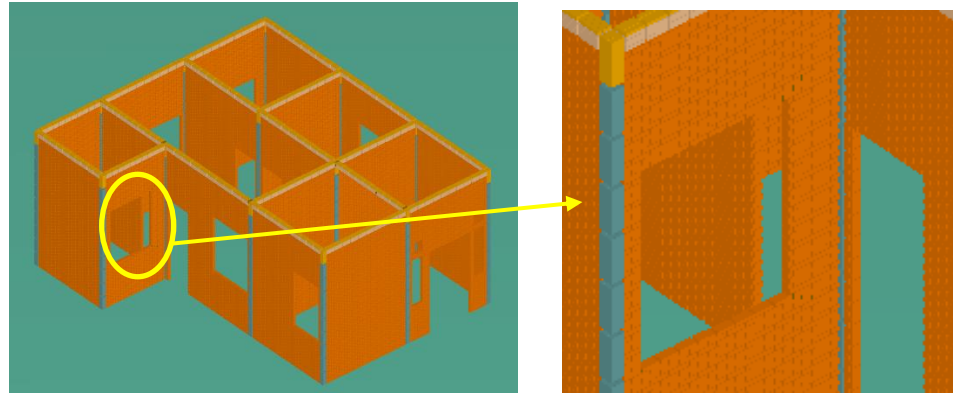
RC Building with Masonry Wall (Infill MRF)	HAZUS 1999
No damage	No damage
Fine Cracks in plaster partition	Slight
Cracking at the wall-frame interface	
Cracking initiates from corners of openings	
Diagonal cracking of walls. The limited crushing of bricks at b/c connection	
Increased brick crushing at b/c connection	Moderate
Start of structural damage	
Some diagonal shear cracking in members especially for exterior frames	
Extensive cracking of infills, falling brick, out of plane bulging	Extensive damage
Partial failure of many infills, heavier damage in frame members, some fail in shear	
Beams and or columns fail in shear causing partial collapse. Near total infill failure	
Complete or impending building collapse	Collapse

5.9. The Fragility Function of Typical RC Buildings in Padang City

5.9.1. Damage Patterns of building

The damage patterns of the buildings were observed through the observation of the crack propagation, deformed shape and extent damage to different structural damage level were explained in Table 5.4.

In this part, some examples of damage patterns of the numerical model will explain.



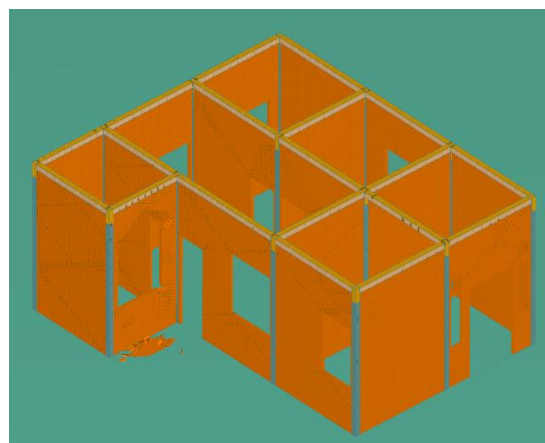
Elcentro GM at PGA: 0.05g

- Cracks at the corner of the opening. At the corner of the opening, some diagonal cracks (green line) can be observed.

Slight Damage

Figure 5. 18. Damage Patterns and Damage Level at 0.05g of Elcentro ground motion for RC building Type A with average (20) concrete strength

Figure 5.18 shows the damage patterns at 0.05g where the crack start to appear at the corner of the opening. To identify the damage patterns and damage classification, these patterns show that the building suffered slight damage level.



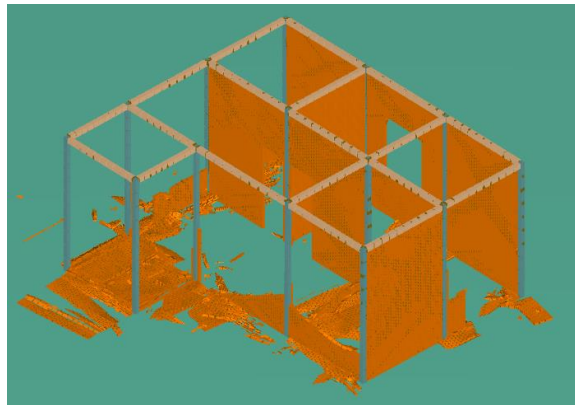
Elcentro GM at PGA: 0.2g

- Some brick is fall from the top of opening.
- Diagonal cracks start from the corner
- Many cracks distributed to almost of the wall

Moderate Damage

Figure 5. 19. Damage Patterns and Damage Level at 0.2g of Elcentro ground motion for RC building Type A

Figure 5.19. shows the damage patterns of RC building type A at 0.2g. At this level, the diagonal cracks are extended throughout the wall, from the corner top to the corner bottom of the wall. Some part of the masonry wall also falls from the top of the opening (window). Some cracks start occurred at structural elements (beam) or the joint area. This observation and comparison with the table, show that this building at 0.2g PGA is in moderate damage level.



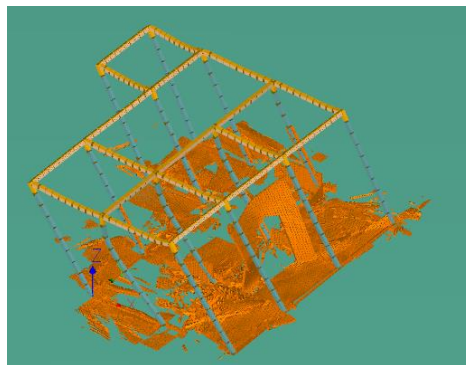
Elcentro GM at PGA:
0.4g

- Partial failure of many infills, heavier damage in frame members

Extensive Damage

Figure 5. 20. Damage Patterns and Damage Level at 0.4g of Elcentro ground motion for RC building Type A

Figure 5.20. shows the damage patterns of RC building type A at 0.4g. At this level, many of infill wall suffered out of plane damage. Although many of the walls are fall, the structural elements are still attached. However, the cracks in structural elements are extending. This observation and comparison with the table, show that this building at 0.2g PGA is in extensive damage level.



Elcentro GM at PGA: 0.6g

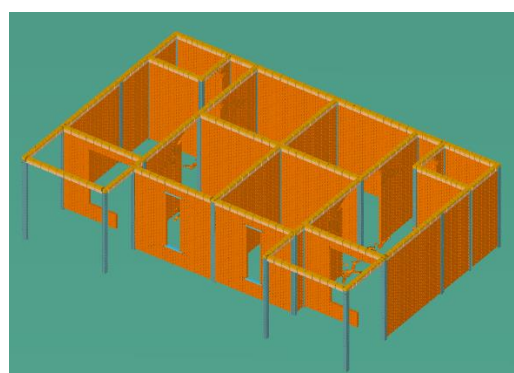
- All of the infill wall are collapse
- Structural members are impending to collapse

Collapse

Figure 5. 21. Damage Patterns and Damage Level at 0.6g of Elcentro ground motion for RC building Type A

Figure 5.21. shows the damage patterns of RC building type A at 0.6g. At this level, all of the infill walls suffered out of plane damage. Structural elements are impending to collapse. This observation and comparison with the table, show that this building at 0.6g PGA is in collapse level.

5.9.2. observation of Damage patterns for RC building



Elcentro GM at PGA: 0.05g

Cracks at the corner of the window

Very small part of brick is fall from the corner of the door

Slight Damage

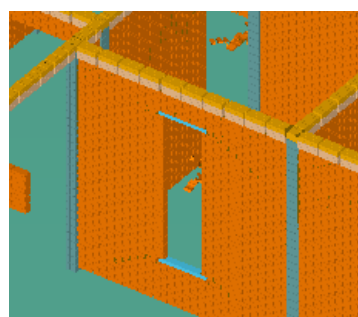
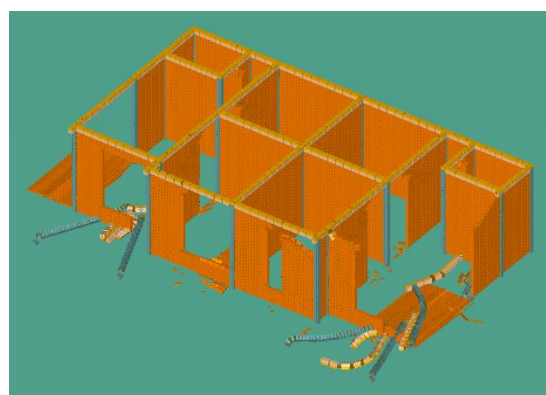


Figure 5. 22. Damage Patterns and Damage Level at 0.1g of Elcentro ground motion for RC building Type B with strong (28) concrete strength

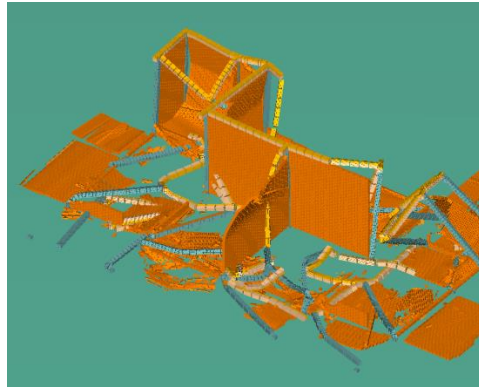


Elcentro GM at PGA: 0.3g

- Some infill walls suffer out of plane failure
- Some structural elements are fail, but still less than 10% and still repairable

Extensive Damage

Figure 5. 23. Damage Patterns and Damage Level at 0.3g of Elcentro ground motion for RC building Type B with strong (28) concrete strength



Elcentro GM at PGA: 0.6g

- Almost all of the infill walls suffer out of plane failure
- Most of structural members are collapse and unrepairable

Collapse

Figure 5. 24. Damage Patterns and Damage Level at 0.6g of Elcentro ground motion for RC building Type A with strong (28) concrete strength

5.9.3. Damage Probability

Numerical simulations of all the buildings with a different storey, configuration, type of roof are analyzed with different concrete properties for three different input motions.

As mentioned in the previous part, there are five types of RC buildings with a different storey. The first case presents the 1st storey buildings; the second one is the 2nd storey.

The other case involves all of the stories, but with different concrete strength. One case will be a strong concrete, and the other one will be a weak concrete. All of the buildings were observed, and the damage level had been judged. The next step is to calculate its damage probability for each damage level.

Table 5. 5. The damage level for all of the RC building types

Building	fc'	Earthquake	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.2
D	strong	Elcentro	S	M	M	E	E	C	C	C	C	C	C	C
	strong	Kobe	S	S	M	M	E	E	C	C	C	C	C	C
	strong	Loma	S	M	M	E	E	E	E	C	C	C	C	C
	med	Elcentro	S	M	M	E	C	C	C	C	C	C	C	C
	med	Kobe	S	M	M	E	E	C	C	C	C	C	C	C
	med	Loma	S	M	M	E	E	E	C	C	C	C	C	C
	weaker	Elcentro	M	M	E	C	C	C	C	C	C	C	C	C
	weaker	Kobe	M	E	C	C	C	C	C	C	C	C	C	C
	weaker	Loma	M	E	E	E	C	C	C	C	C	C	C	C
E	med	Elcentro	S	M	M	E	E	C	C	C	C	C	C	C
	med	kobe	E	E	E	E	E	E	C	C	C	C	C	C
	med	Loma	S	M	E	E	E	E	C	C	C	C	C	C

	strong	Elcentro	M	M	M	M	E	C	C	C	C	C	C	C
	strong	Kobe	M	M	M	M	M	E	C	C	C	C	C	C
	strong	Loma	S	M	M	E	E	C	C	C	C	C	C	C
	weaker	Elcentro	M	M	M	E	E	C	C	C	C	C	C	C
	weaker	Kobe	S	M	M	M	E	C	C	C	C	C	C	C
	weaker	Loma	S	M	E	E	C	C	C	C	C	C	C	C
B	strong	Elcentro	N	S	E	E	C	C	C	C	C	C	C	C
	strong	Kobe	N	S	M	M	E	E	E	E	C	C	C	C
	strong	Loma	S	M	E	E	E	E	E	E	E	E	E	C
	med	Elcentro	S	E	E	E	C	C	C	C	C	C	C	C
	strong	Kobe	S	M	E	E	E	E	E	E	C	C	C	C
	strong	Loma	S	E	E	E	E	E	E	C	C	C	C	C
	weaker	Elcentro	S	M	C	C	C	C	C	C	C	C	C	C
	weaker	Kobe	S	E	E	E	E	E	E	E	C	C	C	C
	weaker	Loma	M	E	E	E	E	C	C	C	C	C	C	C
	strong	Elcentro	N	S	M	M	E	E	E	C	C	C	C	C
A	med	Elcentro	M	E	E	E	E	E	E	C	C	C	C	C
	med	Kobe	M	E	E	E	E	E	E	C	C	C	C	C
	med	Loma	M	M	M	E	E	E	E	C	C	C	C	C
	strong	Elcentro	M	M	E	E	E	E	E	E	C	C	C	C
	strong	Kobe	M	M	E	E	E	E	E	E	C	C	C	C
	strong	Loma	S	M	M	M	E	E	E	E	E	C	C	C
	weaker	Elcentro	M	E	E	E	C	C	C	C	C	C	C	C
	weaker	Kobe	M	E	E	E	C	C	C	C	C	C	C	C
	weaker	Loma	M	M	E	E	E	E	C	C	C	C	C	C
C	weaker	Elcentro	S	E	E	E	E	E	C	C	C	C	C	C
	weaker	Kobe	N	S	M	E	E	E	E	C	C	C	C	C
	weaker	Loma	N	M	E	E	E	E	E	C	C	C	C	C
	med	Elcentro	N	S	M	E	E	E	C	C	C	C	C	C
	med	Kobe	N	S	S	M	E	E	C	C	C	C	C	C
	med	Loma	N	S	M	E	E	E	E	E	C	C	C	C
	strong	Elcentro	N	S	M	M	E	E	C	C	C	C	C	C
	strong	Kobe	N	N	S	M	E	E	C	C	C	C	C	C
	strong	Loma	N	S	M	M	E	E	E	E	C	C	C	C

Table 5. 6. Damage level tables for 5 types RC buildings in Padang City

	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2
No Damage	13	1	0	0	0	0	0	0	0	0	0	0	0
Slight	18	13	4	1	0	0	0	0	0	0	0	0	0
Moderate	12	20	20	12	3	0	0	0	0	0	0	0	0
Extensive	2	11	20	31	34	29	19	10	3	1	1	0	0
Collapse	0	0	1	1	8	16	26	35	42	44	44	45	45
	45	45	45	45	45	45	45	45	45	45	45	45	45

Table 5. 7. Cumulative No table of figures entries found. Damage Probability tables for five types RC buildings in Padang City

	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2
None	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Slight	0.71	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Moderate	0.31	0.69	0.91	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Extensive	0.04	0.24	0.47	0.71	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Collapse	0.00	0.00	0.02	0.02	0.18	0.36	0.58	0.78	0.93	0.98	0.98	1.00	1.00

5.9.4. Fragility Function

Ramesh (2015) used a cumulative log-normal distribution function which followed the recommendation form HAZUS (2003) and other damage assessment tools (Guragain, 2015; Hazus-MH_2.1., 2015). The results show a good correlation between fitting fragility curve and damage probability. Hence, this current study will use the same method.

Porter (2017) (Porter, Hamburger, & Kennedy, 2007; Porter, Kennedy, & Bachman, 2007) also highlighted the reasons that lognormal cumulative distribution is widely used for fragility, which are:

1. Simplicity

Lognormal distribution has a simple, parametric form for approximating an uncertainty quantity that must take on a positive value, using only an estimate of central value and uncertainty;

2. Precedent. It was widely used for several decades in earthquake engineering

3. Often fits data. It often reasonably fits observed distribution of quantities, such as ground motion condition on magnitude and distance, the collapse capacity of structures, and the marginal distribution of loss conditioned on shaking.

For structural damage, at the given Peak Ground Acceleration (PGA), the probability of an element at risk exceeding a damage level is calculated as:

$$P [ds/PGA] = \frac{1}{2} \left[1 + \operatorname{erf} \left(\frac{\ln PGA - \mu}{\beta \sqrt{2}} \right) \right]$$

Where

erf = complementary error function

μ = mean = $\ln \text{PGA}_{ds}$

PGA_{ds} = Median value of PGA at which the building reaches the threshold of the damage state ds .

β = Standard Deviation of $\ln \text{PGA}$

The cumulative probability of the damage at different PGA from table 5.5. is plotted with best fit cumulative log-normal distribution which is shown in Figure 5.15.

The median value and standard deviation for plotting the cumulative lognormal distribution of different damage are calculated from table 5.11 and is presented in Table 5.12

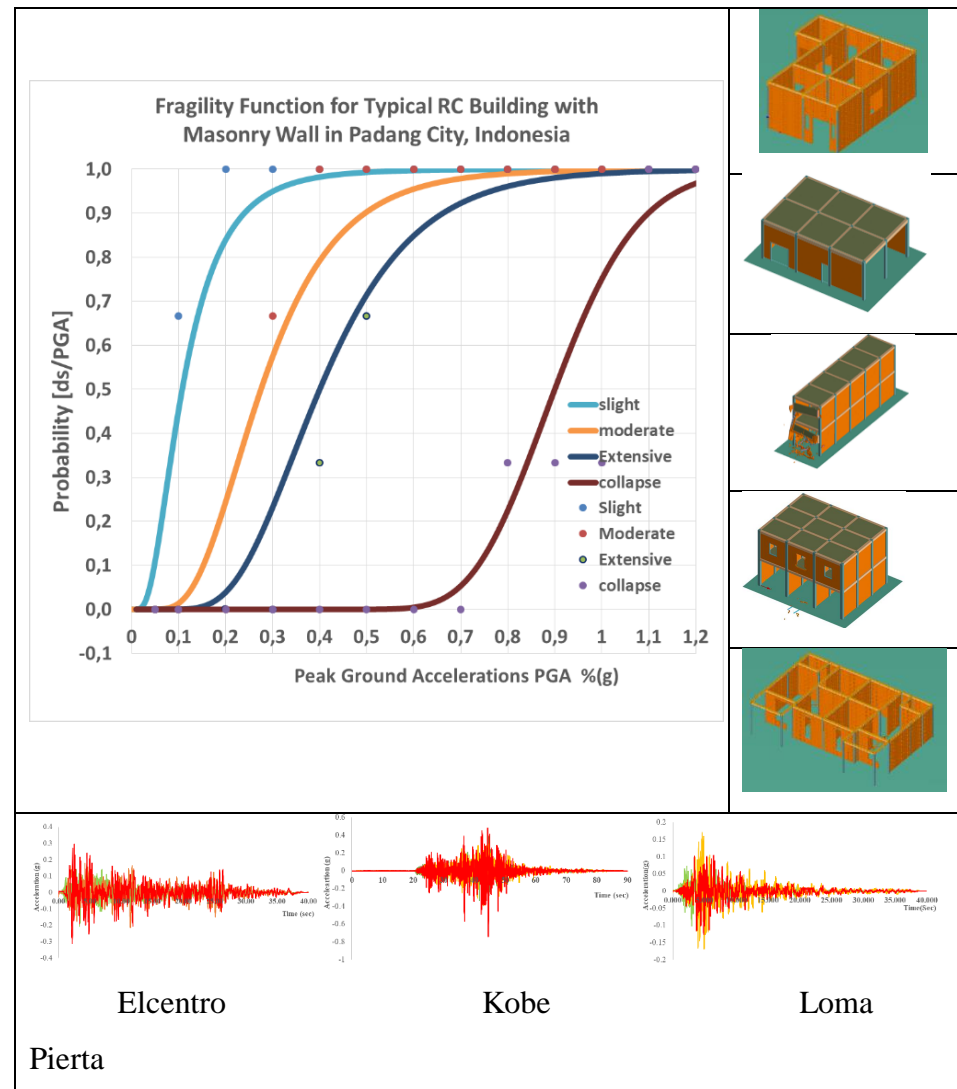


Figure 5. 25. Fragility Function for Typical RC Building with Masonry Wall in

Table 5. 8. Standard Deviation for five types RC buildings in Padang City

Damage States	Median (PGA for 0.5Damage)	Mean (ln Median) μ	Standard Deviation σ (or β)
Slight	0.010	-4.564	1.588
Moderate	0.105	-2.254	0.959
Extensive	0.205	-1.585	0.744
Complete	0.521	-0.651	0.384

5.10. Fragility function for RC building with masonry wall in Padang City, Case 1 storey, and two storey buildings

5.10.1. Damage Patterns and Damage Level

Following parts will discuss the damage patterns of 1 storey and two storey RC buildings in Padang City.

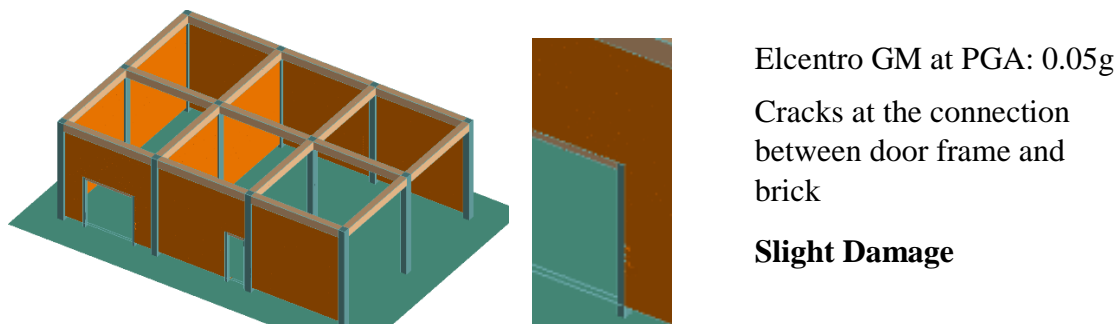


Figure 5. 26. Damage Patterns and Damage Level at 0.05g of Elcentro ground motion for RC building one storey Type D

Figure 5.26. shows the damage patterns of RC building one storey with a rigid roof and symmetric layout. On the rear part is used for housing and in the front is used for a shop. Due to the wide opening on the one side of the building, at 0.05g of target earthquake, had been observed the small crack near the frame of the opening. Hence, at this intensity, the building considered suffered slight damage. Next, at the 0.1g intensity, a small crack at the brittle brick wall leading to the loss of its stability and this building was extensively

damaged due to out of plane failure at the masonry wall, as seen in Figure 5.27. below.

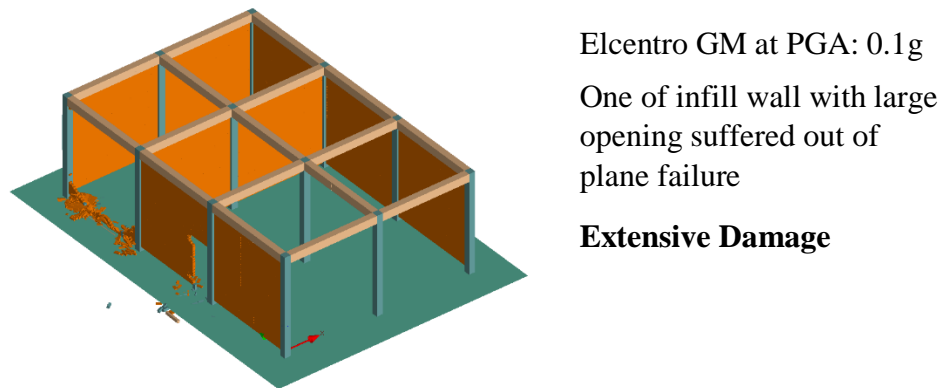


Figure 5. 27. Damage Patterns and Damage Level at 0.1g of Elcentro ground motion for RC building Type D 1 storey

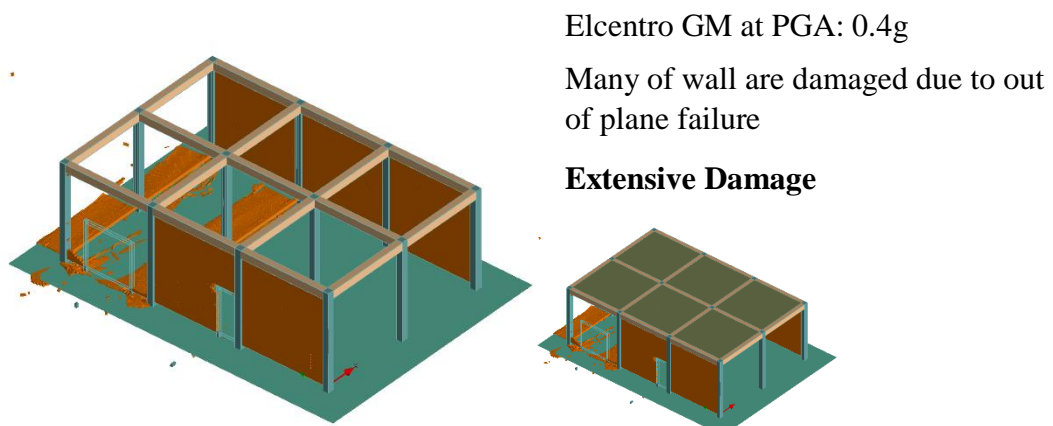


Figure 5. 28. Damage Patterns and Damage Level at 0.4g of Elcentro ground motion for RC building Type D with strong (28) concrete strength

In the Figure 5.28. with the increasing of earthquake intensity, at 0.4g, more brick masonry wall was damaged. This level where many walls are falling off is called extensive damage. Finally, in the Figure 5.29. with the increasing of earthquake intensity, at 0.5g, total collapse of structure (structural members and wall) happened.

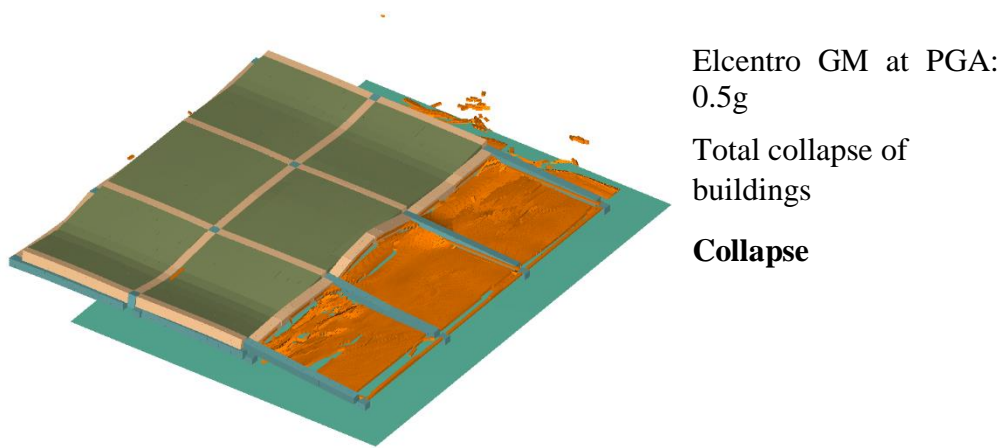


Figure 5. 29. Damage Patterns and Damage Level at 0.5g of Elcentro ground motion for RC building Type A with strong (28) concrete strength

Figure 5.30 shows the damage patterns which occur at the RC building with a masonry wall. This building is 2 storey with 3 bays, indicated as Type A in this research. As seen in the Fig.5.20, the crack started from the corner of opening and diagonally continue to the corner of the frame. In this state, these damage patterns are recognized as slight damage.

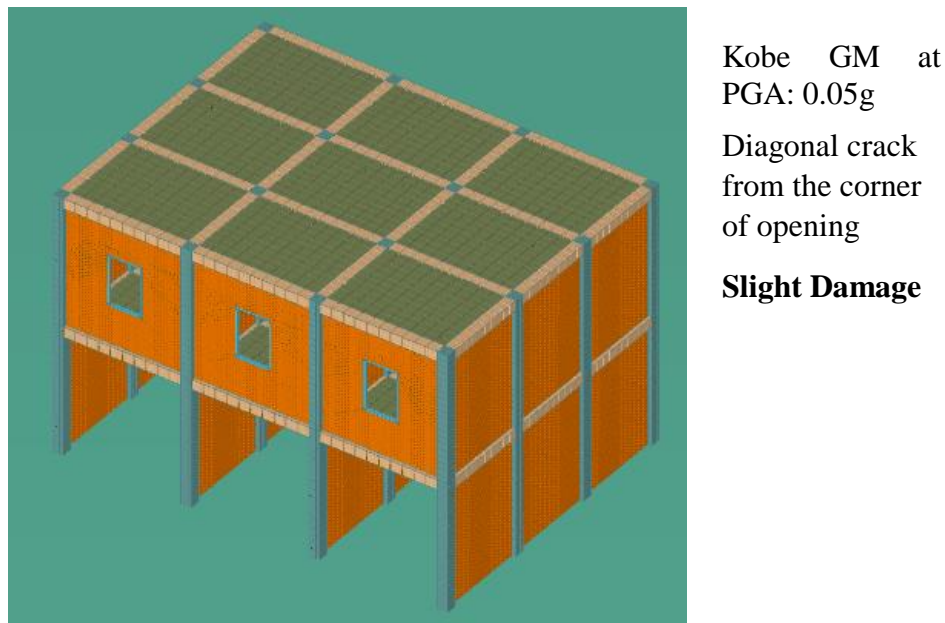
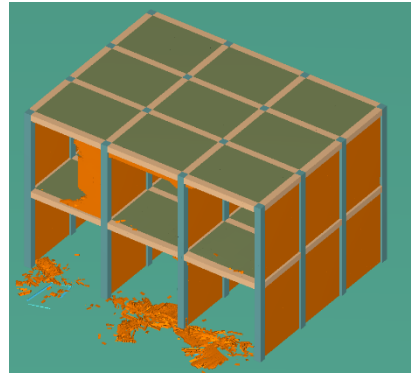


Figure 5. 30. Damage Patterns and Damage Level at 0.05g of Kobe ground motion for RC building Type E with strong (28) concrete strength



Elcentro GM at PGA:
0.2g

Out of plane failure of
some walls at the 2nd
storey

Extensive Damage

Figure 5. 31. Damage Patterns and Damage Level at 0.2g of Kobe ground motion for RC building Type A with strong (28) concrete strength

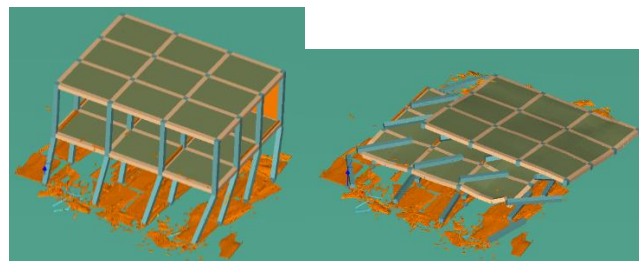


Elcentro GM at PGA:
0.2g

Extensive out of plane
failure of walls at the 2nd
storey and 1st storey

Extensive Damage

Figure 5. 32. Damage Patterns and Damage Level at 0.4g of Kobe ground motion for RC building Type A with strong (28) concrete strength



Elcentro GM at PGA:
0.8g

Total collapse due to
soft storey effect

Collapse

Figure 5. 33. Damage Patterns and Damage Level at 0.8g of Kobe ground motion for RC building Type A with strong (28) concrete strength

In Figure 5.31 and 5.32., out of plane failure occurred and the building survived until it totally collapses at 0.8g.

5.10.2. Damage Probability

This subchapter presents the damage level dan cumulative damage probability for each 1 storey building type which covers 53% of RC building population in Padang City.

Table 5.6. show damage level for 2 storey RC buildings for each level of PGA increments, which by using the cumulative damage probability method, each damage probability was calculated and presented in Table 5.7. Furthermore, damage level and damage probability for 1 storey building are presented in Table 5.9 and Table 5.10.

Then, using a log-normal distribution function in equation 5.4, the estimated damage probability, median for 50% probability of damage and its standard deviation were calculated (see Table 5.10). The best fit of fragility function fitting also presented in Figure 5.34 for 2 storey RC building and at Figure 5.35 for 1 storey RC building.

Table 5. 9. Damage Table for 2 storey RC building type in Padang

Damage Level	Peak Ground Acceleration (%g)												
	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2
No Damage	3	0	0	0	0	0	0	0	0	0	0	0	0
Slight	7	3	0	0	0	0	0	0	0	0	0	0	0
Moderate	9	8	4	3	0	0	0	0	0	0	0	0	0
Extensive	0	8	14	15	14	13	12	7	2	1	1	0	0
Complete	0	0	1	1	5	6	7	12	17	18	18	19	19
	19	19	19	19	19	19	19	19	19	19	19	19	19

Table 5. 10. Cumulative Probability Damage for 2 storey RC building type in Padang

Cumulative Damage Probability	Peak Ground Acceleration (%g)												
	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2
Slight	0.84	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Moderate	0.47	0.84	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Extensive	0.00	0.42	0.79	0.84	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Complete	0.00	0.00	0.05	0.05	0.26	0.32	0.37	0.63	0.89	0.95	0.95	1.00	1.00

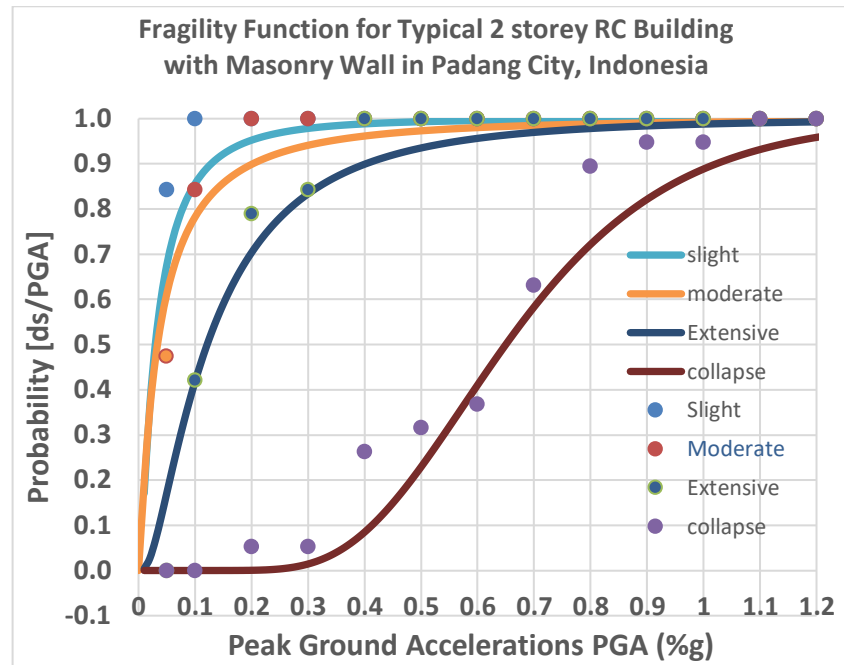


Figure 5. 34. Fragility Function for Typical RC Building with Masonry Wall in Padang City, Indonesia

Fragility curve in Figure 5.34 informed the probability of 2 storey RC building in Padang City for suffering slightly, moderate, extensive damage and collapse, at any level of PGA from 0 to 1.2 PGA level. By using this curve, can be predicted that 2 storey RC building in Padang City has 10% chances to be a collapse at 0.4g earthquake and has 90% probability for extensive damage at the same intensity and almost all of the buildings will have slight damage due to the brittle characteristic of the brick masonry wall.

This curve shows that many buildings will be damaged, for example, when 0.4g earthquake intensity happens in the future. However, to be noted, the building in this model were assumed to have a good joint corner detailing or strong joint. Hence, there is a possibility that more damage will happen at the same point of intensity if the weaker joint corner is used in the numerical model which is based on the survey (chapter 2 and 4) show improper reinforcement detailing in the joint corner area at RC frame elements of RC buildings.

Table 5. 11. Median and Standard Deviation for 2 storey RC Building

Damage States	Median (PGA for 0.5Damage)	Mean (ln Median) μ	Standard Deviation σ (or β)
Slight	0.030	-3.517	1.144
Moderate	0.034	-3.394	1.400
Extensive	0.121	-2.108	0.934
Complete	0.650	-0.431	0.353

Table 5. 12. Median and Standard Deviation for 1 storey RC Building

Damage States	Median (PGA for 0.5Damage)	Mean (ln Median) μ	Standard Deviation σ (or β)
Slight	0.108	-2.230	0.625
Moderate	0.275	-1.291	0.460
Extensive	0.400	-0.916	0.393
Complete	0.802	-0.221	0.212

Table 5. 13. Damage Table for 1 storey RC building type in Padang

Damage Level	Peak Ground Acceleration (%g)												
	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2
No Damage	8	1	0	0	0	0	0	0	0	0	0	0	0
Slight	10	7	2	0	0	0	0	0	0	0	0	0	0
Moderate	3	12	15	8	1	0	0	0	0	0	0	0	0
Extensive	1	2	5	14	19	13	5	2	0	0	0	0	0
Complete	0	0	0	0	0	9	17	20	22	22	22	22	22
	22	22	22	22	22	22	22	22	22	22	22	22	22

Table 5. 14. Cumulative Probability Damage for 1 storey RC building type in Padang

Damage States	Peak Ground Accelerations (%g)													
	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.4
Slight	0.00	0.67	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Moderate	0.00	0.00	0.00	0.67	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Extensive	0.00	0.00	0.00	0.00	0.33	0.67	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Complete	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.33	1.00	1.00	1.00

Fragility curve at Figure 5.35 informed that 1 storey RC building in Padang City has 25% chances to be a collapsed at 0.4g earthquake and has 75% probability for extensive damage at the same intensity and almost all of

the buildings will have slight damage due to the brittle characteristic of the brick masonry wall.

This curve shows that many buildings will damage when 0.5g earthquake intensity happen in the future. If we used 50% probability, so with the 0.8 PGA, 50% of 1 storey building would collapse in Padang City.

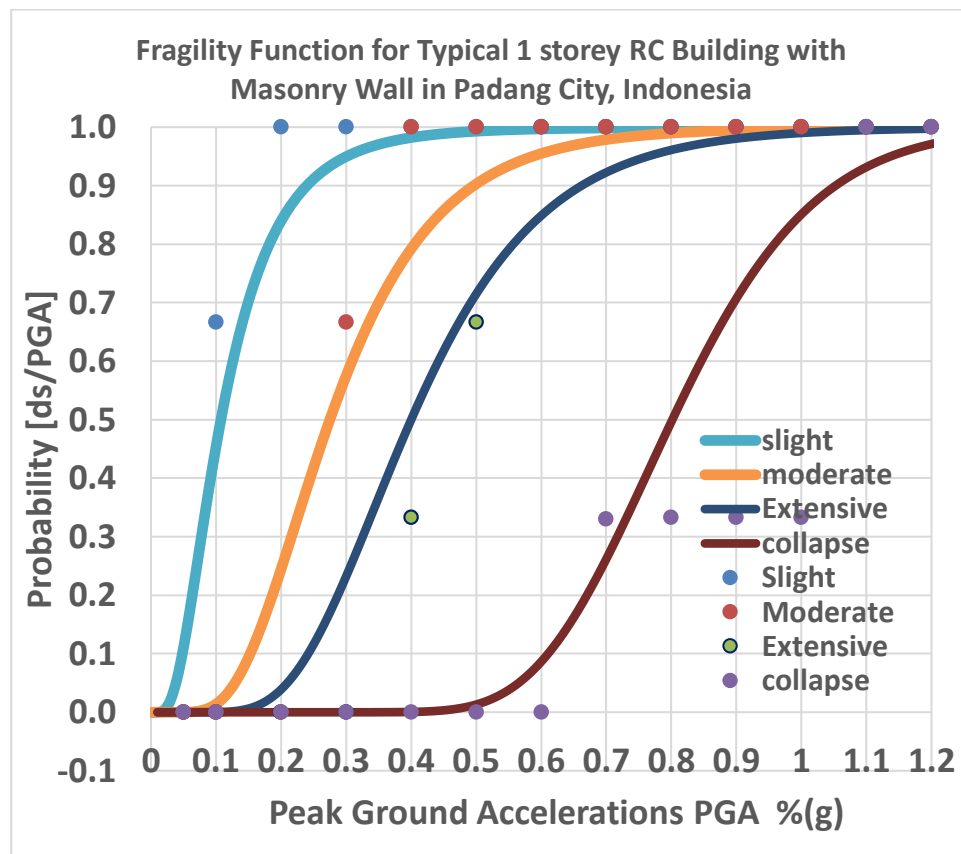


Figure 5. 35. Fragility Function for Typical RC Building with Masonry Wall in Padang City, Indonesia

5.10.3. Fragility function for 1 storey and 2 storey RC buildings in Padang City

Fragility curve in Figure 5.36 shows the multi fragility curves performed the probability of damage of 1 storey and 2 storey RC buildings in Padang City in one curve.

From the curve, information about the different performance of different types of RC buildings based on a number of its storey can be extracted. For

example, at 0.5g earthquake, 2nd storey RC building has a higher probability to be collapsed compare to 1st storey building.

While, for extensive damage, 2 storey RC building has a higher probability to suffered this damage. This could be due to the out of plane failure are very dominant in the 2nd storey of this building when the buildings are displaced. With the small displacement, the brick wall will be easily cracking and then followed by the instability of the infill wall.

The selected RC buildings for 2 storey mainly is RC building with bare frame and infill wall in the upper storey, but without infill wall in some part of the wall in 1st storey. As the damage data records from 2009 September Earthquake in Padang City, this type of building suffered severe to collapse damages. Out of plane failure and soft storey, damages were dominant for this type as the observation after the 2009 September Earthquake.

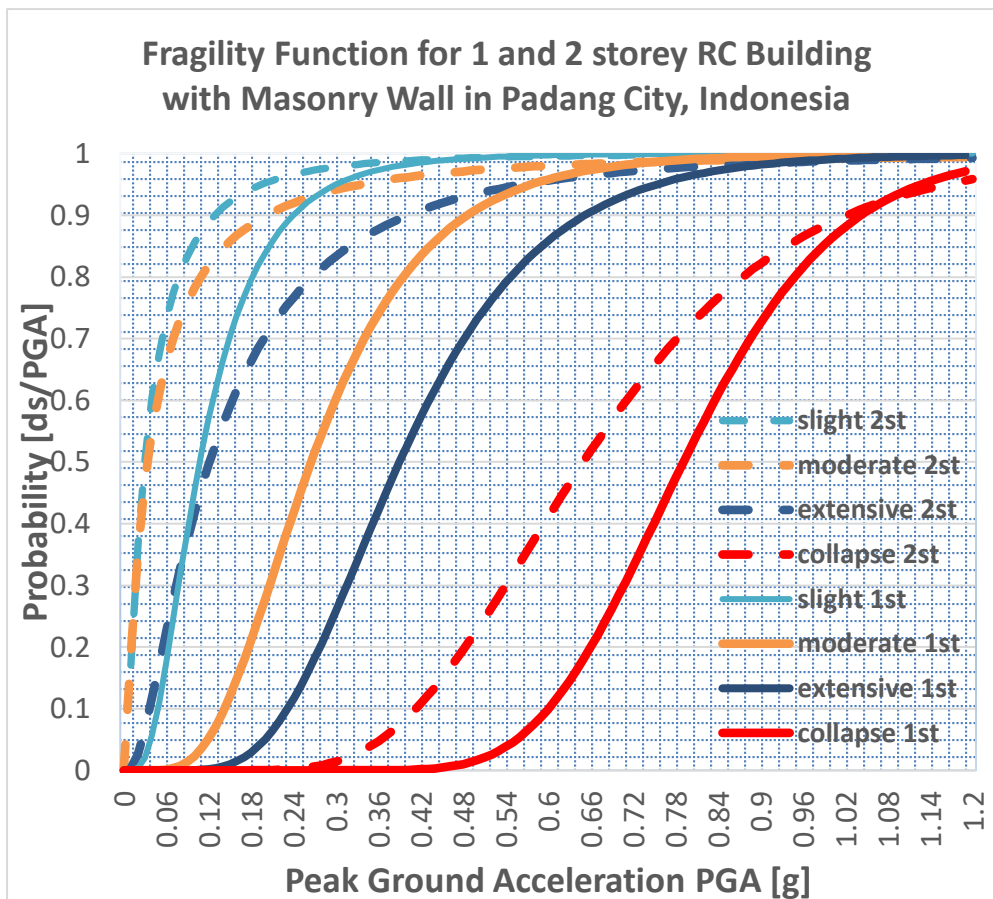


Figure 5. 36. Fragility Function for Typical RC Building with Masonry Wall in Padang City, Indonesia

Table 5. 15. Cumulative Probability Damage for 1 storey RC building type in Padang

Cumulative Damage Probability	Peak Ground Acceleration (%g)												
	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2
Slight	0.63	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Moderate	0.25	0.56	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Extensive	0.00	0.00	0.25	0.44	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Complete	0.00	0.00	0.00	0.00	0.06	0.25	0.50	0.63	0.88	0.94	0.94	1.00	1.00

5.11. The Fragility Function for RC buildings in Padang City with different Concrete Strength

This subchapter discusses the fragility function of typical RC buildings in Padang City under earthquake load with different strength of concrete material properties.

The material properties were decided based on concrete strength material distribution. The median value will present the average concrete property which was used the most based on field study (see chapter 4). Meanwhile, the mean value minus standard deviation (mean-sd) will represent the weaker concrete and the point where the mean value plus standard deviation (mean+sd) represent the stronger concrete.

5.11.1. Damage Level and Cumulative Damage Probability.

As the previous part, before developing fragility function, damage level table has to be arranged, and the cumulative damage probability should be calculated. These table for strong concrete are presented in Table 5.16.

Table 5. 16. Damage Table for 1 storey RC building type in Padang

Damage Level	Peak Ground Acceleration (%g)												
	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2
No Damage	6	1	0	0	0	0	0	0	0	0	0	0	0
Slight	6	6	1	0	0	0	0	0	0	0	0	0	0
Moderate	4	9	11	9	1	0	0	0	0	0	0	0	0
Extensive	0	0	4	7	14	12	8	6	2	1	1	0	0
Complete	0	0	0	0	1	4	8	10	14	15	15	16	16
	16	16	16	16	16	16	16	16	16	16	16	16	16

Fragility curve in Figure 5.37 informed the probability of RC building which built using a strong concrete. By using this curve, can be predicted that if the concrete of the building is strong, at 0.4g earthquake probability of building to be collapse is less than 10%.

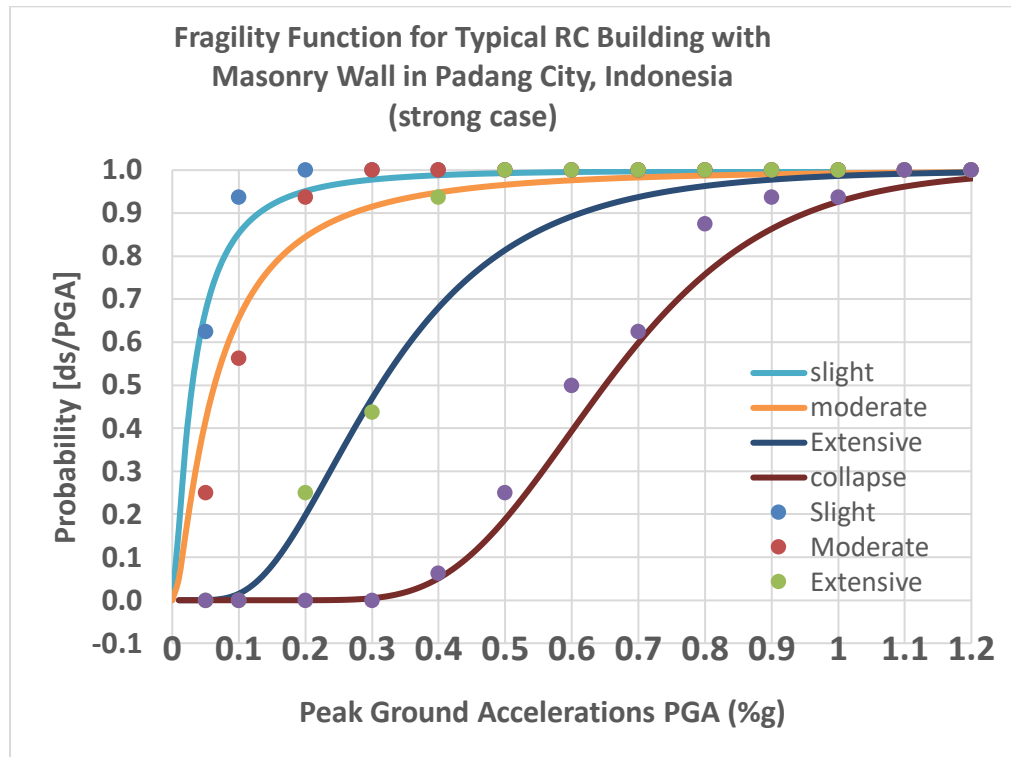


Figure 5. 37. Fragility Function for Typical RC Building with Masonry Wall with Strong Concrete in Padang City, Indonesia

Next, will be discussed the performance and probability of some damage level are being exceeded under some earthquake excitation for RC building in Padang city which were contained weaker concrete strength.

Table 5.17 presents the damage level for each percentage of PGA and table 5.18 presents the cumulative damage probability for each PGA.

Table 5. 17. Damage Table for 1 storey RC building type in Padang

Damage Level	Peak Ground Acceleration (%g)												
	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2
No damage	2	0	0	0	0	0	0	0	0	0	0	0	0
Slight	5	1	0	0	0	0	0	0	0	0	0	0	0
Moderate	8	7	3	1	0	0	0	0	0	0	0	0	0
Extensive	0	7	10	11	8	5	3	1	0	0	0	0	0

Complete	0	0	2	3	7	10	12	14	15	15	15	15	15
	15	15	15	15	15	15	15	15	15	15	15	15	15

Table 5. 18. Cumulative Probability Damage for 1 storey RC building type in Padang

Cumulative Damage Probability	Peak Ground Acceleration (%g)												
	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2
Slight	0.87	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Moderate	0.53	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Extensive	0.00	0.47	0.80	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Complete	0.00	0.00	0.13	0.20	0.47	0.67	0.80	0.93	1.00	1.00	1.00	1.00	1.00

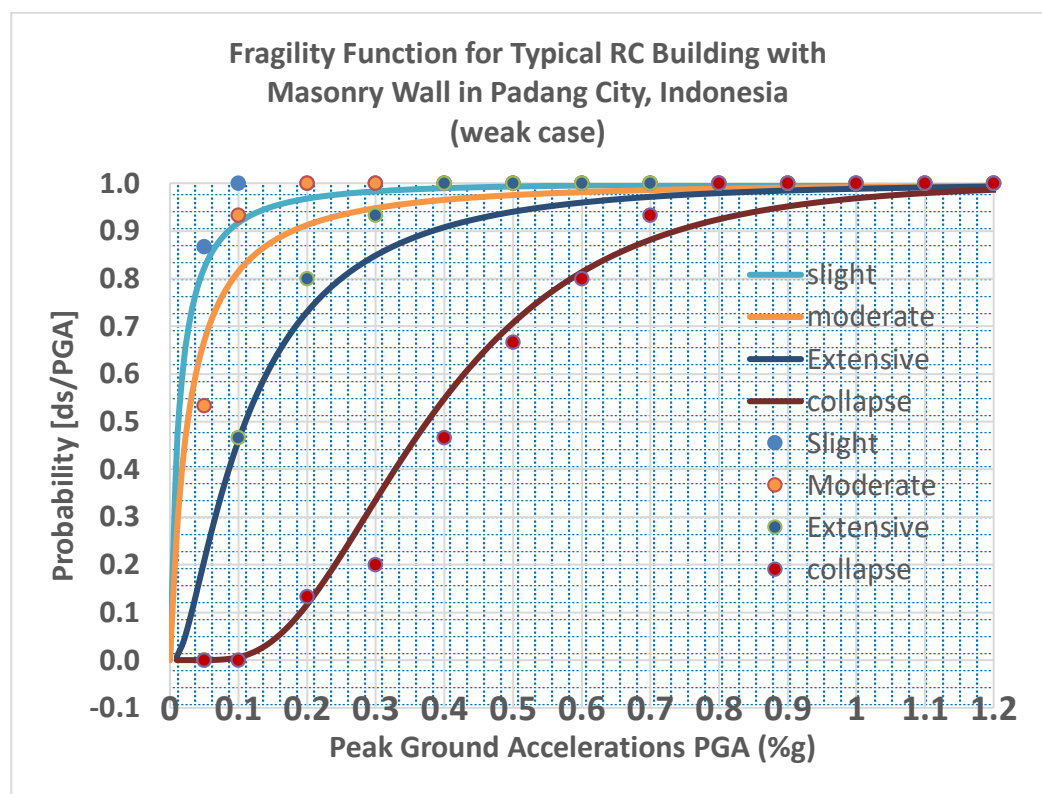


Figure 5. 38. Fragility Function for Typical RC Building with Masonry Wall with Weak Concrete in Padang City, Indonesia

Fragility curve in Figure 5.39 shows the multi fragility curves performed the probability of damage of strong and weaker concrete of RC buildings in Padang City in one curve.

The curve shows that the strength of concrete influences the probability of

damage of RC building due to the earthquake. From the curve, information about the different performance of different types of RC buildings based on concrete strength can be extracted. For example, at 0.5g earthquake, weaker concrete RC building has 50% higher probability to be collapsed compare to strong concrete building.

While, for extensive damage, weaker concrete RC building started to be damaged extensively from earlier PGA level than the strong one. While the predominant strength of RC building will belay between the weak and the strong curve.

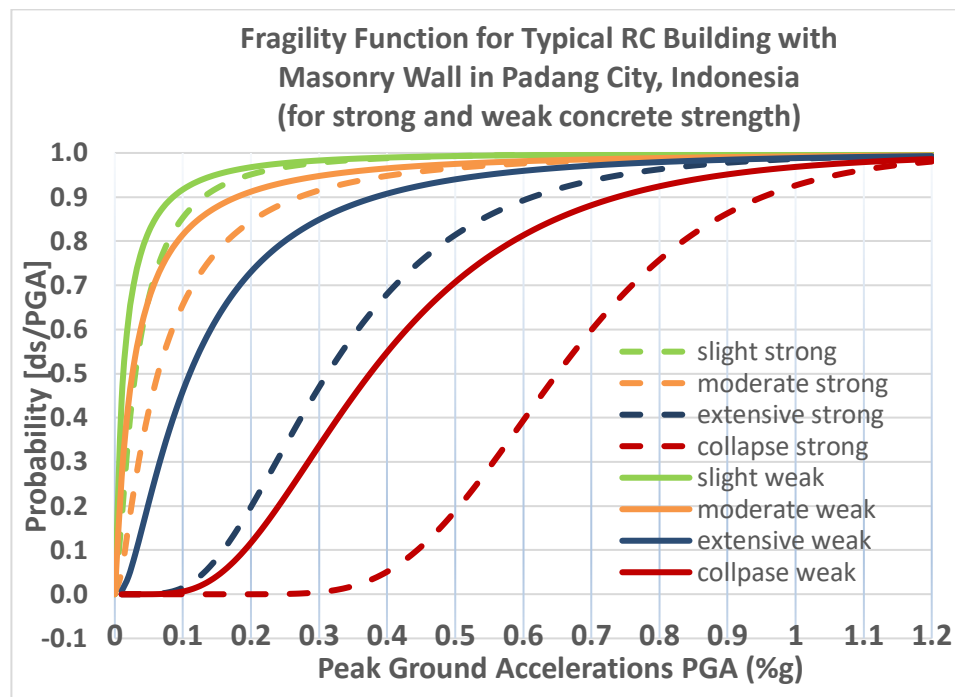


Figure 5. 39. Multi Fragility Function for Typical RC Building with Masonry Wall with Weak and Strong Concrete in Padang City, Indonesia

5.1.1 Reference

- ACI. (2008). *Building code requirements for structural concrete (ACI 318M-08) and Commentary*. American Concrete Institute (Vol. 2007). [https://doi.org/10.1016/0262-5075\(85\)90032-6](https://doi.org/10.1016/0262-5075(85)90032-6)
- Amit, K. (1998). Economic Assessment of Seismic Retrofitting of Non-Engineered Buildings - Case Study from India.
- Andaya, L. Y. (2000). Unravelling Minangkabau Ethnicity. *Itinerario*, 24(2), 20–43. <https://doi.org/10.1017/S0165115300013000>

- ASCE 41-06. (2007). *Seismic rehabilitation of existing buildings*.
<https://doi.org/10.1061/9780784408841>
- ASTM C311-04 C512-02. (2002). Standard Test Method for Creep of Concrete in Compression. *Annual Book of ASTM Standards*, 1–4.
https://doi.org/10.1520/C0512_C0512M-15
- ASTM C823. (2016). Standard Practice for Examination and Sampling of Hardened Concrete in Constructions. *American Society for Testing and Materials*, 1–7.
<https://doi.org/10.1520/C0823>
- Aydan, Ö. (2009). a Reconnaissance Report on the Pariaman-Padang Earthquake of September 30, 2009. *Earthquake*, (October), 1–36. Retrieved from
http://www.jsce.or.jp/library/eq_repo/Vol3/12/20090930report.pdf
- Blackwood, E. (1993). *The politics of daily life: Gender, kinship and identity in a Minangkabau village, West Sumatra, Indonesia*. ProQuest Dissertations and Theses. Retrieved from
<http://search.proquest.com/docview/304063843?accountid=13771>
- Carlberg, C. (2011). *Statistical analysis - Microsoft Excel 2010*. Pearson.
- Chadwick, R. J. (1991). Matrilineal Inheritance and Migration in a Minangkabau. *Indonesia*, 50, 47–81. <https://doi.org/10.2307/3351065>
- Coleman, A., & Karagedikli, Ö. (2018). Residential construction and population growth in New Zealand: 1996-2016, (January), 1–59. Retrieved from
www.rbnz.govt.nz/research/discusspapers
- Dardiri, A., Sutrisno, Kuncoro, T., Ichwanto, M. A., & Suparji. (2017). Enhancing the competitiveness of skilled construction workers through collaborative education and training. *AIP Conference Proceedings*, 1887.
<https://doi.org/10.1063/1.5003488>
- Education, P. (2017). Dynamics of Structures 5th Edition Chopra Solutions Manual Full clear download (no formatting errors) at : Solution :
- Fotopoulou, S. D., & Pitilakis, K. D. (2013). Fragility curves for reinforced concrete buildings to seismically triggered slow-moving slides. *Soil Dynamics and Earthquake Engineering*, 48, 143–161.
<https://doi.org/10.1016/j.soildyn.2013.01.004>
- Fraser, I. A. N. (1983). a New Draft Code for Seismic Design of Buildings in Indonesia, (3), 247–254.
- Guragain, R. (2015). Development of Earthquake Risk Assessment System for Nepal (ネパールを対象とした地震リスク評価システムの開発), (February).
- Hanifa, R., Gunawan, E., Irsyam, M., & Abidin, H. Z. (2016). Outline Earthquake risk reduction strategy in Indonesia after the 2004 tsunami disaster Irwan Meilano Earthquake disaster in Indonesia Earthquake sources : slip-rate and maximum magnitude PSHA map of Indonesia Earthquake risk analysis Building code Conclu.
- Hazus-MH_2.1. (2015). Hazus–MH 2.1: Technical Manual. *Department of Homeland Security Federal Emergency Management Agency Mitigation Division*

- Washington, D.C., 718. Retrieved from www.fema.gov/plan/prevent/hazus
- Intarti, Y. R., Damayanti, S., Rahmayanti, H., Rahmat Widyanto, M., Wahyudi, D., & Nadera, M. M. (2014). Development of Minangkabau Women ' s Roles as an Effort to Reduce Risk in Disaster - prone Cities in Indonesia A Case Study of Western District of Padang , Padang City , West Sumatra , Indonesia 1. *International Journal of Disaster Recovery and Business Continuity*, 5(November 2013), 29–42. <https://doi.org/10.14257/ijdrbc.2014.5.03>
- Irsyam, M., Dangkoa, D. T., Hendriyawan, Hoedajanto, D., Hutapea, B. M., Kertapati, E. K., ... Petersen, M. D. (2008). Proposed seismic hazard maps of Sumatra and Java islands and microzonation study of Jakarta city, Indonesia. *Journal of Earth System Science*, 117(SUPPL.2), 865–878. <https://doi.org/10.1007/s12040-008-0073-3>
- Irsyam, M., Hutabarat, D., Asrurifak, M., Imran, I., Widiyantoro, S., Sadisun, I., ... Pandhu, R. (2014). Development of seismic risk microzonation maps of Jakarta city. In *Geotechnics for Catastrophic Flooding Events* (pp. 35–47). <https://doi.org/10.1201/b17438-6>
- ISDR. (2015). Chart of the Sendai Framework for Disaster Risk Reduction, 2030.
- Juliafad, E., & Andayono, T. (2018). BUILDING OFFICIAL ` S AWARENESS IN TERM OF BUILDING PERMIT SYSTEM IN INDONESIA.
- Kaushik, H. B., Rai, D. C., & Jain, S. K. (2006). Code approaches to seismic design of masonry-infilled reinforced concrete frames: A state-of-the-art review. *Earthquake Spectra*, 22(4), 961–983. <https://doi.org/10.1193/1.2360907>
- Megawati, Kusnowidjaja. (2012). Shear-Wave Velocity Structure underneath the City of Padang, Indonesia. *15th World Conference on Earthquake Engineering (15WCEE)*.
- Megawati, K., & Pan, T. C. (2010). Ground-motion attenuation relationship for the Sumatran megathrust earthquakes. *Earthquake Engineering and Structural Dynamics*, 39(8), 827–845. <https://doi.org/10.1002/eqe.967>
- Meguro, K., & Tagel-Din, H. S. (2002). Applied Element Method Used for Large Displacement Structural Analysis. *Journal of Natural Disaster Science*, 24(1), 25–34.
- Nur, O F. (2012). Earthquake Damage – Intensity Relationship Based on Sumatran 30 September Earthquake. *15th World Conference on Earthquake Engineering (15WCEE)*.
- Porter, K., Hamburger, R., & Kennedy, R. (2005). Practical Development and Application of Fragility Functions.
- Porter, K., Hamburger, R., & Kennedy, R. (2007). Practical Development and Application of Fragility Functions. *Structural Engineering Research Frontiers*, 1–16. [https://doi.org/10.1061/40944\(249\)23](https://doi.org/10.1061/40944(249)23)
- Porter, K., Kennedy, R., & Bachman, R. (2007). Creating fragility functions for performance-based earthquake engineering. *Earthquake Spectra*, 23(2), 471–489. <https://doi.org/10.1193/1.2720892>
- Pribadi, K. S., Kusumastuti, D., & Utami, A. (2008). Earthquake Risk Perception in

- Indonesia : Government Officers and Builders View, (2007), 259–267.
- PusGen. (2017). *Peta Sumber dan Bahaya Gempa Indonesia Tahun 2017*.
- PUTRA, R. R., KIYONO, J., ONO, Y., & PARAJULI, H. R. (2012). SEISMIC HAZARD ANALYSIS FOR INDONESIA. *Journal of Natural Disaster Science*, 33(2), 59–70. <https://doi.org/10.2328/jnds.33.59>
- Rossetto, T., & Elnashai, A. (2003). Derivation of vulnerability functions for European-type RC structures based on observational data. *Engineering Structures*, 25(10), 1241–1263. [https://doi.org/10.1016/S0141-0296\(03\)00060-9](https://doi.org/10.1016/S0141-0296(03)00060-9)
- Sadiq Bhanbhro. (2017). Indonesia's Minangkabau culture promotes empowered Muslim women. *The Conversation* .
- Sieh, K. (2006). Sumatran megathrust earthquakes: from science to saving lives. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 364(1845), 1947–1963. <https://doi.org/10.1098/rsta.2006.1807>
- Sieh, K., Natawidjaja, D. H., Meltzner, A. J., Shen, C. C., Cheng, H., Li, K. S., ... Edwards, R. L. (2008). Earthquake supercycles inferred from sea-level changes recorded in the corals of west Sumatra. *Science*, 322(5908), 1674–1678. <https://doi.org/10.1126/science.1163589>
- SNI 2847. (2013). Persyaratan Beton Struktural untuk Bangunan Gedung. *Bandung: Badan Standardisasi Indonesia*, 1–265.
- Tagel-Din, H., & Meguro, K. (2000). Analysis of a small scale RC building subjected to shaking table tests using applied element method. *12WCEE. New Zealand:[Sn]*, (January 2000), 1–8. Retrieved from <http://www.iitk.ac.in/nicee/wcee/article/0464.pdf>
- Tegnan, H. (2015). Legal pluralism and land administration in west Sumatra: The implementation of the regulations of both local and Nagari governments on communal land tenure. *Journal of Legal Pluralism and Unofficial Law*, 47(2), 312–323. <https://doi.org/10.1080/07329113.2015.1072386>
- UN General Assembly. (2015). A/CONF.224/L.1 Sendai Declaration, 04878(March), 1504878. Retrieved from http://www.preventionweb.net/files/43300_sendaideclaration.pdf.
- UNISDR. (2015). Sendai Framework for Disaster Risk Reduction 2015 - 2030. *Third World Conference on Disaster Risk Reduction, Sendai, Japan, 14-18 March 2015.*, (March), 1–25. <https://doi.org/A/CONF.224/CRP.1>
- Vamvatsikos, D., & Allin Cornell, C. (2002). Incremental dynamic analysis. *Earthquake Engineering and Structural Dynamics*, 31(3), 491–514. <https://doi.org/10.1002/eqe.141>
- Vamvatsikos, D., & Cornell, C. A. (2005). Direct Estimation of Seismic Demand and Capacity of Multidegree-of-Freedom Systems through Incremental Dynamic Analysis of Single Degree of Freedom Approximation. *Journal of Structural Engineering*, 131(4), 589–599. [https://doi.org/10.1061/\(ASCE\)0733-9445\(2005\)131:4\(589\)](https://doi.org/10.1061/(ASCE)0733-9445(2005)131:4(589))
- Wahab, S. N. A., & Hamid, M. Y. (2011). A review factors affecting building defects

of structural steel construction. Case study: Student accommodation in UiTM Perak. *Procedia Engineering*, 20, 174–179. <https://doi.org/10.1016/j.proeng.2011.11.153>

Wibowo Kismiyati El; Haykal, Achmad, S. K. A. K. (2012). Konflik Pengetahuan Kepemilikan Tanah di Minangkabau. *Student E-Journal*, (Vol 1, No 1 (2012): Wisuda Agustus 2012), 18. Retrieved from <http://jurnal.unpad.ac.id/ejournal/article/view/1161>

Wilkinson, S. M., Alarcon, J. E., Mulyani, R., Whittle, J., & Chian, S. C. (2012). Observations of damage to buildings from Mw7.6 Padang earthquake of 30 September 2009. *Natural Hazards*, 63(2), 521–547. <https://doi.org/10.1007/s11069-012-0164-y>

Zachariassen, J. (2001). Paleoseismicity of the northern Horohoro Fault , Taupo Volcanic Zone , New Zealand Australian plate. *New Zealand Journal of Geology and Geophysics*, 44(January 2000), 391–400. <https://doi.org/10.1080/00288306.2001.9514946>

5.12. APPENDIX

Damage scale comparison

Table 5. 19. Damage scale comparison (T.Rosetto and Elnashai (2003))

DI HRC	Infilled MRF	HRC Damage State	HAZUS 1999	ATC-13	AIJ	FEMA 273	VISION 2000	EMS98
0	No damage	No damage	No damage	No damage	No damage	No damage	No damage	No Damage
10	Fine Cracks in plaster partition	Slight	Slight	Slight	Light	Immediate Occupancy	Fully Operational	Grade 1
20	Cracking at wall-frame interface	light		Light	Minor			
30	Cracking initiates form corners of openings						Operational	Grade 2
40	Diagonal cracking of walls. The limited crushing of bricks at b/c connection			Moderate		Damage Control		
50	Increased brick crushing	Moderate	Moderate					Grade 3

	at b/c connection							
60	Start of structural damage				Moderate	Life safe	Life Safe	
70	Some diagonal shear cracking in members especially for exterior frames			Heavy				
80	Extensive cracking of infills, falling brick, out of plane bulging	Extensive	Extensive damage		Major	Near Collapse	Near Collapse	Grade 4
90	Partial failure of many infills, heavier damage in frame members, some fail in shear			Major				
100	Beams and or columns fail in shear causing partial collapse. Near total infill failure	Partial Collapse			Partial collapse	Collapse Prevention	Collapse	
	Complete or impending building collapse	Collapse	Collapse	Collapse	Collapse	Collapse		Collapse

CHAPTER 6

DEVELOPMENT OF NEW ANALYTICAL FRAGILITY FUNCTION FOR RC BUILDING IN PADANG CITY, INDONESIA

6.1.Introduction

Conventional fragility function usually involved one independent variable for Intensity Measure (IM) and one dependent variable for damage measure (DM) (Porter, Hamburger, & Kennedy, 2005),(Porter, Kennedy, et al., 2007),(Porter, Hamburger, et al., 2007). This limitation causes the information of other important IM parameters is excluded.

Hence, this chapter discusses the development of new fragility function that contained information about the Peak Ground Acceleration and ground motion frequency.

First, it is necessary to show the difference of cumulative performance of RC building in Padang City to earthquake excitation (PGA) with consideration of the difference of those ground motion frequency.

As mentioned in Chapter 5, the first part of this chapter will use the same procedure as the development of fragility function in Chapter 5. The next step, the procedure of development of new fragility function for RC building in Padang City will be explained.

6.2. The Difference in Damage Probability in Different Ground Motion Frequency

6.2.1. Damage Probability

Numerical simulations of all the buildings with a different storey, configuration, type of roof are analyzed with different concrete properties for three different input motions.

As mentioned in the previous part, there are five types of RC buildings with a different storey. The first case presents the 1st storey buildings; the second one is the 2nd storey.

The other case involves all of the storey, but with different concrete strength. One case will be a strong concrete, and the other one will be a

weak concrete. All of the buildings were observed, and the damage level had been judged. The next step is to calculate its damage probability for each damage level.

Table 6. 1. The damage level for all of the RC building types

RC Type	Earthquake	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.2
Type A	Elcentro	S	M	M	E	E	C	C	C	C	C	C	C
Type A	Elcentro	S	M	M	E	C	C	C	C	C	C	C	C
Type A	Elcentro	S	M	M	E	E	C	C	C	C	C	C	C
Type B	Elcentro	M	M	M	M	E	C	C	C	C	C	C	C
Type B	Elcentro	M	M	M	E	E	C	C	C	C	C	C	C
Type B	Elcentro	N	S	E	E	C	C	C	C	C	C	C	C
Type C	Elcentro	S	E	E	E	C	C	C	C	C	C	C	C
Type C	Elcentro	S	M	C	C	C	C	C	C	C	C	C	C
Type C	Elcentro	N	S	M	M	E	E	E	C	C	C	C	C
Type D	Elcentro	M	E	E	E	E	E	E	C	C	C	C	C
Type D	Elcentro	M	M	E	E	E	E	E	E	C	C	C	C
Type D	Elcentro	M	E	E	E	C	C	C	C	C	C	C	C
Type E	Elcentro	N	S	M	E	E	E	C	C	C	C	C	C
Type E	Elcentro	E	E	E	E	C	C	C	C	C	C	C	C
Type E	Elcentro	S	E	E	E	E	E	C	C	C	C	C	C
Type A	Elcentro	N	S	M	E	E	E	C	C	C	C	C	C
Type E	Elcentro	N	S	M	M	E	E	C	C	C	C	C	C
Type A	Kobe	S	S	M	M	E	E	C	C	C	C	C	C
Type A	kobe	E	E	E	E	E	E	C	C	C	C	C	C
Type A	Kobe	M	M	M	M	M	E	C	C	C	C	C	C
Type B	Kobe	S	M	M	M	E	C	C	C	C	C	C	C
Type B	Kobe	N	S	M	M	E	E	E	E	C	C	C	C
Type B	Kobe	S	M	E	E	E	E	E	E	C	C	C	C
Type C	Kobe	S	E	E	E	E	E	E	E	C	C	C	C
Type C	Kobe	M	E	E	E	E	E	E	C	C	C	C	C
Type C	Kobe	M	M	E	E	E	E	E	E	C	C	C	C
Type D	Kobe	M	E	E	E	C	C	C	C	C	C	C	C
Type D	Kobe	S	S	S	M	M	E	E	C	C	C	C	C
Type D	Kobe	N	S	M	E	E	E	E	C	C	C	C	C
Type E	Kobe	N	S	S	M	E	E	C	C	C	C	C	C
Type E	Kobe	N	N	S	M	E	E	C	C	C	C	C	C
Type A	Loma	S	M	M	E	E	E	E	C	C	C	C	C
Type A	Loma	S	M	E	E	E	C	C	C	C	C	C	C
Type A	Loma	S	M	M	E	E	C	C	C	C	C	C	C
Type B	Loma	S	M	E	E	C	C	C	C	C	C	C	C
Type B	Loma	S	M	E	E	E	E	E	E	E	E	E	C
Type B	Loma	S	E	E	E	E	E	E	C	C	C	C	C

Type C	Loma	M	E	E	E	E	C	C	C	C	C	C	C
Type C	Loma	M	M	M	E	E	E	E	C	C	C	C	C
Type C	Loma	S	M	M	M	E	E	E	E	E	C	C	C
Type D	Loma	M	M	E	E	E	E	C	C	C	C	C	C
Type D	Loma	N	S	S	M	M	E	E	E	E	C	C	C
Type D	Loma	N	M	E	E	E	E	E	C	C	C	C	C
Type E	Loma	N	S	M	E	E	E	E	E	C	C	C	C
Type E	Loma	N	S	M	M	E	E	E	E	C	C	C	C

Table 6. 2. Damage level tables for 5 types RC buildings in Padang City

PGA	N	S	M	E	C	N	S	M	E	C	N	S	M	E	C
	5	11	24	48	116	5	13	22	52	76	4	11	22	61	
1.2	0	0	0	0	17	0	0	0	0	14	0	0	0	0	14
1	0	0	0	0	17	0	0	0	0	14	0	0	0	1	13
0.9	0	0	0	0	17	0	0	0	0	14	0	0	0	1	13
0.8	0	0	0	0	17	0	0	0	0	14	0	0	0	3	11
0.7	0	0	0	1	16	0	0	0	4	10	0	0	0	5	9
0.6	0	0	0	3	14	0	0	0	7	7	0	0	0	9	5
0.5	0	0	0	7	10	0	0	0	12	2	0	0	0	10	4
0.4	0	0	0	11	6	0	0	2	11	1	0	0	1	12	1
0.3	0	0	3	13	1	0	0	7	7	0	0	0	3	11	0
0.2	0	0	9	7	1	0	3	5	6	0	0	1	6	7	0
0.1	0	5	7	5	0	1	5	4	4	0	0	3	9	2	0
0.05	5	6	5	1	0	4	5	4	1	0	4	7	3	0	0
Frequency Of Ground Motion	EL CENTRO					KOBE					LOMA				

In this study, the damage level that wants to be emphasized is the collapse level, since this level given the significant impact on the number of fatality and risk in earthquake hazards for RC buildings.

Hence, Table 6.3 presented the cumulative damage probability of collapse for the RC building in Padang City under selected three different frequency of ground motions.

Table 6. 3. Cumulative Damage Probability tables for 5 types RC buildings in Padang City

PGA	N	S	M	E	C	N	S	M	E	C	N	S	M	E	C
1.2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93
0.9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93
0.8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.79
0.7	1.00	1.00	1.00	1.00	0.94	1.00	1.00	1.00	1.00	0.71	1.00	1.00	1.00	1.00	0.64
0.6	1.00	1.00	1.00	1.00	0.82	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	1.00	0.36
0.5	1.00	1.00	1.00	1.00	0.59	1.00	1.00	1.00	1.00	0.14	1.00	1.00	1.00	1.00	0.29
0.4	1.00	1.00	1.00	1.00	0.35	1.00	1.00	1.00	0.86	0.07	1.00	1.00	1.00	0.93	0.07
0.3	1.00	1.00	1.00	0.82	0.06	1.00	1.00	1.00	0.50	0.00	1.00	1.00	1.00	0.79	0.00
0.2	1.00	1.00	1.00	0.47	0.06	1.00	1.00	0.79	0.43	0.00	1.00	1.00	0.93	0.50	0.00
0.1	1.00	1.00	0.71	0.29	0.00	1.00	0.93	0.79	0.29	0.00	1.00	1.00	0.79	0.14	0.00
0.05	1.00	0.71	0.35	0.06	0.00	1.00	0.71	0.57	0.07	0.00	1.00	0.71	0.21	0.00	0.00
Frequency	EL CENTRO					KOBE					LOMA				

Table 6. 4. Cumulative Damage Probability tables for five types RC buildings in Padang City for collapse level

mm/sec2	Collapse Level Damage Probability			
PGA				
1.2	1.00	1.00	1.00	
1	1.00	1.00	0.93	
0.9	1.00	1.00	0.93	
0.8	1.00	1.00	0.79	
0.7	0.94	0.71	0.64	
0.6	0.82	0.50	0.36	
0.5	0.59	0.14	0.29	
0.4	0.35	0.07	0.07	
0.3	0.06	0.00	0.00	
0.2	0.06	0.00	0.00	
0.1	0.00	0.00	0.00	
0.05	0.00	0.00	0.00	
Frequency	2.13	4	6.67	HZ

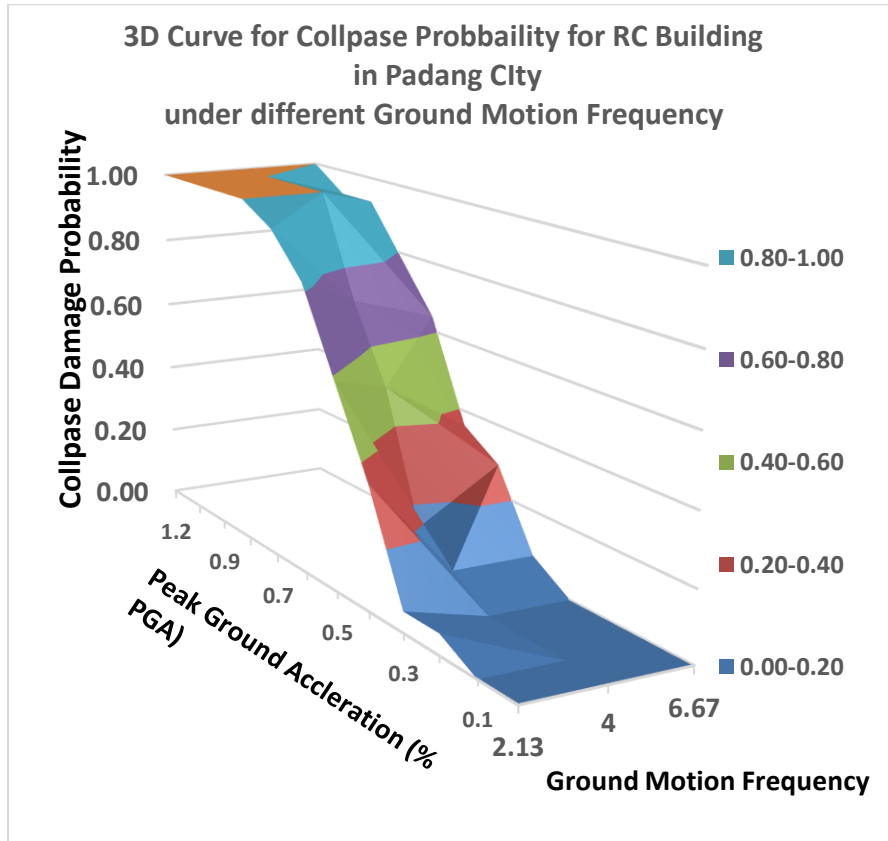


Figure 6. 1. 3D curve of Collapse Damage Probability for a different level of Peak Ground Acceleration and Different Ground Motion Frequency

6.3. The New Fragility Function based on Peak Ground Acceleration and Ground Motion Frequency

6.3.1 The procedure

As this new fragility function for RC Buildings in Padang City was developed to account the ground motion frequency and Peak Ground Acceleration to increase the accuracy of the results of estimated damage probability, the function will be the probability of PGA and Ground Motion Frequency (GMFreq).

$$F = P(PGA, GMFreq)$$

As the actual collapse damage probability (P_d) has been calculated, as presented in Table 6.2 and Table 6.3 for each GMfreq and each percentage

of Peak Ground Acceleration, the table of Pd, PGA and GMfreq should be arranged.

For simplicity and which assumption that the building type in Padang City is low rise building (1 storey and 2 storey), and will be located in Padang City, this equation was used multilinear regression analysis.

$$P_{d-est} = a \times PGA + b \times GMfreq. + c$$

Where:

P_{d-est} = estimated damage probability

PGA = Peak Ground Acceleration

GMFreq = Ground Motion Frequency

Table 6. 5. Actual Damage and Estimated Damage Probability Table

Pd	PGA	GMFreq.	Pd-est
0.0000	0.10	2.13	0.0000
0.0000	0.05	2.13	-0.0557
0.0000	0.40	4.00	0.3026
0.0000	0.30	4.00	0.1912
0.0000	0.20	4.00	0.0798
0.0000	0.10	4.00	-0.0316
0.0000	0.05	4.00	-0.0873
0.0000	0.30	6.67	0.1461
0.0000	0.20	6.67	0.0347
0.0000	0.10	6.67	-0.0767
0.0588	0.05	6.67	-0.1324
0.0588	0.30	2.13	0.2228
0.0714	0.20	2.13	0.1114
0.0714	0.40	6.67	0.2575
0.1429	0.50	4.00	0.4140
0.2857	0.50	2.13	0.4456
0.3529	0.40	2.13	0.3342
0.3571	0.60	6.67	0.4803
0.5000	0.50	6.67	0.3689
0.5882	0.60	4.00	0.5254
0.6429	0.70	2.13	0.6684
0.7143	0.70	6.67	0.5917
0.7857	0.70	4.00	0.6368
0.8235	1.00	6.67	0.9259
0.9286	0.90	6.67	0.8145
0.9286	0.80	6.67	0.7031
0.9412	0.60	2.13	0.5570

1.0000	1.20	2.13	1.2255
1.0000	1.00	2.13	1.0027
1.0000	0.90	2.13	0.8913
1.0000	0.80	2.13	0.7799
1.0000	1.20	4.00	1.1939
1.0000	1.00	4.00	0.9711
1.0000	0.90	4.00	0.8597
1.0000	0.80	4.00	0.7482
1.0000	1.20	6.67	1.1487

As the regression analysis was executed using normal distribution (Figure 6.2.) the coefficient for each parameter were obtained

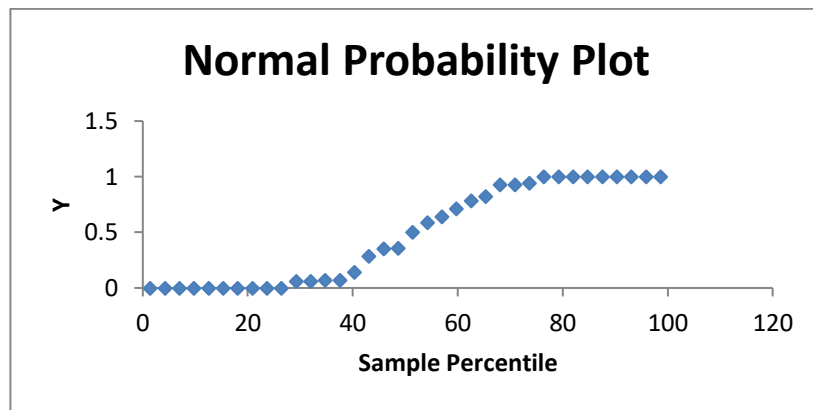


Figure 6. 2. Normal Probability Distribution of Input Data

$$P_{d-est} = 1.11 \times PGA + (-0.0181) \times GMfreq. + (-0.0758)$$

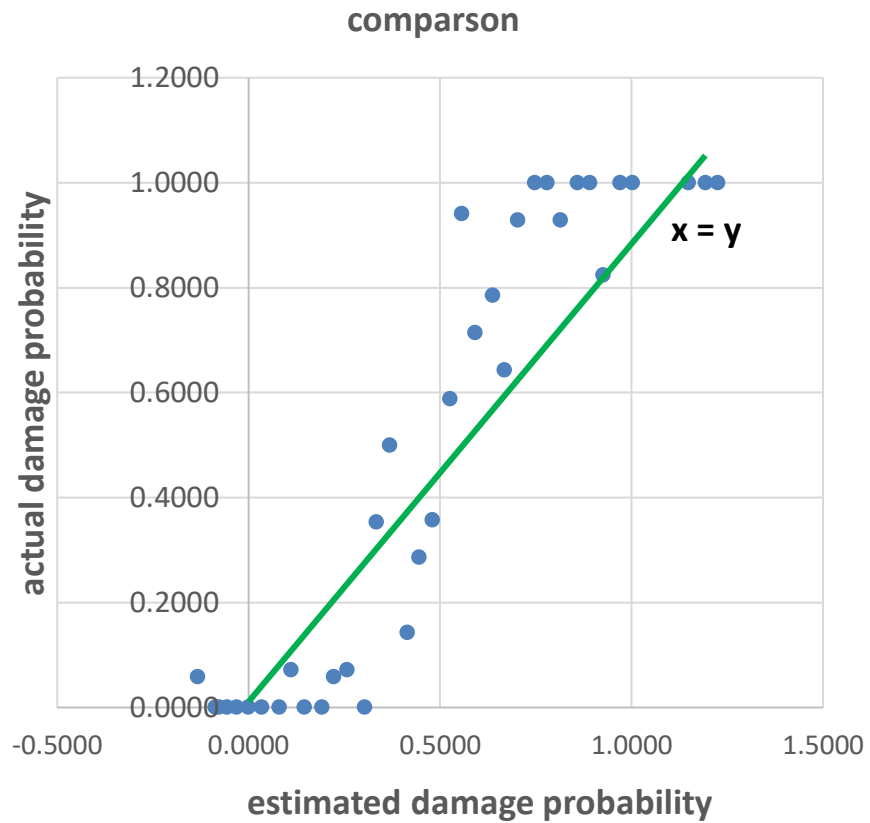
Where

PGA = Peak Ground Acceleration

GMfreq.= Ground Motion Frequency

Pd-est = estimated Damage Probability

The correlation between actual damage probability (Pd) and estimated damage probability (Pd-est) had been checked by using the Pearson Test and as can be seen in Figure 6.3. the correlation between Pd and Pd-est is highly correlated with the R-value is 0.94 (Carlberg, 2011)



intercept	-0.0754
PGA	1.11406
Frequency	-0.0169

Figure 6. 3. the correlation between Pd and Pd-est

6.4. The Use of New Fragility Function for Low-Rise RC Building with Masonry Wall in Padang City

Megawati and Rusnardi developed the distribution of shear wave velocity in Padang City area by using microtremor record and field study (Kusnowidjaja Megawati, 2012),(K. Megawati & Pan, 2010),(PUTRA, KIYONO, ONO, & PARAJULI, 2012).

As the s known, and the engineering bedrock depth is known, the period of site location also been known. While $f = 1/T$, the frequency can be calculated (Education, 2017)

By using the Peak Ground Acceleration (PGA) distribution in Padang City and known frequency for target location, the collapse damage probability for the target building can be calculated.

6.5. Limitation of the new fragility function

The buildings under earthquake excitation will provide resonance more when the ground motion frequency closer to buildings pre-dominant frequency. However, as presented in Eq. 6.1. the new fragility function uses a linear equation which shows the limitation of this function.

In this section, the limitation of this new fragility function is stated:

1. The function is limited to low storey RC building with a red brick masonry wall
2. The number of the storey includes 1 storey building and 2 storey building
3. The typical building should have referred to the typical building which is used in this research
4. The building is located in Padang City.
5. This function is used to calculated collapse probability

6.6. References

- ACI. (2008). *Building code requirements for structural concrete (ACI 318M-08) and Commentary*. American Concrete Institute (Vol. 2007).
[https://doi.org/10.1016/0262-5075\(85\)90032-6](https://doi.org/10.1016/0262-5075(85)90032-6)
- Amit, K. (1998). Economic Assessment of Seismic Retrofitting of Non-Engineered Buildings - Case Study from India.
- Andaya, L. Y. (2000). Unravelling Minangkabau Ethnicity. *Itinerario*, 24(2), 20–43.
<https://doi.org/10.1017/S0165115300013000>
- ASCE 41-06. (2007). *Seismic rehabilitation of existing buildings*.
<https://doi.org/10.1061/9780784408841>

- ASTM C311-04 C512-02. (2002). Standard Test Method for Creep of Concrete in Compression. *Annual Book of ASTM Standards*, 1–4. https://doi.org/10.1520/C0512_C0512M-15
- ASTM C823. (2016). Standard Practice for Examination and Sampling of Hardened Concrete in Constructions. *American Society for Testing and Materials*, 1–7. <https://doi.org/10.1520/C0823>
- Aydan, Ö. (2009). a Reconnaissance Report on the Pariaman-Padang Earthquake of September 30, 2009. *Earthquake*, (October), 1–36. Retrieved from http://www.jsce.or.jp/library/eq_repo/Vol3/12/20090930report.pdf
- Blackwood, E. (1993). *The politics of daily life: Gender, kinship and identity in a Minangkabau village, West Sumatra, Indonesia*. ProQuest Dissertations and Theses. Retrieved from <http://search.proquest.com/docview/304063843?accountid=13771>
- Carlberg, C. (2011). *Statistical analysis - Microsoft Excel 2010*. Pearson.
- Chadwick, R. J. (1991). Matrilineal Inheritance and Migration in a Minangkabau. *Indonesia*, 50, 47–81. <https://doi.org/10.2307/3351065>
- Coleman, A., & Karagedikli, Ö. (2018). Residential construction and population growth in New Zealand: 1996-2016, (January), 1–59. Retrieved from www.rbnz.govt.nz/research/discusspapers
- Dardiri, A., Sutrisno, Kuncoro, T., Ichwanto, M. A., & Suparji. (2017). Enhancing the competitiveness of skilled construction workers through collaborative education and training. *AIP Conference Proceedings*, 1887. <https://doi.org/10.1063/1.5003488>
- Education, P. (2017). Dynamics of Structures 5th Edition Chopra Solutions Manual Full clear download (no formatting errors) at : Solution :
- Fotopoulou, S. D., & Pitilakis, K. D. (2013). Fragility curves for reinforced concrete buildings to seismically triggered slow-moving slides. *Soil Dynamics and Earthquake Engineering*, 48, 143–161. <https://doi.org/10.1016/j.soildyn.2013.01.004>
- Fraser, I. A. N. (1983). a New Draft Code for Seismic Design of Buildings in

- Indonesia, (3), 247–254.
- Guragain, R. (2015). Development of Earthquake Risk Assessment System for Nepal (ネパールを対象とした地震リスク評価システムの開発), (February).
- Hanifa, R., Gunawan, E., Irsyam, M., & Abidin, H. Z. (2016). Outline Earthquake risk reduction strategy in Indonesia after the 2004 tsunami disaster Irwan Meilano Earthquake disaster in Indonesia Earthquake sources : slip-rate and maximum magnitude PSHA map of Indonesia Earthquake risk analysis Building code Conclu.
- Hazus-MH_2.1. (2015). Hazus–MH 2.1: Technical Manual. *Department of Homeland Security Federal Emergency Management Agency Mitigation Division Washington, D.C.*, 718. Retrieved from www.fema.gov/plan/prevent/hazus
- Intarti, Y. R., Damayanti, S., Rahmayanti, H., Rahmat Widyanto, M., Wahyudi, D., & Nadera, M. M. (2014). Development of Minangkabau Women ' s Roles as an Effort to Reduce Risk in Disaster - prone Cities in Indonesia A Case Study of Western District of Padang , Padang City , West Sumatra , Indonesia 1. *International Journal of Disaster Recovery and Business Continuity*, 5(November 2013), 29–42. <https://doi.org/10.14257/ijdrbc.2014.5.03>
- Irsyam, M., Dangkoa, D. T., Hendriyawan, Hoedajanto, D., Hutapea, B. M., Kertapati, E. K., ... Petersen, M. D. (2008). Proposed seismic hazard maps of Sumatra and Java islands and microzonation study of Jakarta city, Indonesia. *Journal of Earth System Science*, 117(SUPPL.2), 865–878. <https://doi.org/10.1007/s12040-008-0073-3>
- Irsyam, M., Hutabarat, D., Asrurifak, M., Imran, I., Widiyantoro, S., Sadisun, I., ... Pandhu, R. (2014). Development of seismic risk microzonation maps of Jakarta city. In *Geotechnics for Catastrophic Flooding Events* (pp. 35–47). <https://doi.org/10.1201/b17438-6>
- ISDR. (2015). Chart of the Sendai Framework for Disaster Risk Reduction, 2030.
- Juliafad, E., & Andayono, T. (2018). BUILDING OFFICIAL ` S AWARENESS IN TERM OF BUILDING PERMIT SYSTEM IN INDONESIA.
- Kaushik, H. B., Rai, D. C., & Jain, S. K. (2006). Code approaches to seismic design

- of masonry-infilled reinforced concrete frames: A state-of-the-art review. *Earthquake Spectra*, 22(4), 961–983. <https://doi.org/10.1193/1.2360907>
- Megawati, Kusnowidjaja. (2012). Shear-Wave Velocity Structure underneath the City of Padang, Indonesia. *15th World Conference on Earthquake Engineering (15WCEE)*.
- Megawati, K., & Pan, T. C. (2010). Ground-motion attenuation relationship for the Sumatran megathrust earthquakes. *Earthquake Engineering and Structural Dynamics*, 39(8), 827–845. <https://doi.org/10.1002/eqe.967>
- Meguro, K., & Tagel-Din, H. S. (2002). Applied Element Method Used for Large Displacement Structural Analysis. *Journal of Natural Disaster Science*, 24(1), 25–34.
- Nur, O F. (2012). Earthquake Damage – Intensity Relationship Based on Sumatran 30 September Earthquake. *15th World Conference on Earthquake Engineering (15WCEE)*.
- Porter, K., Hamburger, R., & Kennedy, R. (2005). Practical Development and Application of Fragility Functions.
- Porter, K., Hamburger, R., & Kennedy, R. (2007). Practical Development and Application of Fragility Functions. *Structural Engineering Research Frontiers*, 1–16. [https://doi.org/10.1061/40944\(249\)23](https://doi.org/10.1061/40944(249)23)
- Porter, K., Kennedy, R., & Bachman, R. (2007). Creating fragility functions for performance-based earthquake engineering. *Earthquake Spectra*, 23(2), 471–489. <https://doi.org/10.1193/1.2720892>
- Pribadi, K. S., Kusumastuti, D., & Utami, A. (2008). Earthquake Risk Perception in Indonesia : Government Officers and Builders View, (2007), 259–267.
- PusGen. (2017). *Peta Sumber dan Bahaya Gempa Indonesia Tahun 2017*.
- PUTRA, R. R., KIYONO, J., ONO, Y., & PARAJULI, H. R. (2012). SEISMIC HAZARD ANALYSIS FOR INDONESIA. *Journal of Natural Disaster Science*, 33(2), 59–70. <https://doi.org/10.2328/jnds.33.59>
- Rossetto, T., & Elnashai, A. (2003). Derivation of vulnerability functions for

- European-type RC structures based on observational data. *Engineering Structures*, 25(10), 1241–1263. [https://doi.org/10.1016/S0141-0296\(03\)00060-9](https://doi.org/10.1016/S0141-0296(03)00060-9)
- Sadiq Bhanbhro. (2017). Indonesia's Minangkabau culture promotes empowered Muslim women. *The Conversation* .
- Sieh, K. (2006). Sumatran megathrust earthquakes: from science to saving lives. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 364(1845), 1947–1963. <https://doi.org/10.1098/rsta.2006.1807>
- Sieh, K., Natawidjaja, D. H., Meltzner, A. J., Shen, C. C., Cheng, H., Li, K. S., ... Edwards, R. L. (2008). Earthquake supercycles inferred from sea-level changes recorded in the corals of west Sumatra. *Science*, 322(5908), 1674–1678. <https://doi.org/10.1126/science.1163589>
- SNI 2847. (2013). Persyaratan Beton Struktural untuk Bangunan Gedung. *Bandung: Badan Standardisasi Indonesia*, 1–265.
- Tagel-Din, H., & Meguro, K. (2000). Analysis of a small scale RC building subjected to shaking table tests using applied element method. *I2WCEE. New Zealand: [Sn]*, (January 2000), 1–8. Retrieved from <http://www.iitk.ac.in/nicee/wcee/article/0464.pdf>
- Tegnan, H. (2015). Legal pluralism and land administration in west Sumatra: The implementation of the regulations of both local and Nagari governments on communal land tenure. *Journal of Legal Pluralism and Unofficial Law*, 47(2), 312–323. <https://doi.org/10.1080/07329113.2015.1072386>
- UN General Assembly. (2015). A/CONF.224/L.1 Sendai Declaration, 04878(March), 1504878. Retrieved from http://www.preventionweb.net/files/43300_sendaideclaration.pdf.
- UNISDR. (2015). Sendai Framework for Disaster Risk Reduction 2015 - 2030. *Third World Conference on Disaster Risk Reduction, Sendai, Japan, 14-18 March 2015.*, (March), 1–25. <https://doi.org/A/CONF.224/CRP.1>
- Vamvatsikos, D., & Allin Cornell, C. (2002). Incremental dynamic analysis. *Earthquake Engineering and Structural Dynamics*, 31(3), 491–514.

<https://doi.org/10.1002/eqe.141>

- Vamvatsikos, D., & Cornell, C. A. (2005). Direct Estimation of Seismic Demand and Capacity of Multidegree-of-Freedom Systems through Incremental Dynamic Analysis of Single Degree of Freedom Approximation. *Journal of Structural Engineering*, 131(4), 589–599. [https://doi.org/10.1061/\(ASCE\)0733-9445\(2005\)131:4\(589\)](https://doi.org/10.1061/(ASCE)0733-9445(2005)131:4(589))
- Wahab, S. N. A., & Hamid, M. Y. (2011). A review factors affecting building defects of structural steel construction. Case study: Student accommodation in UiTM Perak. *Procedia Engineering*, 20, 174–179. <https://doi.org/10.1016/j.proeng.2011.11.153>
- Wibowo Kismiyati El; Haykal, Achmad, S. K. A. K. (2012). Konflik Pengetahuan Kepemilikan Tanah di Minangkabau. *Student E-Journal*, (Vol 1, No 1 (2012): Wisuda Agustus 2012), 18. Retrieved from <http://jurnal.unpad.ac.id/ejournal/article/view/1161>
- Wilkinson, S. M., Alarcon, J. E., Mulyani, R., Whittle, J., & Chian, S. C. (2012). Observations of damage to buildings from Mw7.6 Padang earthquake of 30 September 2009. *Natural Hazards*, 63(2), 521–547. <https://doi.org/10.1007/s11069-012-0164-y>
- Zachariasen, J. (2001). Paleoseismicity of the northern Horohoro Fault , Taupo Volcanic Zone , New Zealand Australian plate. *New Zealand Journal of Geology and Geophysics*, 44(January 2000), 391–400. <https://doi.org/10.1080/00288306.2001.9514946>

CHAPTER 7

DAMAGE ESTIMATION AND COMPARISON WITH ACTUAL DAMAGE DATA IN PADANG CITY

7.1. Introduction

This chapter discusses the building damage data based on the information from the 2009 Earthquake event in Padang City. This data will be used to compare the building damage estimation based on developed fragility curve from this study. By comparing both data, the future needs to improve developed fragility function can be explained.

7.2. Building Damage Data of 2009 Earthquake in Padang City

a. Peak Ground Acceleration Distribution of Padang City

Figure 7.1. show the Peak Ground Acceleration (PGA) distribution map for Padang City which is developed by Volcanology and Geology Agency of Republic of Indonesia. This PGA was developed by using deterministic and probabilistic method considering the sources of the earthquake in this area. The main sources are the subduction area and Semangko fault. The PGA of each coordinate in Padang City can be found on the link provided in the appendix of this chapter.

Indonesia Seismic Map was established based on Ground Motion Prediction Equation (GMPE) based on local geological and tectonic condition. Moreover, GMPE selection was based on the comparative study on available GMPE with the soil movement records/accelerograph in Indonesia (PusGen, 2017) .

Based on the earthquake source mechanism, GMPE equation that is used in Indonesia can be categorized into subduction zone source, fault transform zone and derivation of the equation based on seismic focus depth. Hence, the GMPE equation for subduction zone uses attenuation function for megathrust zone (interpolate) and Benioff zone (intraplate). Pga distribution map in this study uses the Indonesian seismic map where uses the GMPE equation available worldwide. That equation can be listed as below:

- 1) Shallow crustal source model: fault dan shallow background (1) Equation of Boore-Atkinson NGA. (Boore dan Atkinson, 2008) (2) Equation Campbell-Bozorgnia NGA. (Campbell dan Bozorgnia, 2008) (3) Equation Chiou-Youngs NGA. (Chiou dan Youngs, 2008)
- 2) Subduction interface model (Megathrust):(1) Equation Geomatrix subduction (Youngs et al., SRL, 1997), (2) Equation Atkinson-Boore BC rock and global source subduction (Atkinson dan Boore, 2003) (3) Equation Zhao et.al., with variable Vs30 (Zhao et.al., 2006)
- 3) Benioff sources (deep intraslab): deep background (1) Equation AB intraslab seismicity Cascadia region BC-rock condition. (Atkinson-Boore, Cascadia 2003) (2) Equation Geomatrix slab seismicity rock, 1997 srl. July 25, 2006. (Youngs et al., 1997) Equation AB 2003 intraslab seismicity worldwide data region BC-rock condition. (Atkinson-Boore, Worldwide 2003)

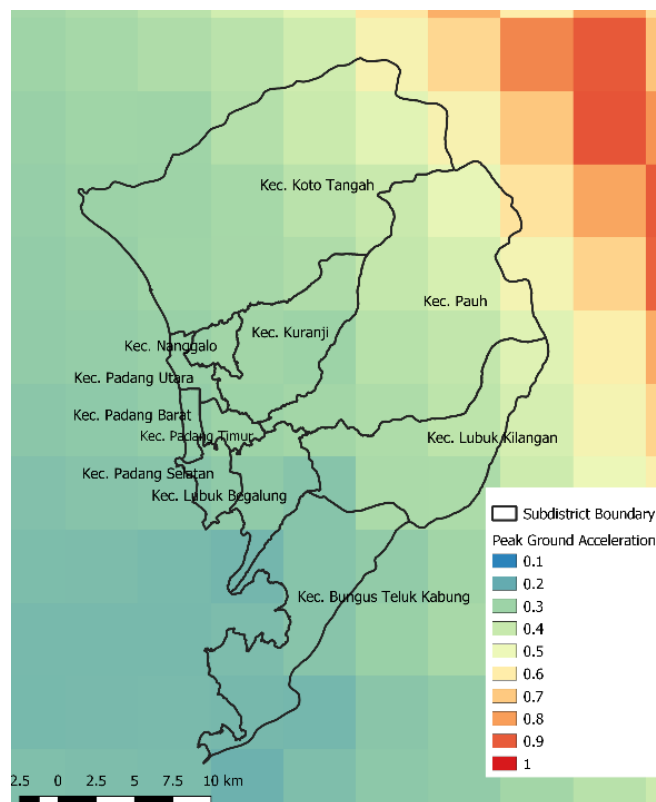


Figure 7. 1 Peak Ground Acceleration of Padang City, Indonesia.
(source: Center for Volcanology and Geological Hazard Mitigation of Indonesia)

b. Building Damage Data due to 2009 Earthquake in Padang City

Table 8.1. show the estimation of damage data of housing in Padang City which is compiled from local government offices in Padang City. The local government classified the building damage into 3 (three) damage categories; severe or over, moderate or over and slight damage. Severe damage means that the observed buildings were structurally damaged till collapsed. In this state, the building could not be repaired. Moderate damage means that the damages are widespread but still repairable, and slight damage means the damage is easily repairable. in this study.

Table 7.1. presents the housing damage data for 11 sub-districts in Padang City due to the 2009 Earthquake. By using this data, damage ratio for each damage level was calculated by using the cumulative damage method which will be used to be compared with the damage ratio based on developed fragility function for typical housings made from RC building with masonry wall in Padang City.

Table 7. 1. Housing Damage Data in Padang City due to 2009 Earthquake

	Number of Damaged Building (housing)				Damage Ratio of Building (housing)		
district	severe	moderate	slight	Total	severe	Moderate or over	Slight or over
L.kilangan	2441	2098	2315	9047	0.27	0.50	0.76
K. Tengah	7191	8423	7566	25888	0.28	0.60	0.90
Kuranji	4990	4749	4753	16098	0.31	0.60	0.90
Padang Barat	2160	2202	2399	10604	0.20	0.41	0.64
Padang Utara	2666	3036	3102	11446	0.23	0.50	0.77
P.Selatan	2436	2535	2887	8843	0.28	0.56	0.89
P.Timur	1670	3087	3395	12152	0.14	0.39	0.67
Nanggalo	2787	1911	1468	11528	0.24	0.41	0.53
L.Begalung	4976	5305	6506	17993	0.28	0.57	0.93
Pauh	1129	1426	2005	6947	0.16	0.37	0.66
B.t.Kabung	1151	1044	1219	23414	0.05	0.09	0.15

7.3. Building Damage Data Estimation based on Developed Fragility

Function

To calculate the damage probability of RC buildings in each sub-district in Padang City, the average value of PGA of each sub-district area were calculated. By utilizing the developed fragility function for typical RC building for housings in Padang City resulted in this study (see Fig.7.2), each damage probability of RC building in 11 sub-districts was calculated. The results were compared with actual damage of 2009 Earthquake.

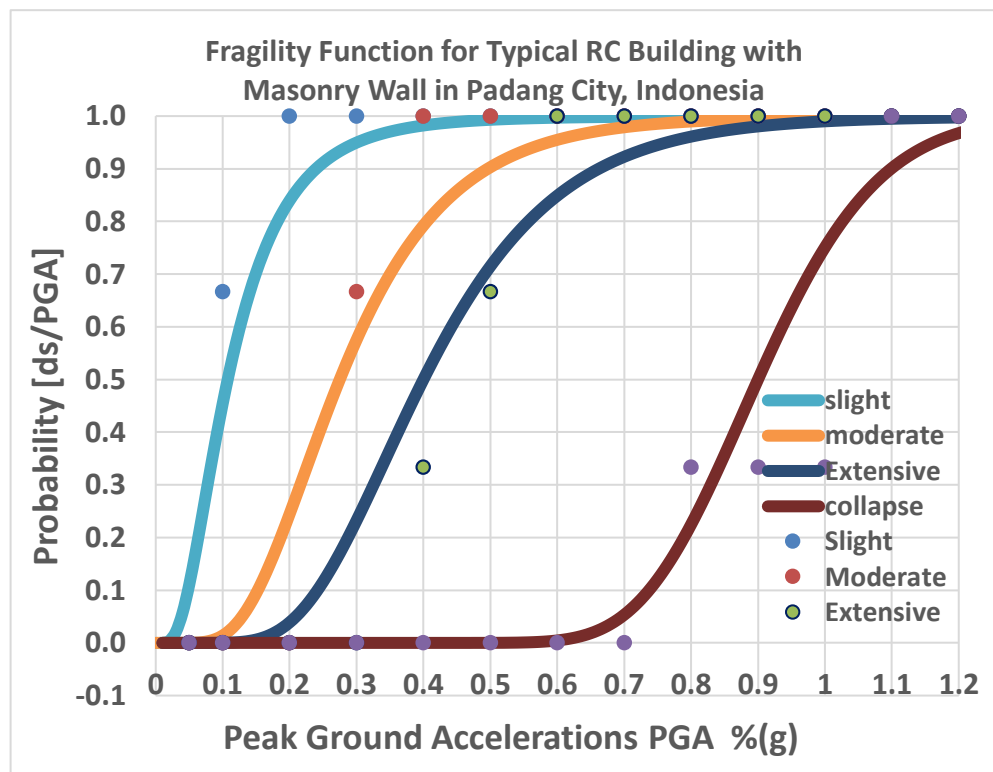


Figure 7. 2. Fragility Function for Typical low rise RC building with Maosnry Wall in Padang Clty

The comparison is presented in Table 7.2 below.

Table 7. 2. Damage Ratio for Housing RC Buildings in Padang City based on Developed Fragility Function

district	average PGA	collapse	extensive	moderate	slight
L.kilangan	0.38g	0.00	0.44	0.74	0.97
K. Tengah	0.36g	0.00	0.39	0.72	0.97
L.Kuranji	0.35g	0.00	0.25	0.69	0.97

Padang Barat	0.31g	0.00	0.25	0.60	0.95
Padang Utara	0.3g	0.00	0.23	0.57	0.95
Padang Selatan	0.29g	0.00	0.20	0.54	0.94
Padang Timur	0.29g	0.00	0.20	0.54	0.94
Nanggalo	0.28g	0.00	0.18	0.51	0.93
L.Begalung	0.28g	0.00	0.18	0.51	0.93
Pauh	0.25g	0.00	0.16	0.42	0.91
B.t.Kabung	0.25g	0.00	0.16	0.42	0.91

From Table 7.1 and 7.2, the damage due to actual building damage was compared with the damage probability based on developed fragility function. The slight damage from fragility function shows a higher value than the actual one. This could be due to a difference of damage patterns judgment and a limited number of RC buildings that have been analyzed in this study. The moderate or more and severe or more damage level show a good correlation with the actual damage. The histogram of comparison between damage ratio based on developed fragility curve and actual damage data can be seen in Figure 7.3.

While the actual damage was based on one earthquake event, the developed fragility functions were based on some extreme earthquake ground motion and the different condition of the building.

The damage patterns in this study have been judged strictly compare to the actual damage patterns judgment. With the limitation on the field, the observer for actual damage find difficulties to detect the fine crack or small wide cracks in detail due to the limitation of field inspector experience, limitation on inspection timing, tool and access to all of part of observed buildings.

Hence, the developed fragility function could give an estimation that can be used by the government or other disaster reduction stakeholders to develop vulnerability map and disaster reduction countermeasures activities/program.

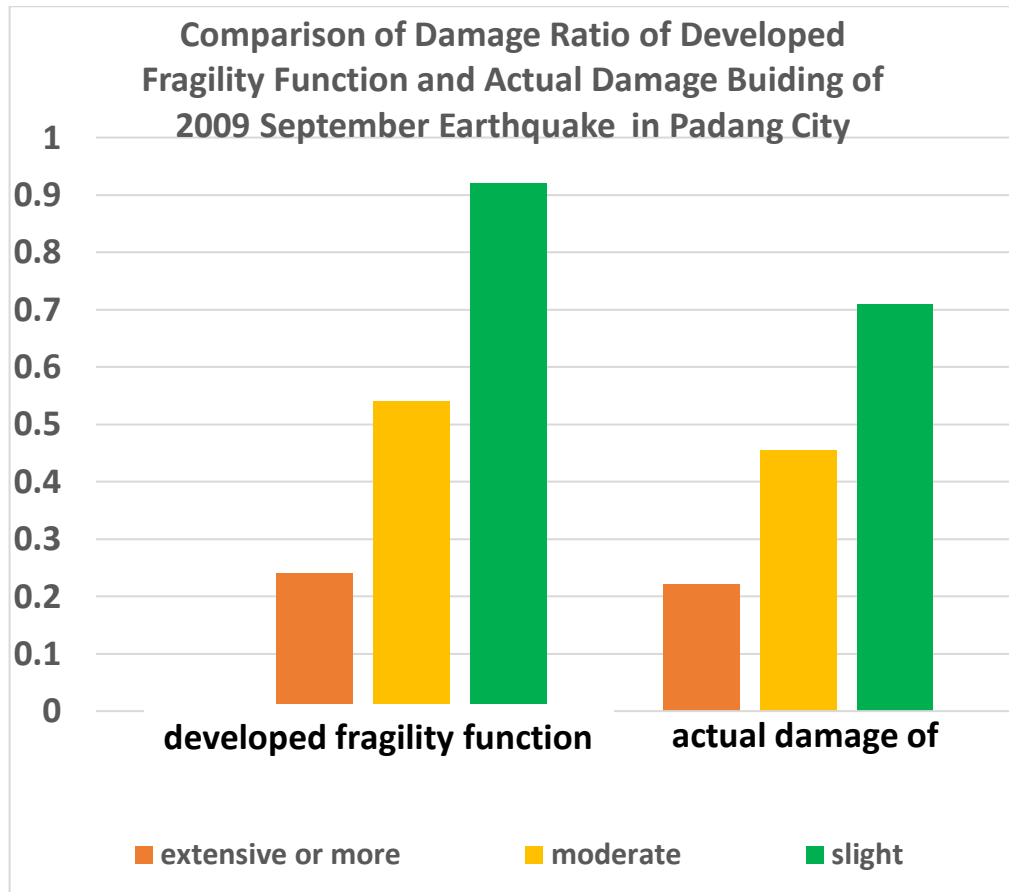


Figure 7. 3 Histogram of Comparison of Damage Ratio of Developed Fragility Function and Actual Damage Building Data of 2009 September Earthquake in Padang City.

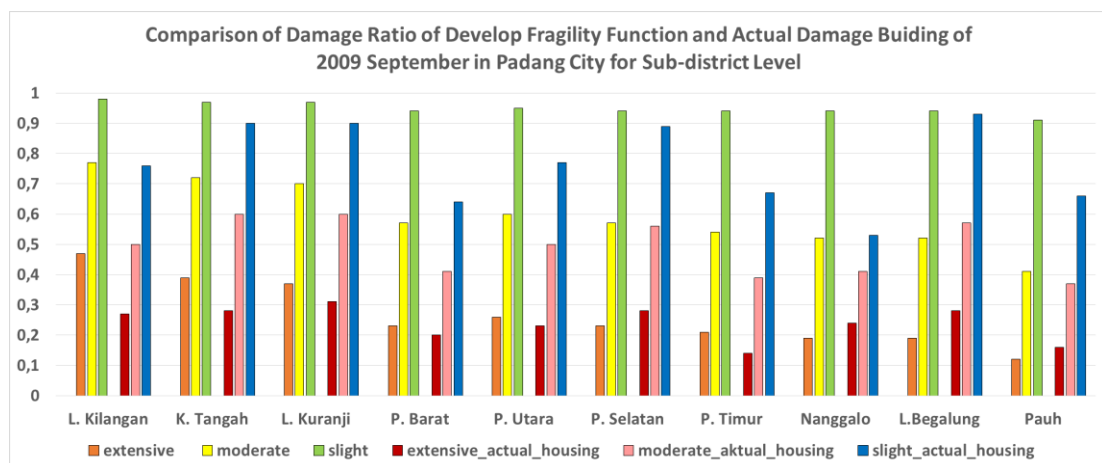


Figure 7. 4 Histogram of Comparison of Damage Ratio of Develop Fragility Function and Actual Damage Building Data of 2009 September Earthquake in Padang City for each Sub-district.

Figure 7.4. shows the comparison of damage ratio of developed Fragility Function and actual damage building data of 2009 September Earthquake in Padang City for each sub-district. As the comparison from average damage ratio as presented in Figure 7.2, the damage ratio between developed fragility function and actual damage data ratio show a good correlation. However, some gap was found in some area that possibly due to the different condition of the local site. The condition of local soil; hard soil or soft soil will affect the building performance as part of soil structure interaction. In some districts a significant gap also found, that might be due to some liquefaction that occurred and observed on 2009 September Earthquake.

The difference in existing RC buildings quality also contributes to the actual performance under the 2009 September earthquake. There could be an influence of the self-supervision of building owners supported by the advice from the tribe leaders which have knowledge of earthquake resistance buildings. For example, based on the tribe leader interview, one of the tribe leader, Dr.M.Giatman, is the lecturer (Associate Professor) in the civil engineering department of Universitas Negeri Padang. He informed, when the tribe members want to construct their building, they usually come to ask his advices for constructing a good quality RC building. These facts can show that the tribe leader can lead their members to have an earthquake resistance RC building. This condition could give some explanation on how the difference of damage ratio of buildings in each subdistrict is different.

However, the limitation on detailing modeling at the joint area which was assumed to adequately follow the standard beam-column joint reinforcement, also the limitation on the variation of building layout/dimension, might results also on the difference on the damage ratio.

CHAPTER 8

EMPOWERMENT OF MINANGKABAU TRIBE SYSTEM FOR RC BUILDING DISASTER REDUCTION IN PADANG CITY BY TRANSFORMING SCIENTIFIC TOOLS INTO DISASTER REDUCTION ACTION

8.1.Introduction

This chapter discusses the recommendation for disaster reduction for RC Building due to the future earthquake in Padang City Indonesia.

The disaster reduction concept that will be proposed is based on the environmental system that was investigated during a field study in Padang City, Indonesia. The explanation of the environmental system in Padang City can be found in Chapter 2. The key point in the environmental system will be addressed to be enhanced or to be empowered through the information provided by developed assessment tools which are fragility function based on the actual condition in Padang City.

Meguro (2008) proposed “Meguro Set” for disaster mitigation, “Public Assistance,” “Mutual Assistance,” and “Self-Assistance.” Among them, “Self-Assistance is important and Public, and Mutual Assistance must be conceived so they can trigger “Self-Assistance.”

The study to reduce disaster of RC Building in Padang City adopt the “Self-Assistance” which based on the local uniqueness on the social-cultural indigenous system in Padang City. As we explained in Chapter 1 and 2, Padang City has a unique Minangkabau tribe system that influences the building construction permit that will be constructed in their tribe land. “Self-Assistance” in this research means that to reduce RC Building disaster the owner should assist them self by using knowledge about the earthquake risk. Since the owner is a member of a tribe, he/she have to follow the rules for land use which is directed by the tribe leaders. The tribe leader-universities-social organization has a function to be the “mutual assistance.”

8.2.The Empowerment of Indigenous Minangkabau Tribe System for Disaster Reduction of RC Building in Padang City, Indonesia

Indigenous knowledge has been passed down generations, gained from knowledge of the environment which is revealed through intuitions, dreams or visions [1]. This concept is also known as local or traditional knowledge [2]. However, some argued that indigenous knowledge is essential in community development and how policy strategies cannot succeed entirely without the implementation of local knowledge [3].

Indigenous knowledge provides communities with ideas for tackling local problems and helps in their developmental processes. The knowledge sustains the local communities while strengthening their cultural identity [4]. Indigenous knowledge forms the basis for local communities coping strategies that have helped them survive over an extended period. This knowledge has been harnessed by the interaction of indigenous people with their natural environment. It provides valuable information with regards to the local environment and can be adapted for use in tackling hazards in other local communities. Local empowerment is attained through the use of indigenous knowledge in local communities, empowerment which leads to improved community participation and educating individuals on disaster risk reduction [5]. Indigenous knowledge is unique to a particular community and is stable for such a community as it has been used over an extended period – sometimes evolving through generations [6].

In this study, the indigenous knowledge will be used as the source of local wisdom involvement on disaster reduction action. To reach the objective, a study about the structure of the local community in Padang City had been conducted and find the key person or key position that can be addressed as the target for disaster reduction plan for RC Building in Padang City. This study finds that the tribe leader as the key person who has influence and roles in the tribe and their group of families to help the government increase the awareness of the local community about the effect of the earthquake for RC Building in Padang City.

The field study had been conducted, and the information about the study can be found in Chapter 4, subchapter 4.5

In this section, the discussion will be focused on the structure of the tribe, its position in the city, in relation with the government and how the developed assessments tools can be used to reduce the disaster.

8.2.1. Minangkabau Tribe System in Padang City

The government of Minangkabau is essentially tribal rather than territorial, and the actual rulers of the land are the tribe (Suku) heads, the Datuk. These heads, receive their orders from lower family councils and therefore are representatives rather than governors.

Figure 8.1. explained the structure of the indigenous system of Minangkabau system in Padang City. The organization at village level is named by Kerapatan Adat Nagari (KAN) or Village Tribe Organization (in English). The higher level is Lembaga Kerapatan Adat Alam Minangkabau (LKAAM) or Minangkabau Tribe Unity Organization, which organized all of the KAN in Padang City. KAN organization usually involved the tribe leaders (mamak) to discuss the related issues in their tribes or the village. Any information that the tribe leaders get from the KAN will be dispatched to the prominent families and each family.

To be compared with the organization of government, which has an organization in each level of administration, the tribe system does not have an organization in the sub-district, since the tribe system or the Minangkabau is based on tribal rather than territorial.

On the other hand, the government does not have a further line to reach the family. Compare to the tribe system, Minangkabau system has a tribe leader that can support, advice and manage their prominent families and the family.

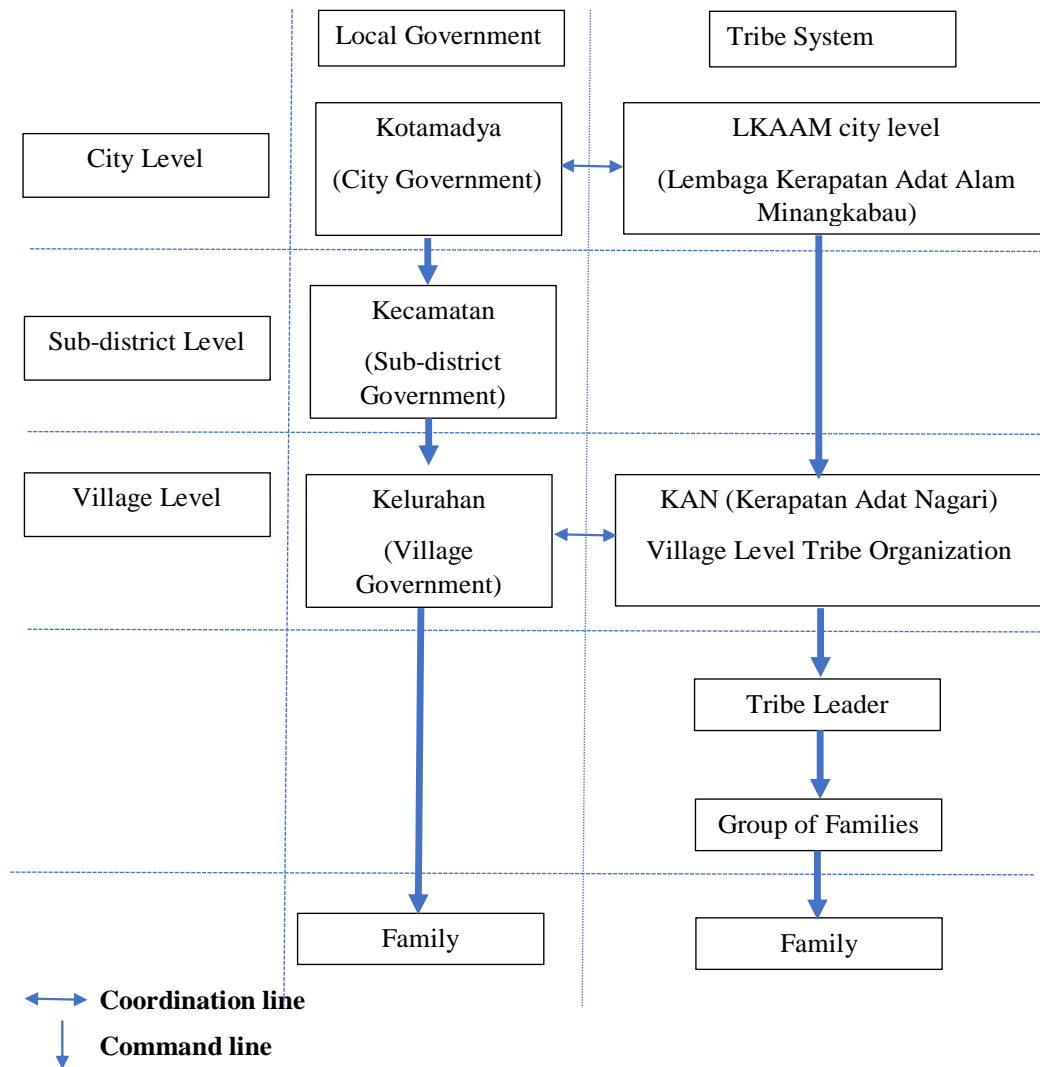


Figure 8. 1. The Comparison of Local Community Structure with Government Structure

8.2.2. The Tribe leader and its Roles in the Family

The roles of the tribe leaders in socio-politic in Padang City is significant which is admitted in Local Regulation of Padang City. The concept is called “Tungku Tigo Sajarangan” which is “three stone for cooking.” The philosophy is the food bowl to cook cannot be installed when there are no at least three stoves (stone). The stones are government, tribe leaders, and religious leader. The discussion principal is the soul of this concept. Whenever, significant problems that affect the safety, security and wealth of the community in the city occurs, the government, religious leader, and tribe leader will discuss and work together to find the solution

The leader has responsibility for taking care of their family members. Hence the tribe leader should be the wisest person, usually the oldest one. They are acknowledged for their influence on the community due to their charisma and broad knowledge about tribe system and community.

Minangkabau people live their daily life inspired and valued by the proverbs. On learning the truth and how to follow the leader. However, the truth and knowledge should be the “king,”

The Minangkabau people have a philosophy for an ideal house, which should follow four requirements, which are:

1. The indoor house is comfortable
2. The outdoor house is beautiful landscaping
3. Kitchen is clean
4. The lavatory is clean, and water is available for cleaning after defecation and urination.

Based on the rules in the Minangkabau system, four characters must be possessed by a leader, which are:

1. Truthful; meaning that the leader is following the truth based on the science
2. Intelligent; meaning the leader should be a person who easily understand and smart to overcomes problem. Cleverness is believed can be gained by education.
3. Clever at speaking; meaning that the leader should be talented at speaking, active on communication, and able to convey thought, opinion, advice, and the idea that constitutes the leader`s duty
4. Can be trusted; meaning the leader can hold message, promise, oath, and utterance firmly. There is a proverb that says: “Once someone makes a forgery, other people will not believe him forever” (sakali lancuang ka ujian, saumua hiduik urang tak pacayo)

Based on the previous information, the leader must be someone that is intelligent, talented at speaking, truthful, and can be trusted. This character shows that he can learn and understand the given knowledge easily.

However, based on the interview, the tribe leader does not understand about the earthquake resistance building. The main reason is the message and knowledge about the building and earthquake yet reached them.

Therefore, this study recommends that by educating the tribe leader about the building performance under earthquake load and discuss a different type of predominant RC building in Padang city under a different level of earthquake load with them.

By using fragility function with simplification on the information and show the performance of the different type of building in a different location in Padang City, they can learn that different case of a building, and different strength of RC building will influence the performance of building when the earthquake comes.

8.2.3. The Mechanism of the Empowerment of Minangkabau Tribe Leader

Figure 8.2 shows the strategy to reduce the disaster of RC Building in Padang City. Current construction mechanism normally involves construction stakeholders (designer, contractor, and supervisor), and government. However, that mechanism works effectively for mid to high rise building in general. Meanwhile, for low rise building especially residential building, this mechanism provides very less support due to less supervisor from local government (see chapter 4, subchapter 4.6). Hence the quality of low rise RC buildings become poor as evidence that emphasized and explained in previous chapters.

As explained on sub-chapter 8.1 the approach to reduce disaster cannot fully succeed, without bottom-top action or increasing the “self-assistance” efforts. Hence, in this mechanism (see Fig.8.5) the tribe leader will be the key person who can bridge the earthquake risk awareness to the people under their leadership.

Since 70% of land in Padang City is the tribe land, and the leader has a significant influence to manage and take a decision regards the tribe land, this study proposed to empower them. By using the fragility curves and damage

patterns from many simulation results of predominant RC Building type in Padang City, the information about the building performance under earthquake load can be delivered. The information about the probability of the building might be damaged or not damaged, under earthquake load for some building, or some cases for the building can influence their decision about the RC Building.

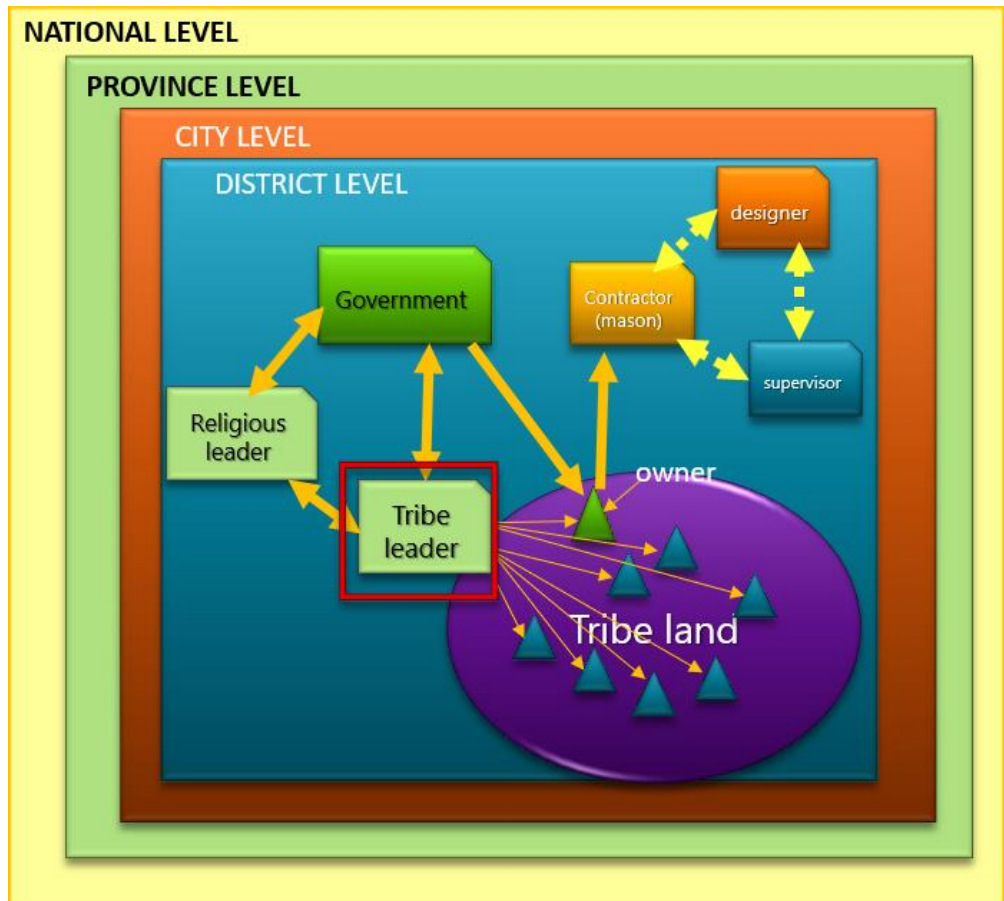


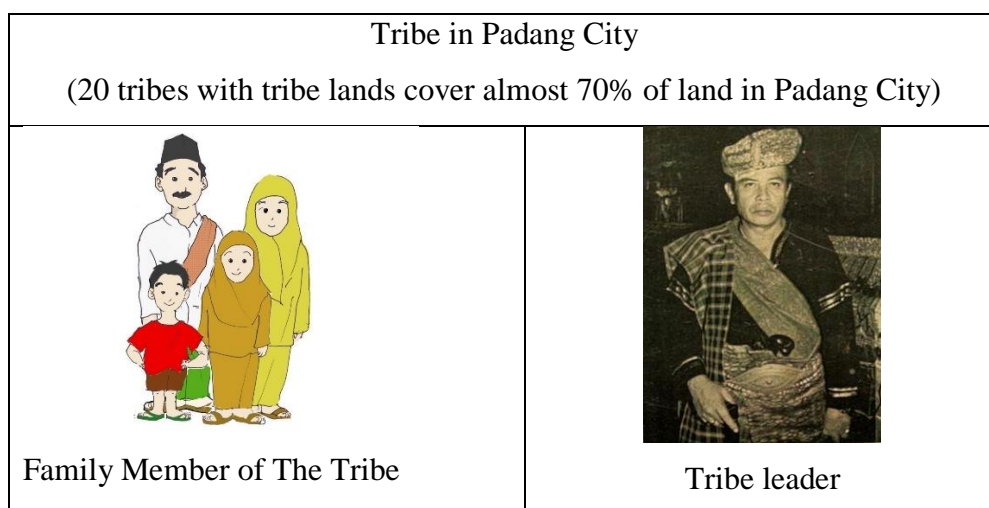
Figure 8. 2.. The mechanism of the community to empowerment the tribe leader for disaster reduction of RC Building

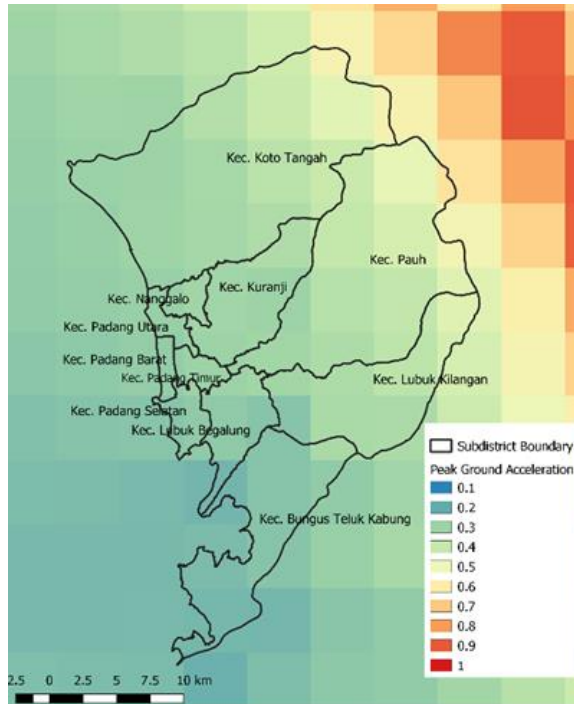
The scenario on this strategy is

1. By cooperating with the local government and tribe organization, the meeting with the tribe leader will be held.
2. The disseminated material including fragility curve, PGA distribution map, and simple information about the scenario when a family in their tribe want to construct an RC building in their land

3. Find the location of the tribe-land in the map with PGA distribution.
4. Referring to the information on the PGA level from the map is obtained, the fragility function can show them the probability of the building in some cases to be damaged or damage at the referred PGA level.
5. Since the fragility curve can show some cases of the buildings, for example, type of RC building, or RC building with strong concrete and weak concrete, they can learn how to make decision on what type of building that should be constructed on their land or can avoid their building to be constructed with the weak concrete strength.

This study also tried to transform the information of fragility function and seismic map as the scientific tools into simplified risk information of RC Buildings under earthquake load in Padang City. By using their memories and experience, the tribe leader could imagine the earthquake shaking, and by using developed fragility function, the tribe leader can have information about their building performance that might be constructed or exist in their land. The detail mechanism can be found in Figure 8.3. below.

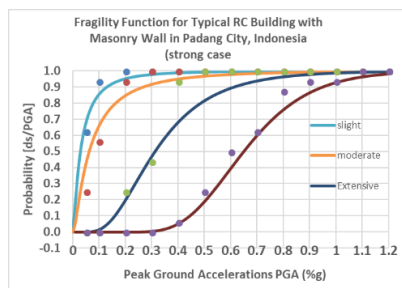




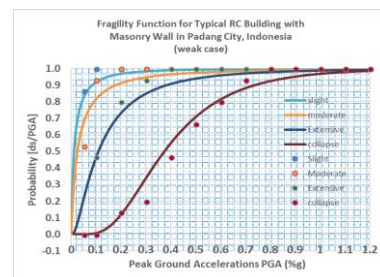
Padang City PGA Distribution Map

- 1) Find the location of Building in Tribe land
- 2) The tribe leader points the location in Padang City in PGA distribution map
- 3) Show the coordinate
- 4) Show the value of PGA at the location
- 5) Find the information of the building condition when earthquake such as 2009 earthquake happen again
- 6) Check the building condition using developed fragility function

Simplified Procedure for RC Building Risk Information for Minangkabau Tribe



Strong Case

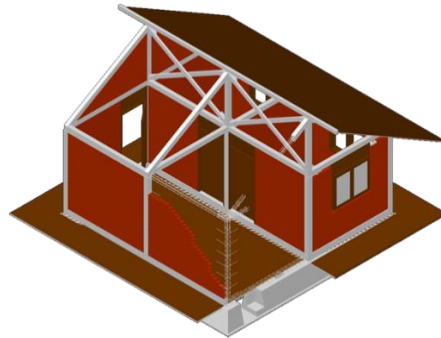


Weak Case

Example of Information for Minangkabau Disaster Reduction Action Mechanism

Tribe Name	Jambak
Tribe leader	Rizal
Location of land	Pauh (coordinate)
Average PGA	0.25

Weak Building	Collapse or damage
Strong Building	Not collapse



The Tribe Leader advice and give an additional requirement for tribe member who wants to construct RC building in the tribe land, to be committed to build a strong and earthquake resistant building for a new building or increase their existing building capacity by using available strengthening method, for example, PP-Band Mesh Strengthening Method.

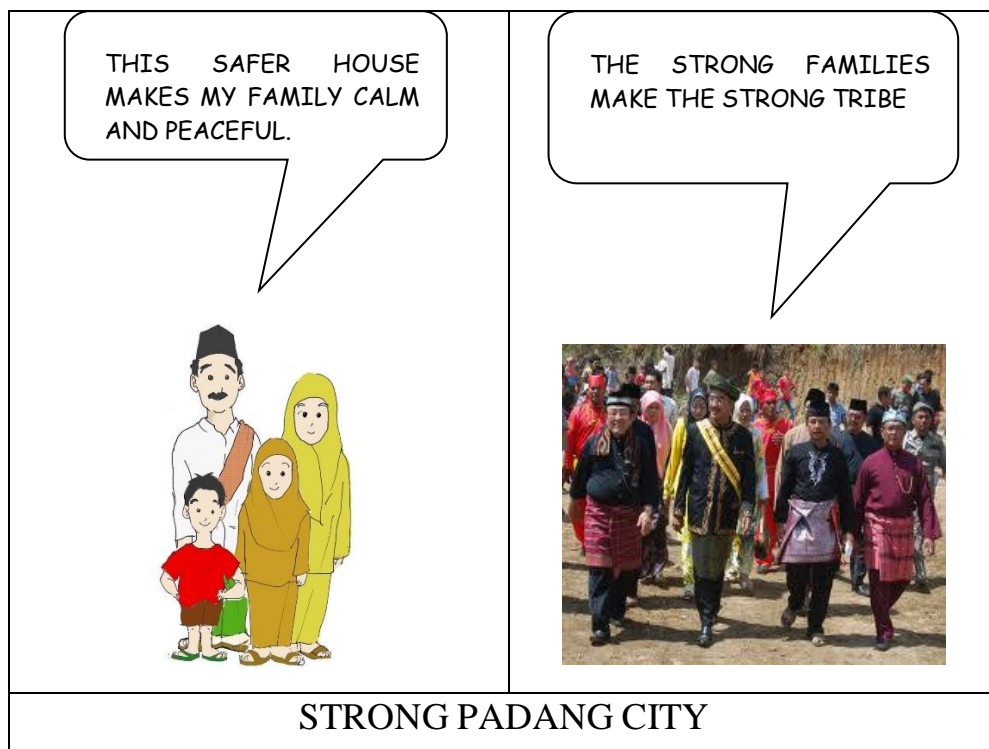


Figure 8. 3.. The Steps to Transform the Risk Information from Developed Fragility Function to Disaster Reduction Action Mechanism based on Empowerment of Indigenous Tribe in Padang City

8.4 Reference

- [1] Agrawal, A., 1995, 'Dismantling the divide between indigenous and scientific knowledge,' *Development and Change* 26, 413–439.
- [2] Kelman, I., Mercer, J. & Gaillard, J.C., 2012, 'Indigenous knowledge and disaster risk reduction,' *Geography* 97(1), 12–21.
- [3] Nyong, A., Adesina, F. & Osman Elasha, B., 2007, 'The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel,' *Mitigation and Adaptation Strategies for Global Change* 5, 787–797.
- [4] Jabulani, S., 2007, 'The challenges faced by African libraries information centers in documenting and preserving indigenous knowledge,' *IFLA Journal* 33(2), 117–123.
- [5] Shaw, R., Takeuchi, Y., Uy, N. & Sharma, A., 2008b, *Indigenous knowledge: Disaster risk reduction, policy note*, United Nations International Strategy for Disaster Risk Reduction, Kyoto, Japan.
- [6] Dekens, J., 2007, 'Local knowledge for disaster preparedness: A literature review,' *International Centre for Integrated Mountain Development*, Kathmandu, viewed n.d.,
from <http://www.preventionweb.net/publications/view/2693>

CHAPTER 9

CONCLUSIONS AND RECOMMENDATION

Padang City is the capital city of West Sumatra province, Indonesia, located on the western coast of Sumatra island. On September 30th, 2009 at 17:16:09 West Indonesian Time (WIB), an earthquake with 7,6 magnitudes on scale Richer (SR) happened. Padang city becomes the most damaged areas due to this earthquake, with more than 1000 fatalities. Building damage was dominated by housing, school, and office which made from Reinforced Concrete (RC). With the increasing population rate in Padang City and the threat of predicted Mega-Earthquake in the future, the effective disaster reduction strategy for RC buildings in Padang City is a must.

The objective of this research is:

1. To develop fragility function as the assessment tools for disaster reduction of RC structure in Padang City, Indonesia
2. To identify the environmental system which contributes to the quality of RC building and studies the structure of the local community
3. To build the timeframe of disaster reduction action for RC building in Indonesia
4. To provide the actual condition of RC building in Padang City
5. To propose a new function for fragility curve with the account the effects of ground motion frequency and Peak Ground Acceleration

Conclusion on the environmental system in Padang City.

By using the analysis of building documents, street survey and google street view, have been found RC building dominates more than 85% of the building population in Padang City. The field observation and the interview with building officers also found that even though the building code keeps improving, but due to the limitation on building staff number, the supervision effort is limited. This situation results in the poor quality of concrete, reinforcement arrangement and other building defects as the finding in our field survey. In case of this situation, the building owner has a crucial position to make the final decision for their building quality.

Conclusion on a study on the structure of the local community in Padang City

This research also found the structure of the local indigenous community in Padang City and West Sumatra in general. West Sumatra has a unique culture which dominantly influenced by the indigenous Minangkabau tribe system. The Minangkabau system regulates the land acquisition system in the Padang area and another area in West Sumatra, which based on matriakhat (mother line) family system. The land which covers more than 70% of the total land area must be inherited from generation to generation to woman in the tribe. Then, by the time, the land area becomes not clear and complicated for the government to manage including to control building construction. However, the tribes have their leader who is called “mamak” that control the use of the land, including managing the family member that wants to construct a building in the tribe land.

Conclusion on the study on review and developing the timeframe for disaster reduction action for RC Building in Indonesia

The time frame of disaster reduction action for RC building in Indonesia categorize the activities into 3 (three) levels, which are building law/code/standard level, which is the main reference for every building and disaster action regulation in national and local level. The last improvement is the amendment of Indonesia seismic code and RC building code. The second level is the regulation for strengthened the code implementation. One of the newest actions is the release of regulation for Indonesian Seismic Agency and the certification for the builder in Indonesia. The last one is the implementation level, which includes the activities of a government agency, social community or local community. About the previous finding and consideration of using the local wisdom of the indigenous system, the empowerment of the local community to strengthen the disaster reduction action is needed to be increased.

Conclusion on the field study and development of RC building fragility function

Through the field study, fundamental information that is needed to conduct analytical fragility function was obtained. The material properties and geometry of existing RC building were used as the input material and geometry for a numerical model which

has been developed by using the Applied Element Method. As the method that can follow the building failure till collapse state, the AEM enable the observation of the damage patterns for each intensity level accurately. Finally, some fragility function for five typical RC buildings in Padang city which cover 64% of the total RC building population can be obtained. The comparison between average actual damage ratio of 2009 September earthquake in Padang City and average damage ratio based on developed fragility function show a good correlation. In the slight damage level, the gap is big, which might be due to difference damage pattern observation and judgment results between the actual one and numerical study. Meanwhile, the severe damage or over and moderate damage or over show a good comparison. This comparison can show that developed fragility function can show an actual performance of low rise RC buildings in Padang City.

However, the limitation on modeling the beam-column joint area and variation of building dimension/layout should be considered as one factor that seems to contribute to some difference of damage ratio at sub-district level. The local site condition also did not consider in this study. The other factor could be the difference between construction method quality. Construction method highly contributes to the final quality of constructed RC building.

Finally, in the last chapter, this study tries to arrange a mechanism to use the fragility function to inform the local community through indigenous Minangkabau Tribe leader in Padang City. Consider that the tribe leader was chosen due to his intelligent and his ability to convey information, there is a hope that they can achieve a good understanding about the RC building under earthquake load through fragility curve and the visualization of some damage patterns from RC buildings. This study also tries to transform the information of fragility function and seismic map as the scientific tools into simplified risk information of RC Buildings under earthquake load in Padang City. By using their memories and experience, the tribe leader could imagine the earthquake shaking, and by using developed fragility function, the tribe leader can have information about their building performance that might be constructed or exist in their land. Hopefully, that can increase their awareness and knowledge to influence their decision which also can have an impact on the families on their tribe decision when constructing RC building in their land or give

encouragement to reduce the damage level of their existing building by strengthening their building using available strengthening method, for example, PP-Band Mesh Method.

Recommendations

1. The building typology that obtained in this study can be used by the government to update the building data inventory in Padang City.
2. The government can use the fragility function based on the actual condition that obtained as the tools to make Padang City vulnerability map and the preparedness for earthquake disaster
3. The tribe leader can be empowered to help the government reduce disaster of RC building in Padang City. The mechanism which developed in this study can be used by the government to inform, disseminate and increase the awareness of the local community towards earthquake resistance RC building

Limitations

The limitations of the study are as follows:

- This study finds the environmental system in Padang City. There should include another component that can be accountable for the system that contributes to the RC building in Padang City. This study covers the building typology, construction method and indigenous system in Padang City
- The buildings models selected for numerical simulation includes only low storey RC building, which covers 64% of total RC building population. Other RC building types yet been analyzed and represented in the fragility curve.
- This study is yet updating seismic hazard map and ground motions which is also part of components for risk assessment.

Future Research Direction

There are two central area where the future research can enhance the disaster reduction strategy and development of fragility function in Padang City

1. Developed fragility functions for other building types

Development of fragility functions for other RC building types and another type of building typology for example timber building and steel building to provide complete tools for Padang City.

2. Developed fragility function that considers the improper detailing in beam-column joint area

Many observed RC buildings show improper detailing in the beam-column joint area which is a dominant defect that increases the vulnerability of RC buildings under seismic load. The research regards to this condition is important, and the development of fragility function by modeling this area is necessary to do in the future

3. Update of fragility functions using earthquake damage data

The developed fragility functions should be updated if the earthquake damage data and acceleration distribution are obtained in future earthquakes. There can be several possible options for availability of earthquake damage data as well as ground motion distribution.

4. Held the meeting to disseminate the fragility curve and find the feedback from the tribe leaders and also the government

5. Since the awareness, knowledge level and the condition of the local community will be different in time, it is necessary to study and evaluate their condition and adjust the mechanism that has been developed in the future.