BUILDING REPLACEMENT COST FOR SEISMIC RISK ASSESSMENT IN PALBAPANG VILLAGE, BANTUL SUB-DISTRICT, YOGYAKARTA INDONESIA

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Thesis submitted to the Double Degree M.Sc. Program, University of Gadjah Mada and Faculty of Geo-Information Science and Earth Observation, ITC, University of Twente in partial fulfillment of the requirement for the degree of Master of Science in Geo-Information for Spatial Planning and Risk Management

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THESIS

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Disclaimer

This document describes work undertaken as part of a program study at the Double Degree International Program of Geo-information for Spatial Planning and Risk Management, a Joint Educational Program of Faculty of Geo-information and Earth Observation University of Twente – The Netherlands and Gadjah Mada University – Indonesia. All views and opinions expressed therein the sole responsibility of the author and do not necessarily represent those of the institute.

I certify that although I may have conferred with others in preparing for this assignment, and drawn upon arrange of sources cited in this work, the content of this thesis report is my original work.

Signed……………………

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Abstract

Yogyakarta region especially Bantul listed in Indonesian seismic zoning as one of the most earthquake prone city in the country. The 2006 earthquake in Bantul created a lot of victims caused by the fallen building materials. The replacement cost on building damaged by Government was not representing the appropriate way on building losses due to earthquake. For that reason, more studies on building loss estimation are needed. This research was intended to analyze the use of HAZUS methodology in building replacement cost for seismic risk assessment in Indonesian practice.

HAZUS is a Geographic Information System (GIS) based software tool developed in the United States that supports the evaluation of hazards and assessment of inventory and loss estimates for the kind of hazards, in this case was earthquake hazard. The research was divided into three major stages; identification and generation of the dataset, modifications of building inventory required in HAZUS for calculating building replacement cost and the last stages is evaluation in the use of HAZUS for building loss estimation in the study area.

The Palbapang Village in Bantul Sub-district was taken as the study area in the implementation of HAZUS. It was selected as a study area due to the densely populated mix of urban and rural communities. *The Unreinforced Masonry* (URM), *Reinforced Masonry* (RM2), *Steel Moment Frame* (S1) and *Wood Light Frame* (W1) have been selected as most representative buildings in the study area. The HAZUS damage probability matrix has been developed for each model building types showing the four probability of building damaged; *Slight, Moderate, Extensive and Complete*. The URM was considered as the most building with a higher risk and shows the highest in replacement cost while the S1 has a lowest in building replacement cost.

The calculation of damage probability and building replacement cost by HAZUS seems not giving a realistic results in Indonesian practice. It needs a detailed modification and re-defining of building structures and occupancy class on the application of HAZUS in Indonesia. The methodology on the data collection also needs to be simplified in giving more accurate results in Indonesian practice.

Keywords: earthquake, hazard, seismic risk assessment, HAZUS

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Abbreviations

ADPC	Asian Disaster Preparedness Center
BAKOSURTANAL	National Coordinating Agency for Survey and Mapping
BAPPEDA	Regional Board for Planning and Development
BAPPENAS	National Development Planning Board
BNPB	National Disaster Management Board
BPN	National Land Agency
BPS	Central Bureau of Statistics
DEPKIMPRASWIL	Public Works Affair
ERA	Earthquake Risk Assessment
FEMA	Federal Emergency Management Agency
GBS	General Building Stock
GIS	Geographic Information System
GPS	Global Positioning System
HAZUS	Hazard United States
IDR	Indonesian Rupiah
ITC	International Institute for Geo-information Science and Earth Observation, The Netherlands
JEP	Joint Educational Program
JRF	Java Reconstruction Funds
MDR	Mean Damage Ratio
MMI	Modified Mercalli Intensity
NGO	Non-Governmental Organization
PGA	Peak Ground Acceleration
PEMDA	Local Government
POKMAS	*Kelompok Masyarakat* (Society Groups)
RADIUS	Risk Assessment Tools for Diagnosis of Urban Areas Against Seismic Disasters
RBI	Topographic Map
RC	Reinforced Concrete

RM	Reinforced Masonry
RS	Remote Sensing
RT	*Rukun Tetangga* (sub area of village)
UGM	Gadjah Mada University, Yogyakarta
UN-ISDR	United Nations International Strategy for Disaster Reduction
UNDP	United Nations Development Program
UNDRO	United Nations Disaster Relief Organization
URM	Unreinforced Masonry
USGS	United States Geological Survey

1. INTRODUCTION

This chapter describes the context of the study, background of the research, problems statement, research objectives, research questions and benefits of the research. This research will focus on buildings as element at risk and the replacement cost in order to give the best standards replacement cost for building losses due to earthquake disaster

1.1 Background

Earthquakes have long been feared as one of nature‟s most devastating natural hazards. When seismic waves reach the surface of the earth at such places, they give rise to what is known as ground motion. A strong ground motion causes buildings and other structures to move and shake in a variety of complex ways.

Earthquakes continue to remind us that nature can strike without warning and leave casualties and damage. On May 27 2006, an earthquake with a magnitude of 6.3 on the Richter scale (Figure 1) hit Central Java, Indonesia, causing considerable damage in the Bantul District, south of Yogyakarta, and the large surrounding area including the outskirts of Yogyakarta. Although the magnitude of the earthquake was rather moderate, dwelling house damage and human casualties severely affected densely populated farming villages and towns in the urban area of Bantul City (low-medium seismic hazard but high seismic risk). USGS (2006) predicted that the ground shaking in Bantul and its surrounding area reached a scale of VIII MMI (Modified Mercalli Intensity). According to an early report (BAPPENAS, 2006), the total death toll was 4,121 in Bantul and 79,890 housing units were destroyed (appendix 1).

Earthquake associated risk poses an obstacle to developmental process as well as a threat to the livelihood of the resident population, especially in developing countries (Ponnusamy, 2010). The lack of handling disaster management leads to an increase in risk in more densely populated cities. As one of the developing countries, Indonesia is already loaded with various urban problems like population growth, urban sprawl, lack of economic/financial strength and building density while on the other side it is also facing an earthquake disaster threat. This country has a high seismic activity due to the geographical location situated at the confluence of three major tectonic plates colliding with one another: Eurasian Plate, Indo-Australian Plate and Pacific Plate. Almost 60% of the Indonesian cities lies in a high risk seismic zone or with (approximately 290 of 481 cities) (IUDMP, 2001).

Figure 1 General location map and epicenter near the Yogyakarta City
Source : *http://mae.cee.uiuc.edu/publications/research_reports.html#2006*

An earthquake becomes a huge disaster when a large number of settlements are affected. Buildings in urban areas are highly vulnerable structures especially in developing countries like Indonesia due to the poor implementations of building regulation. In Indonesia, the building types are classified by The National Standard of Building (SNI) of Indonesian Public Works Affair (DEPKIMPRASWIL, 2002).

Earthquake damage and loss estimation is a very complex analysis process but also a very useful tool to create, preparing and developing emergency preparedness plans for seismic risk assessment. A Geographic Information System (GIS) and Remote Sensing (RS) are tools which have a capability to overcome the difficulties in evaluating the damage of urban infrastructures in pre-disaster or post-disaster events. (Chiroiu, Andre, & Bahoken, 2001) state that the recent progresses of remote sensing in terms of spatial resolution and data processing are opening new possibilities concerning natural hazard assessment while GIS can be used to display the spatial distribution of damages. When earthquake occurs, most of loss of life and property is caused by the damage of the densely occupied weakest buildings that are located in earthquake hazard zone. Therefore with the advancement of RS-GIS techniques, forecasting the expected losses of buildings for seismic risk assessment can help the urban planners and local authorities to make programs for disaster management.

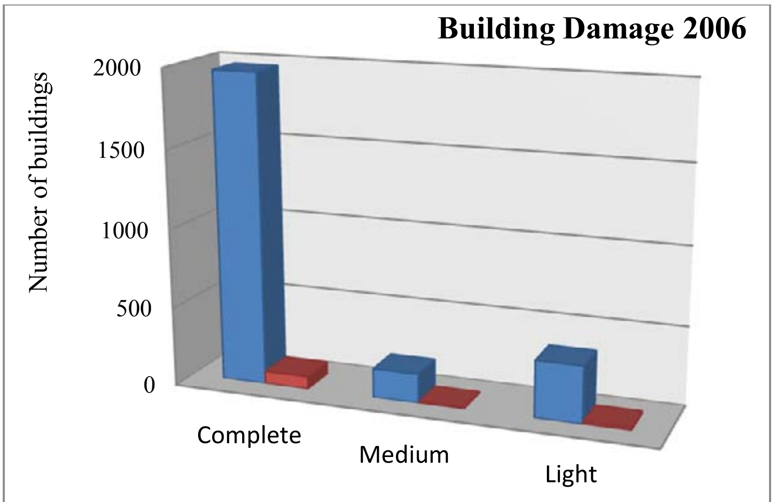
There exist a direct relationship between the damage to building construction and the number of casualities. Montoya (2002) states that most casualities, damage and economic losses caused by earthquake result from ground motion acting upon buildings incapable of with standing such motion. Damage to buildings also causes a variety of secondary effects that can be greatly destructive (Gulati, 2006). The destroying effects of disaster cause on economic asset of the region. Direct losses such damages of buildings can cause indirect losses of business activities, economic and services. In order to estimate probable future losses in earthquake prone regions, cost estimation of the potential damage can be used as a technique. Market prices can be used in ways when valuing the effect of earthquake to the replacement cost of building damage as element at-risk.

In the framework of Joint Educational Program (JEP) between UGM and ITC, the author with 2 other researcher from JEP doing a research project on seismic risk assessment using different research approaches; generating data base with cadastral data and modeling HAZUS for building damage assessment. The location of the study area is Palbapang Village Bantul Sub-district. The data of damage assessment in Bantul from previous reports by UGM and ITC staff were used besides the data from field survey. In this research project, the author wants to emphasis the replacement cost in the framework of seismic risk assessment. The HAZUS multi-hazard loss estimation methodology is considered as a tool for estimating building loss due to earthquake in terms of monetary.

1.2 Building Damage based on Preliminary Damage Assessment in 2006

The earthquake occurred early on 27 May 2006 at a shallow depth of approximately 10 km and 20 km SSE of Yogyakarta. Only limited damage occurred in Yogyakarta; the district of Bantul however suffered the most. Almost 6000 people died and an estimated 154.000 houses were destroyed in Yogyakarta and surroundings (Kerle & Widartono, 2008). Preliminary estimates of damage exceed 3 billion US$ of with over 50% is caused by housing damage (BAPPENAS, 2006).

The building damage in the study ward, Palbapang Village, was derived from previous reports on rapid damage assessment of buildings after earthquake 2006 by UGM staff and students in collaboration with Norman Kerle, ITC. The damage assessment was divided into 3 classes which are complete damage, medium damage and light damage. Various of occupancy class type were found; which are government buildings, educational buildings, commercial buildings and residential. Among all 3014 buildings were mapped using rapid survey method among which 2513 residential. The rest of the occupancy types were commercial, educational and government buildings. The percentage of complete damage is higher compared to medium and light damage; this was 79% as shown in Figure 2 below.



	Complete	Medium	Light
Building count	1969	184	360
Percentage	79	7	14

Figure 2 Number of building damage in study ward according to rapid damage assessment by Kerle (2006)

1.3 Problems Statement

Urban earthquake risk today derives from the combination of local seismicity - the likelihood of a large-magnitude earthquake - combined with large numbers of poorly built or highly vulnerable dwellings (Coburn & Spence, 2002). Most casualties, damage and economic losses caused by earthquakes result from strong ground motion acting upon buildings incapable of withstanding such motion. It is for this reason that it is often said, "Earthquakes don"t kill people, but buildings do" (Montoya, 2002).

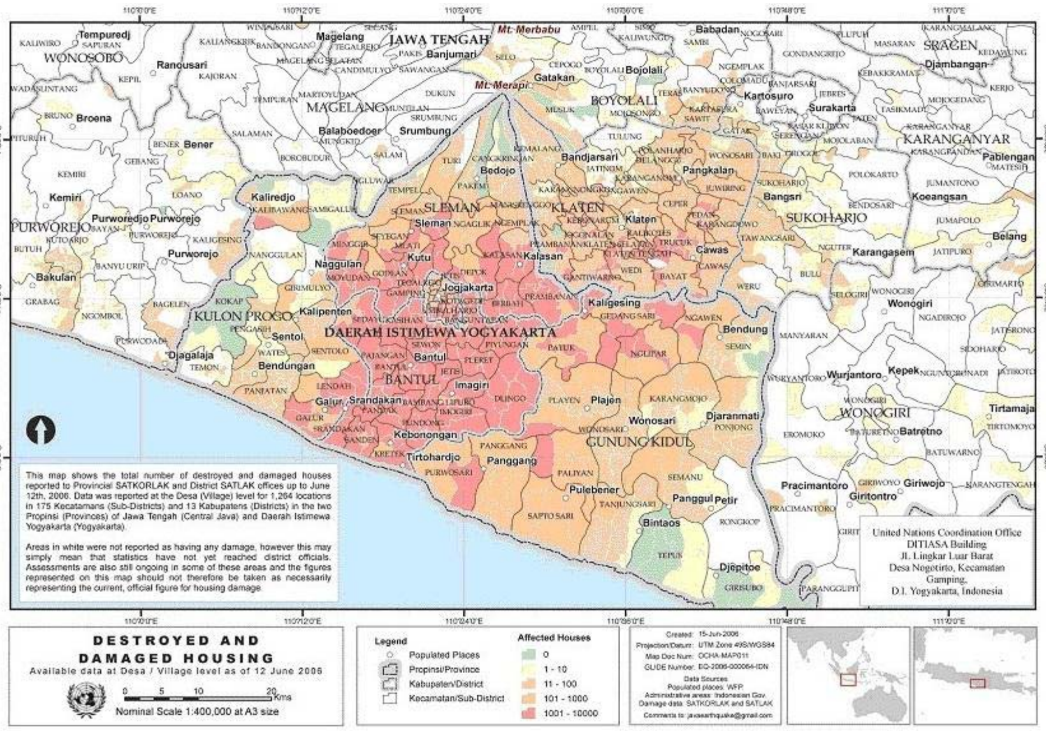


Figure 3 Destroyed and damaged housing in Yogyakarta area and surrounding (IASC-UN, 2006)

Yogyakarta region especially Bantul area is a prone area for earthquake. When earthquake strikes on 27 May 2006, a lot of buildings were damaged. With an epicenter approximately 20 km SSE of Yogyakarta nears the densely populated of Bantul District. It is difficult to predict which city will become the next victim. In this aspect, it is always important to study and evaluate the vulnerability of existing infrastructure systems and find out the expected losses before an earthquake in terms of monetory losses.

The study area, Palbapang Village, is located in Bantul Sub-district Bantul Regency, approximately 25 km south from the center area of Yogyakarta City. Palbapang was selected as a study area due to the densely populated mix of urban and rural communities. According to (DMC, 2006), the level of building damaged in Palbapang varies from collapsed and heavy damaged; 1,784 and 1,430 buildings. The total of all buildings is 3,214, which is higher compared with the rest of the villages in Bantul Sub-district.

During post-disaster events, the Indonesian Government starts to rebuild facilities and provide payment to people whose houses have been damaged. According to BAPENAS (2006), Vice President of Indonesia has announced that IDR 30 million will be provided for each destroyed house, and IDR 10 million for damaged houses. This is not an appropriate way of repayment on building losses because replacement cost should use the market values instead of the values which are not based on anything. They don"t represent the actual values as the market values do.

The market values can be derived from recent building transaction in certain areas, in this case Palbapang Village. Between 2007, when houses rebuilding started until 2010, during the field work survey, not much market price could be found in the study area. This is also strengthened by the fact the recent population data of Palbapang Village that shows not much increase. In the absence of market values, the values of buildings which are based on the data of the Tax Office for taxation purpose and the price that comes from the house owner will be used as a basic standard to determining replacement cost on buildings.

One of the standardized tools for earthquake loss estimation is HAZUS developed in the US in 1997 by The Federal Emergency Management Agency (FEMA). It was released in response to the need for more effective national-state and community level planning and the need to identify areas that face the highest risk and potential for loss. HAZUS-MH is a Geographic Information System (GIS) based software tool that supports the evaluation of hazards and assessment of inventory and loss estimates for the kind of hazards (DMA, 2007). In HAZUS, the seismic performance of typical buildings in the US is given. The seismic performance of buildings, however, should be region-specific because of the different design level and construction quality in each region. It is not appropriate to apply the building performance in HAZUS to other regions (Miura, 2008). It requires therefore some modification in the application of HAZUS model for implementation in Indonesia.

The study of building damage type has been done in several big cities in the world, for instance; New York by Tantala (2001), Dehradun by Gulati (2006) and Yogyakarta by Sarwidi (2006). The research in New York by Tantala has been using the HAZUS method. Building damage analysis has been done in the standard format of HAZUS in every state in the US. Estimation on building damage in Dehradun was also using HAZUS method with some modification of the parameter input of building inventory.

Sarwidi (2006) adopted *fragility curves* on dwelling house developed in the US and Taiwan to estimate the damage of buildings due to earthquake disaster on May 27, 2006 in Yogyakarta. The curve was developed based on observed damage of many seismic events, showing relationship between *peak ground acceleration* (PGA) and the damage level of building. It was assumed that the curve follows the log-normal distribution (FEMA, 2003).

The study of building loss estimation using a specific method such as HAZUS is very limited in Indonesia especially in Yogyakarta Province. For that reason, more the studies on building loss estimation are needed. This research will focus on buildings as the element at risk and the replacement cost using HAZUS methodology in order to estimate replacement cost for building losses due to earthquake disaster.

1.4 Research Objectives

The main objective of this research is analyzing the use of HAZUS methodology in building replacement cost for seismic risk assessment in Indonesian practice. The main objective can be detailed in several specific objectives:

1. To identify and modify the parameters of seismic risk assessment that are required in HAZUS for building loss estimation in the Indonesian practice
2. To estimate the building replacement costs due to the Yogyakarta earthquake of 2006 using deterministic earthquake scenarios in the HAZUS methodology
3. To evaluate the use of HAZUS methodology for seismic risk assessment in building loss estimation in the Bantul Sub-district

1.5 Research Questions

No	Research Objectives	Research Questions
1	To identify and modify the parameters of seismic risk assessment that are required in HAZUS for building loss estimation in the Indonesian practice	1. What modifications are needed in terms of data availability to apply HAZUS methodology in Indonesian practice? 2. What are the limitations in HAZUS methodology for seismic risk assessment on building structure in Bantul Sub-district?
2	To estimate the building replacement costs due to the Yogyakarta earthquake of 2006 using deterministic earthquake scenarios in the HAZUS methodology	1. How to identify and collect the data of building within the homogeneous in mapping unit? 2. How to determine building structural mean damage factors in a census track?

		3. How to estimates the money loss of buildings per census tract level? 4. How to calculate the building replacement cost using HAZUS methodology?
3	To evaluate the use of HAZUS methodology for seismic risk assessment in building loss estimation in the Bantul Sub-district	1. How to evaluate and validate the HAZUS methodology of building replacement cost? 2. How the difficulties in the use of HAZUS methodology for calculating loss estimation in Bantul Sub-district?

1.6 Benefits of the Research

1. The HAZUS methodology can be applied, adopted and implemented in Indonesia
2. Replacement cost on the building damage using HAZUS methodology would help the government after disaster occurs in order to estimate replacement cost for building losses due to earthquake disaster
3. It could be used as consideration in formulation of loss estimation and replacement cost on the building damage due to earthquake disaster in Indonesia

1.7 Limitation of the Research

The current study has a limited scope due to the limited time and sources. This research has estimated the replacement cost of buildings using deterministic earthquake scenarios which is The Yogyakarta earthquake of 27 May 2006 with Mw 6.3. Residential buildings are considered taking into account while the other types of occupancy class like government buildings, commercial buildings and hospital are not. The estimation of non-structural damage of buildings also cannot be done due to the limited of data sources.

1.8 Expected Output

The expected outcomes of the research are:

1. Generating building damage on structural damage.
2. The HAZUS methodology can be applied, adopted and implemented in Indonesia

1.9 Outline of the Research

This research is design in seven chapters, which are:

Chapter 1 describes the context of the study; background of the research, problems statement, research objectives, research questions benefits of the research and the expected output

Chapter 2 provides the literature review which contains some reviews of the literatures related to the works in the study. Brief explanations are given on general terms of risk assessment, hazard and seismic risk assessment, building replacement cost, seismic zoning of Indonesia, loss estimation methodology and the use of remotely sensed data and GIS. The theoretical background in the literatures will be used as the basis in conducting the works of the research

Chapter 3 introduces the general study area of Bantul District and also gives a general idea about its geographical location, geological conditions, hydrological conditions and land use pattern, characteristic of surveyed village in Palbapang , earthquake susceptibility on Java, and building characteristic and its practice in Bantul

Chapter 4 outlines the research methods and tools used for data collection and data needed. The field work stage also describes in three phase, pre-field work, field work and post-field work

Chapter 5 outlines the data preparation needed in building loss estimation. Building data generated from the building inventory during the field work. Generating the building type and occupancy class in HAZUS methodology also done in this chapter.

Chapter 6 provides result and discussion, is about building replacement cost for seismic risk assessment using earthquake deterministic scenarios. Building data generated after the calculation and analysis has been given in this chapter.

Chapter 7 provides conclusion and recommendation. This chapter concludes this study and also some recommendations have been given for further studies and also for local authorities.

2. LITERATURE REVIEW

This chapter contains some reviews of the literatures related to the works in the study. Brief explanations are given on risk assessment and hazard definition, earthquake in Java region, seismic risk assessment, building replacement cost, seismic zone of Indonesia, loss estimation methodology and the use of remotely sensed data and GIS. The theoretical background in the literatures will be used as the basis in conducting the works of the research

2.1 Risk Assessment

The word *risk* refers to the expected losses that related to lives lost, persons injured, damage to property and disruption of economic activity from a given hazard and it is became to the product of hazard, vulnerability and the amount (such as building replacement cost) of the element at risk. As defined by the Federal Emergency Management Agency (FEMA, 2003), risk is "a combination of hazard, vulnerability and exposure or amount. The amount refers to the quantification of the element at risk, for instance rebuilt or replacement cost of buildings, loss of economic activity and number of people loss" (Westen et al, 2009).

Risk assessment process identifies relevant hazards and assesses the impact. (UN-ISDR, 2004) defines risk assessment as "a methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, livelihoods and the environment on which they depend."

As mentioned in paragraph above, risk is a combination of hazard, vulnerability and exposure or amount. This approach is called a quantitative risk assessment which tries to quantify the risk itself.

Risk = Hazard*Vulnerability*Amount of Elements at Risk

The equation given above can be actually calculated with spatial data in GIS to quantify the risk from hazards (Westen, 2009). The hazard component refers to the probability of occurrence within a specified period of time (e.g. year). The amount of elements at risk in this research refers to the number of building loss and the economic value.

2.2 Hazard

Hazard is "A potentially damaging physical event, phenomenon or activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Hazards can include latent conditions that may represent future threats and can have different origins: natural (geological, hydro-meteorological and biological) or induced by human processes (environmental degradation and technological hazards). Hazards can be single, sequential or combined in their origin and effects. Each hazard is characterized by its location, intensity, frequency and probability."(UN-ISDR, 2004)

2.2.1 Seismic Hazard

An earthquake is "the vibration of the earth"s surface by the release of energy in the earth"s crust." (Montoya, 2002). The earth"s crust consists of portions called plates, when these plates contact each other, stresses arise in the crust. The area of stresses on the plate boundaries that release accumulated energy by slipping and rupturing are known as faults and it causes an earthquake.

2.2.2 Seismic Impact

Generally, the primary impact caused by earthquake consists of ground shaking and ground faulting. Ground shaking can destroy buildings unless it has well planned construction due to earthquake while ground faulting is a vulnerable area situated along the fault that causes earthquake. Both of the events can cause secondary impact which can destroy buildings, devastating rice fields, isolation of settlement area, road networks and liquefaction (PSBA-UGM, 2010).

2.2.3 Seismic Measurements

The severity of an earthquake can be expressed in terms of both *magnitude and intensity.* The magnitude of an earthquake is a quantitative measure of the amount of seismic energy released at the hypocenter. It is estimated from instrumental observation that located at various positions. The most popular measurement of an earthquake is the Richter scale, defined 1936 (Gulati, 2006). While the intensity of an earthquake is a qualitative measure of the actual ground shaking at location during an earthquake assigned as Roman Capital Numerals. Intensity is based on the observed effects of ground shaking on people, buildings and natural features and depending on the location of the observer that respect to the earthquake epicenter and local site conditions. Table 1 gives the approximate relationship between earthquake magnitude in Richter scale and earthquake intensity.

Table 1 Modified Mercalli Scale and Richter Scale (FEMA)http://www.fema.gov/kids/intense.htm

The Modified Mercalli Scale	Level of Damage	The Richter Scale
1 - 4 Instrumen-tal to Moderate	No damage.	4.3 or Below
5 - Rather Strong	Damage negligible. Small, unstable objects displaced or upset; some dishes and glassware broken.	4.4 - 4.8
6 - Strong	Damage slight. Windows, dishes, glassware broken. Furniture moved or overturned. Weak plaster and masonry cracked.	4.9 - 5.4
7 - Very Strong	Structure damage considerable, particularly to poorly built structures. Chimneys, monuments, towers, elevated tanks may fail. Frame houses moved. Trees damaged. Cracks in wet ground and steep slopes.	5.5 - 6.1
8 - Destructive	Structural damage severe; some will collapse. General damage to foundations. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground; liquefaction.	6.2 - 6.5
9 - Ruinous	Most masonry and frame structures/foundations destroyed. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Sand and mud shifting on beaches and flat land.	6.6 - 6.9
10 - Disastrous	Few or no masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Rails bent. Widespread earth slumps and landslides.	7.0 - 7.3
11 - Very Disastrous	Few or no masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Rails bent. Widespread earth slumps and landslides.	7.4 - 8.1
12 - Catastrophic	Damage nearly total. Large rock masses displaced. Lines of sight and level distorted.	Above 8.1

2.3 Seismic Risk Assessment

2.3.1 Hazard Assessment

Hazard assessment quantifies the physical character of a hazard, including probability of occurrence, magnitude, intensity, location and influence of geological factors (Gulati, 2006). Two main methods are used in hazard assessment, seismic macro-zonation and seismic micro-zonation. In this particular study, seismic micro-zonation is used to determine the influence of site effects on the amplification of seismic acceleration, due to soil characteristics, topographic variations and the effect of buildings. Seismic micro-zonation can be divided into probabilistic method and deterministic method.

Probabilistic and deterministic methods play an important role in seismic hazard and risk analysis. Probabilistic method incorporates both historical seismicity and geologic information in a particular level of ground motion at a site during a specific time interval. Deterministic method is based on the calculation of the acceleration related to a particular earthquake scenario and determines the effects from this particular event without considering the likelihood of its occurrence during a specified exposure period.

2.3.2 Vulnerability Assessment

Vulnerability is defined as "the degree of loss to a given element at risk or set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude an expressed on a scale from 0 (no damage) to 1 (total loss) or in percent of the new replacement value in the case of damage to property" (UNU-EHS, 2006). Vulnerability can be expressed or presented in various ways which are vulnerability indices, vulnerability curves, fragility curves and vulnerability tables (Westen et al, 2009). UNU-EHS (2006) in (Westen et al, 2009) describes that vulnerability changes continuously over time and is driven by physical, social, economic and environmental factors. Earthquake vulnerability of a building is defined as the amount of expected damage induced to it by a particular level of earthquake intensity.

2.3.3 Element at Risk

Element at risk refer to all object, persons, animals, activities and processes that may be adversely affected by hazardous phenomena, in a such places, either directly or indirectly. (Westen et al, 2009) defines "elements at risk refer to the population, buildings, economic activities, public services, facilities, livestock, environment etc., that are risk in a given area". (ADPC, 2004) classified the element at risk into physical, economic, societal and environmental elements. The study will concentrate only on the physical vulnerability of the element at risk.

Physical vulnerability refers to the potential for physical impact on the built environment, in this case is buildings. This aspect is related to the characteristics of the element at risk and the intensity and magnitude of the hazard. One of the requirements for assessing the building losses is mapping the element at risk, which is by generating building stock in the study ward.

2.4 Building Replacement Cost

Building replacement cost models within HAZUS are based on industry-standard cost-estimation models published in Means Square Foot Costs. Replacement cost data are stored within HAZUS at the census tract level for each occupancy class. A basic default structure full replacement cost model (cost per square foot) has been determined for each HAZUS occupancy class (FEMA, 2009).

The study about replacement cost on buildings has been done in Indonesia. Sarwidi (2006) on his research about Study Comparative of Earthquake Disaster Losses on Dwelling House in Yogyakarta City adopted *fragility curves* on dwelling house that developed in USA and Taiwan to estimates the damage of building due to earthquake disaster on May 27, 2006 in Yogyakarta. Fragility curves that used in this study only as a tool to predict the damaged building rather than predicting in detail for each type of dwelling house. It is assumed to followed normal logarithm distribution as describes in Figure 4 below.

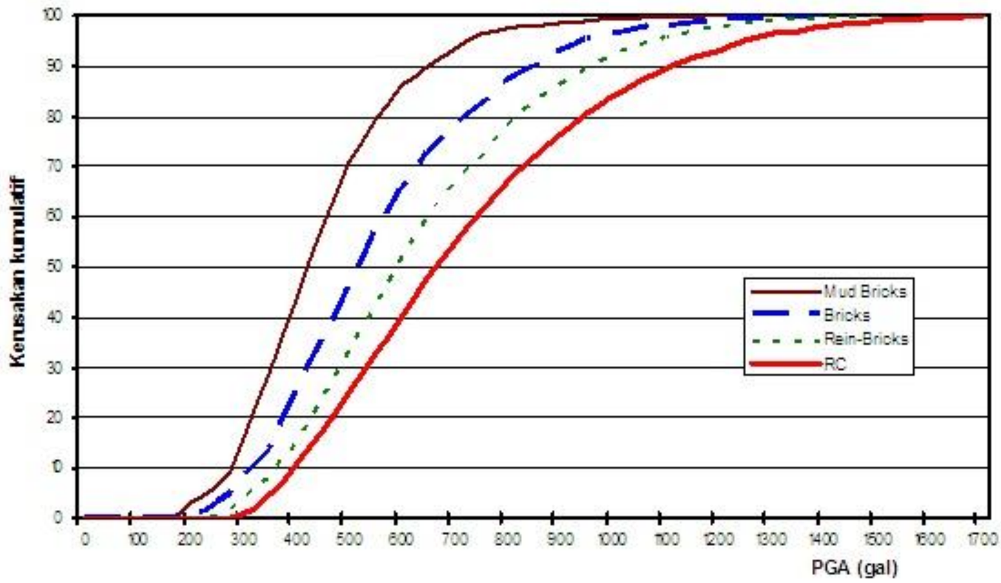


Figure 4 Fragility curves for each type of dwelling house in Yogyakarta City represented the relationship between Damage Cumulative Probability with PGA (Sarwidi & Winarno, 2006)

Sarwidi (2006) states that basically there are five main components in calculating loss estimation on residential unit/dwelling house in this study as shown in the Figure 5 below.

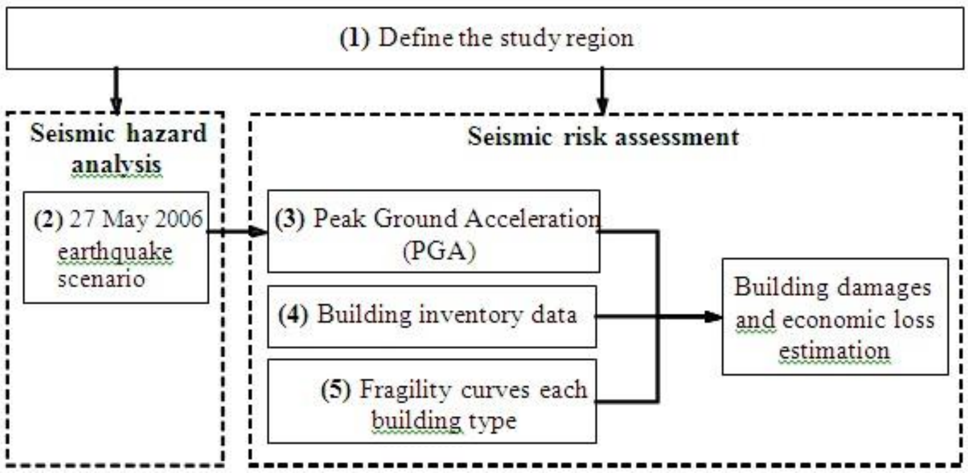


Figure 5 Methodology for calculating loss estimation by FEMA in (Sarwidi & Winarno, 2006)

Syamsudin (2010) on his research title of Seismic Micro-zonation Using Geographic Information System for Earthquake Risk Analysis in Surakarta City adopted HAZUS method to calculate loss estimation on hospital as an essential building. Replacement cost on eleven hospitals in Surakarta City was determined using seismic micro-zonation approach.

2.5 Earthquake in Java, Indonesia

MAE Center Report (MAE Center, 2006) describes that earthquakes around the Island of Java show two distinct features; earthquakes to the north are of deep focus, whilst those to the south have shallower origins of nucleation (Figure 6). The 27 May 2006 earthquake seems to have nucleated closer to the city of Yogyakarta (about 10 km) than first calculated, with a left-lateral strike-slip inconclusive and the depth is a shallow within 10-21 km.

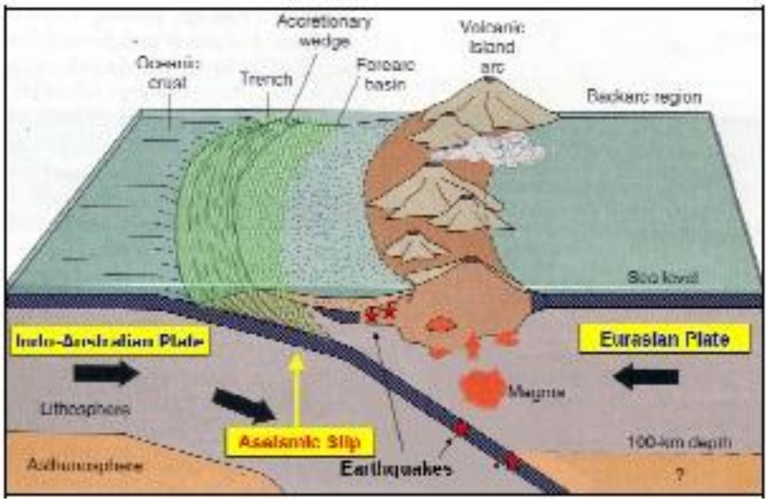


Figure 6 Inter-plate and Intra-plate earthquake potential in Java

The literature on earthquakes in Java Region is abundant. Table 2 indicate that there were many strong events affecting Java and confirm that the tectonics of the region are dominated by the subduction of the Australia plate beneath the Sunda micro-plate. Major earthquakes larger than magnitude 7 have occurred every about 25 years.

Table 2 Historical earthquakes in the Java Region (MAE Center, 2006)

Year	Month	Date	Ms, Intensity or the reported description	Depth (km)
1797	-	-	8.4	-
1833	-	-	8.7	-
1840	January	4	Tsunami	-
1859	October	20	Tsunami	-
1867	June	10	MM>VIII	-
1875	March	28	MM=V~VII	-
1903	February	27	7.9	25
1921	September	11	7.5	-
1937	September	27	7.2	-
1955	May	29	6.38	-
1962	December	21	6.27	-
1963	December	16	6.13	-
1972	May	28	6.2	-
1974	September	7	6.5	-
1976	July	14	6.5	36
1977	August	19	7.9	33
1977	October	7	6.3	33
1979	July	24	6.9	31
1979	October	20	6.2	33
1979	November	2	6.0	25
1979	December	17	6.3	33
1982	March	11	6.4	33
1982	August	7	6.2	33
2006	May	27	6.3	10
2006	July	17	7.7	34

Not very far from the occurrence time when earthquake struck in Bantul and surrounding area, on July 17 2006 at 3:19 PM local time, the USGS reports a magnitude Mw 7.7 occurred off the south coast of Western Java in about 165 miles south of Bandung, Indonesia. The earthquake was centered on the Java trench, the subduction zone between the Australian plate and the Sunda plate at shallow depth. The epicenter was located 34 km deep below the South of Pangandaran coastal resort. The 17 July 2006 earthquake has been generated as a "tsunami earthquake", an earthquake of medium or high scale that triggers a tsunami of high magnitude. At the beginning of August, the Indonesian Ministry of Health reported that approximately 668 people died, 65 were missing and 9299 were in-treatment as a result of the disaster (http://www.searo.who.int/LinkFiles/Indonesia__Emergency_Situation_Report_ESR_11_3_Aug-06.pdf).

The latest deadly earthquake occurred in Java Region was on 2nd of September 2009. The powerful earthquake measuring magnitude Mw 7.3 as recorded by European-Mediterranean Seismological Center, strikes the south cost of Java. The quake struck offshore with the epicenter about 115 km west-southwest of Tasikmalaya City (190 km SSE of the capital Jakarta), at a depth of about 60 km. More than 80 people have been killed with hundreds of structures destroyed or damaged in the city of Tasikmalaya and town of Sukabumi West of Java.

2.6 Seismic Zone of Indonesia

A major earthquake that occurred on a large distance will produce a weak ground shaking. The size of ground vibrations caused by earthquakes that occur in certain places often measured in terms of earthquake intensity. The intensity of the earthquake is a qualitative measure of the actual ground shaking of an earthquake in a certain places and expressed with Roman letters. The value of earthquake intensity varies depending on the measurements location. One unit of earthquake intensity is often used is called Modified Mercalli Intensity (MMI) scale. It varies from I to XII.

Another way to determine the degree of the ground shaking is using *peak ground acceleration* (PGA) which is a maximum acceleration experienced by the soil surface during an earthquake. The empirical correlation between PGA, MMI, perceived shaking and the potential damage that might be happened during an earthquake illustrates as Table 3 below.

Table 3 Empirical correlation between PGA, MMI, perceived shaking and the potential damage (Chen et al, 2003 on (Sarwidi & Winarno, 2006))

PGA (% g)	<0.17	0.17 - 1.4	1.4 – 3.9	3.9 - 9.2	9.2 - 18	18 - 34	34 – 65	65 - 124	>124
MMI scales	I	II-III	IV	V	VI	VII	VIII	IX	X+
Perceived shaking	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
Potential damage	None	None	None	Very light	Light	Moderate	Moderate /heavy	Heavy	Very heavy

According to the seismic zoning of Indonesia from Public Works (DEPKIMPRASWIL, 2002), seismic code in Indonesia considers Yogyakarta Region as a seismic zone 3 among 6 seismic zones (MAE Center, 2006). The expected peak ground acceleration (PGA) for zone 3 varies between 0.18 g and 0.3 g, depending on the soil type. Although the Indonesian seismic code includes ductility detailing requirements, these were not satisfied in many of the damaged multi-story RC buildings. The SNI-03-1726-2002 Seismic Code of Indonesia can be describes in Figure 7 below.

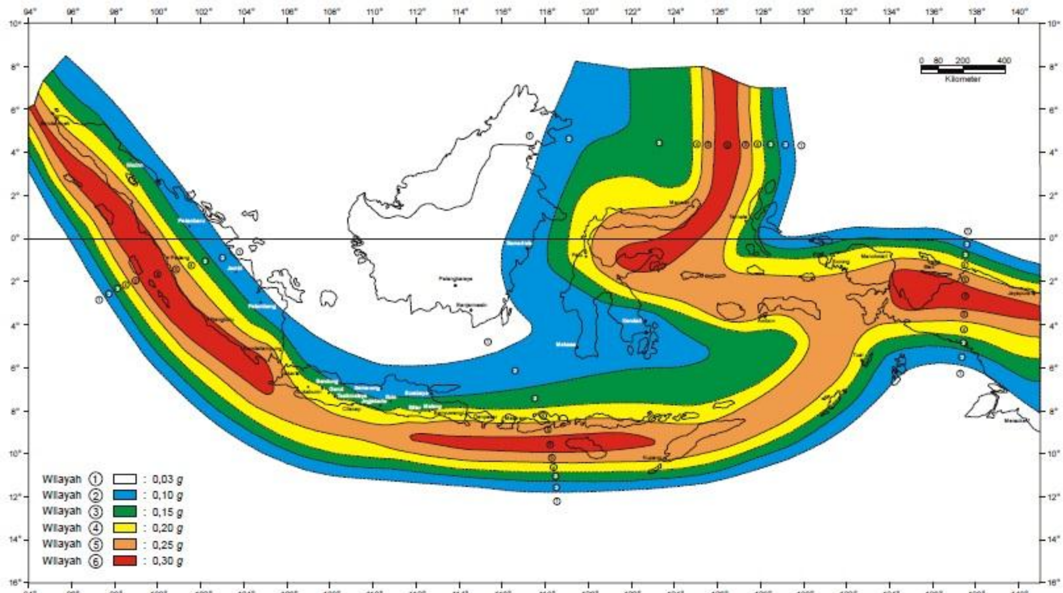


Figure 7 Seismic Zone of Indonesia with 500 years of return period (DEPKIMPRASWIL, 2002)

Figure 7 describes the old seismic zone of Indonesia which divided Indonesia into 6 different zoning. The regions which had the same earthquake intensity illustrates in the same color. The red color describes the regions that have the high risk of earthquake. Yogyakarta placed on region 4 with peak ground acceleration (PGA) maximum is 0.20 g. This map shows in a very small scale. The local characteristic areas like fault types were not explained on detail. The seismic zone of Indonesia was revised in 2010.

The current seismic code in Indonesia (Masyhur Irsyam, 2010) placed Yogyakarta Region with expected peak ground acceleration (PGA) varies between 0.2 – 0.3 g in almost of the whole area of Yogyakarta and 0.3 – 0.4 g in small part of Opak Fault and surrounding areas, as illustrated in the Figure 8 below. Beneath it all indicates even though the earthquake hazard in south of Java Island relatively low-moderate but because located in the densely populated areas, it becomes high in seismic risk (low-medium seismic hazard but high seismic risk).

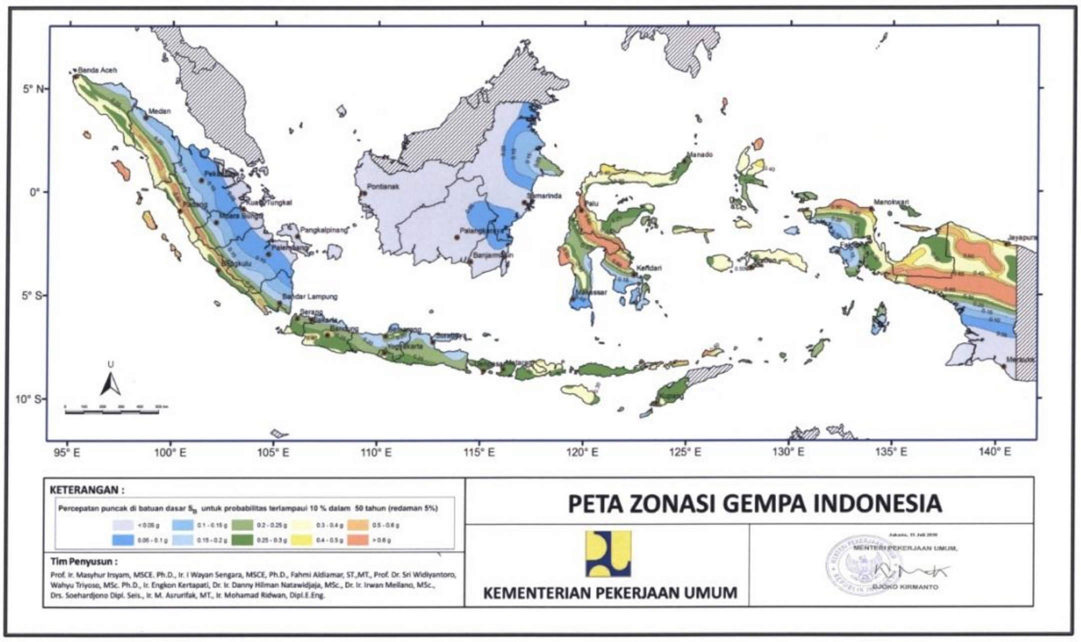


Figure 8 Peak Ground Acceleration (PGA) of Indonesia for 10% 50 years with 5% damping (Masyhur Irsyam, 2010)

Haifani (2008) on his research title GIS Application on Macro-seismic Hazard Analysis in Yogyakarta Province defined the generation of seismic hazard using GIS application based on PGA in Yogyakarta Province and calculated the PGA value using deterministic method for 500 years of return period is 0.329 g.

2.7 Risk Assessment Methodology

Several methodologies and software (such as RADIUS, HAZUS) exist for computation of urban earthquake risk using hazard, inventory and vulnerability inputs through a GIS system for data manipulation and outputs display. The commonly methods used for seismic risk assessment are discussed in this section, which are RADIUS method (USA) and HAZUS method (USA).

2.7.1 RADIUS Methodology

RADIUS (Risk Assessment Tools for Diagnosis of Urban Areas against Seismic Disasters) is a simple tool by assessing earthquake risk reduces the seismic risk in urban areas, particularly in developing countries. The methodology calculates risk at the ward level and provides a rapid assessment of possible damages according to the detail of information provided (Westen, 2009). The RADIUS program aims at providing a preliminary methodology for earthquake damage estimation, using non-GIS tools. One of the main objectives was to develop practical tools for urban risk management (http://www.gripweb.org/grip.php?ido=2222&idMat=26554986).

Maithani et al (2004) has been developed RADIUS methodology in Dehradun City, India. He was limited his study in the municipal area of the city and only considered in hazard assessment and vulnerability assessment of residential buildings while other facilities like essential building was not. The schematic diagram of RADIUS methodology illustrates in Figure 9 below.

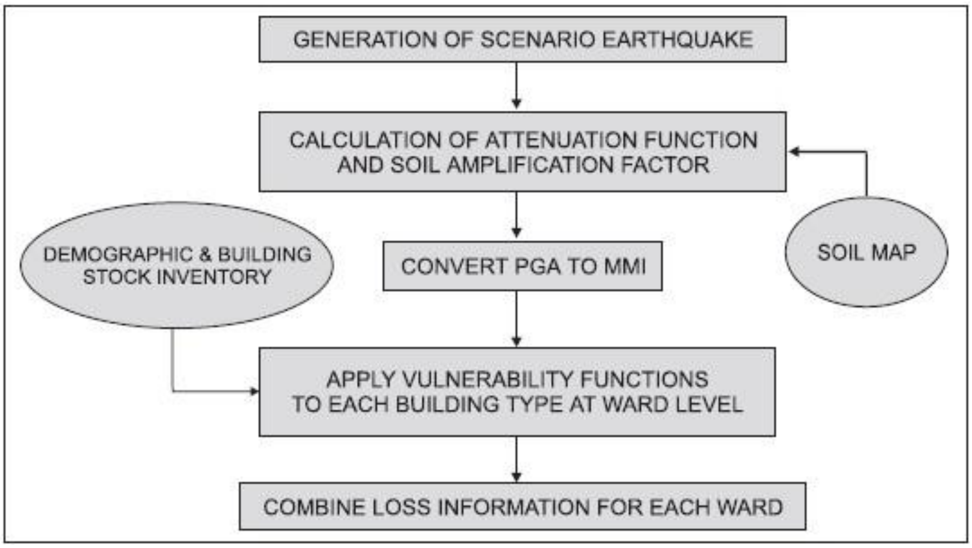


Figure 9 Flow chart of RADIUS methodology,
Source: (Sandeep Maithani et al, 2004)

RADIUS methodology divides the building class into 10 different categories according to construction type, material or structural type, occupancy type, seismic code and the number of stories (Villacis, 1999). Vulnerability functions were determined as a function of acceleration or MMI based on seismic damage observed using previous sample of earthquakes. In general, the methodology only gives the result in the form of percentage of building damage. It does not consider the complex structural aspect of the building vulnerability (Gulati, 2006).

2.7.2 HAZUS MH Methodology

The National Institute of Building Science (NIBS) developed a methodology referred to as HAZUS for assessing earthquake risk in the USA. This methodology was developed for the Federal Emergency Management Agency (FEMA). HAZUS uses Geographical Information System (GIS) technology to produce maps and analytical reports that estimate a community‟s direct physical damage to building stock, critical facilities, transportation systems and utility systems. This brief overview of the earthquake loss estimation methodology is intended for local, regional, or state officials contemplating an earthquake loss study.

The HAZUS methodology provides estimates of the structural and non-structural repair costs caused by building damage and the associated loss of building contents and business inventory using structural repair and replacement ratios that are weighted by the probability of a given occupancy being in a given structural damage state (Tantala, 2007).

According to (FEMA, 2003), the formula for estimating building damage due to ground shaking has been developed. The extent and severity of damage to structural and non-structural components of a building are described by five levels of damage states: *None, Slight, Moderate, Extensive and Complete.* The functions for estimating building damage due to ground shaking include: (1) fragility curves that describe the probability of reaching or exceeding different states of damage given peak building response, and (2) building capacity (push-over) curves that are used (with damping-modified demand spectra) to determine peak building response (FEMA, 2003).

HAZUS uses a technique to estimate peak building response as the intersection of the building capacity curve and the response spectrum shaking demand at the building‟s location (demand spectrum) (FEMA, 2003). Figure 10 illustrates the intersection of a typical building capacity curve and a typical demand spectrum. Design capacity, yield capacity and ultimate capacity points define the shape of building capacity curves. Peak building response (either spectral displacement or spectral acceleration) at the point of intersection of the capacity curve and demand spectrum is the parameter used with fragility curves to estimate damage state probabilities.

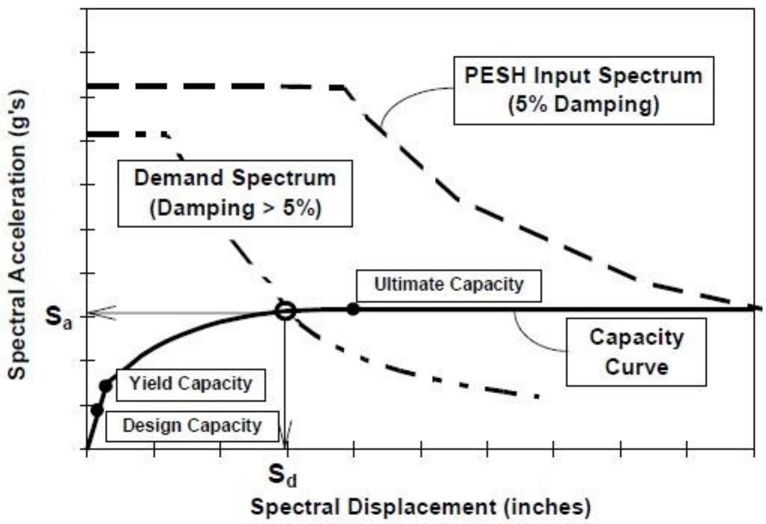


Figure 10 Example building capacity curve and demand spectrum (FEMA, 2003)

The fragility curves (see Figure 11) describe the probability of being in a specific damage state and express damage as a function of building displacement (Montoya, 2002). The output of fragility curves is an estimate of the cumulative probability of being in, or exceeding, each damage state for the given level of ground shaking. Discrete damage state probabilities are created using cumulative damage probabilities and used directly as an input to induced physical damage and direct economic loss to the buildings.

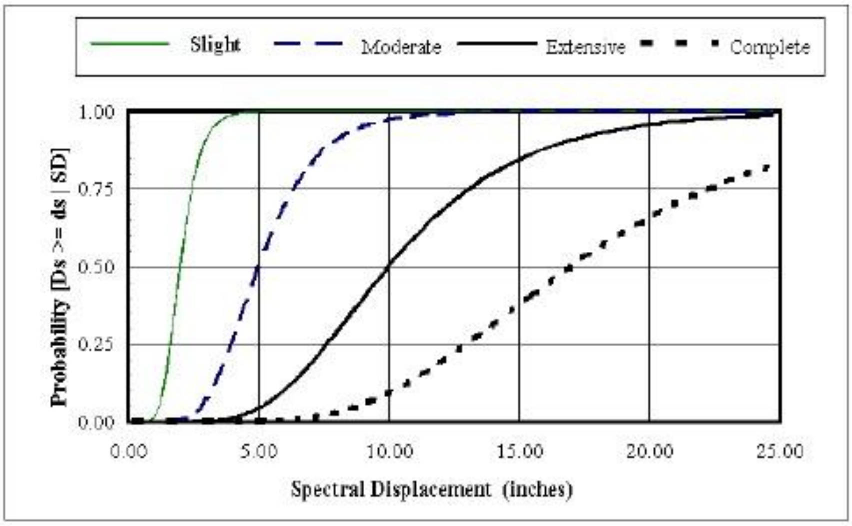


Figure 11 Example of fragility curves for Slight, Moderate, Extensive and Complete Damage (FEMA, 2003)

2.7.2.1 General Building Stock

The general building stock (GBS) includes residential, commercial, industrial, agricultural, religious, government, and educational buildings. The damage state probability of the general building stock is computed at the center of the census tract. The entire composition of the general building stock within a given census tract is concentrate at the center of the census tract. The inventory information required for the analysis to evaluate the probability of damage to occupancy classes is the relationship between the specific occupancy class and the model building types. This can be computed directly from the specific occupancy class square meters inventory (FEMA, 2003). Table 4 shows the structural building classifications or model building types that developed by FEMA for HAZUS methodology.

Table 4 Structural building classifications (Model Building Types)

No.	Label	Description	Height			
			Range		Typical	
			Name	Stories	Stories	Feet
1 2	W1 W2	Wood, Light Frame (≤ 5,000 sq. ft.) Wood, Commercial and Industrial (> 5,000 sq. ft.)		1 - 2 All	1 2	14 24
3 4 5	S1L S1M S1H	Steel Moment Frame	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
6 7 8	S2L S2M S2H	Steel Braced Frame	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
9	S3	Steel Light Frame		All	1	15
10 11 12	S4L S4M S4H	Steel Frame with Cast-in-Place Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
13 14 15	S5L S5M S5H	Steel Frame with Unreinforced Masonry Infill Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
16 17 18	C1L C1M C1H	Concrete Moment Frame	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
19 20 21	C2L C2M C2H	Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
22 23 24	C3L C3M C3H	Concrete Frame with Unreinforced Masonry Infill Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
25	PC1	Precast Concrete Tilt-Up Walls		All	1	15
26 27 28	PC2L PC2M PC2H	Precast Concrete Frames with Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
29 30	RM1L RM2M	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms	Low-Rise Mid-Rise	1-3 4+	2 5	20 50
31 32 33	RM2L RM2M RM2H	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
34 35	URML URMM	Unreinforced Masonry Bearing Walls	Low-Rise Mid-Rise	1 - 2 3+	1 3	15 35
36	MH	Mobile Homes		All	1	10

General building stock is also classified based on occupancy. Occupancy classes are used to account for the fact that contributions to losses are from damage to both the structural system and non-structural elements. The types and costs of non-structural elements are often governed by the occupancy of the building, for instance in a warehouse there may be few expensive wall coverings, whereas, a bank may have expensive lighting and wall finishes (FEMA, 2009).

The occupancy classification is divided into general occupancy and specific occupancy classes. For the methodology, the general occupancy classification system consists of six groups: residential, commercial, industrial, religion/non-profit, government, and education. Specific occupancy consists of 33 classes as shown in Table 5.

Table 5 Occupancy class classifications (Building occupancy)

Label	Occupancy Class	Example Descriptions
	Residential	
RES1	Single Family Dwelling	House
RES2	Mobile Home	Mobile Home
RES3	Multi Family Dwelling RES3A Duplex RES3B 3-4 Units RES3C 5-9 Units RES3D 10-19 Units RES3E 20-49 Units RES3F 50+ Units	Apartment/Condominium
RES4	Temporary Lodging	Hotel/Motel
RES5	Institutional Dormitory	Group Housing (military, college), Jails
RES6	Nursing Home	
	Commercial	
COM1	Retail Trade	Store
COM2	Wholesale Trade	Warehouse
COM3	Personal and Repair Services	Service Station/Shop
COM4	Professional/Technical Services	Offices
COM5	Banks	
COM6	Hospital	
COM7	Medical Office/Clinic	
COM8	Entertainment & Recreation	Restaurants/Bars
COM9	Theaters	Theaters
COM10	Parking	Garages
	Industrial	
IND1	Heavy	Factory
IND2	Light	Factory
IND3	Food/Drugs/Chemicals	Factory
IND4	Metals/Minerals Processing	Factory
IND5	High Technology	Factory
IND6	Construction	Office
	Agriculture	
AGR1	Agriculture	
	Religion/Non/Profit	
REL1	Church/Non-Profit	
	Government	
GOV1	General Services	Office
GOV2	Emergency Response	Police/Fire Station/EOC
	Education	
EDU1	Grade Schools	
EDU2	Colleges/Universities	Does not include group housing

2.7.2.2 Direct Economic Losses

Direct economic losses start with the cost of repair and replacement of damaged or destroyed buildings. Building damage will result in a number of consequential losses that in HAZUS are defined as direct.

Building Loss Estimation

The HAZUS methodology provides estimates of the structural and non-structural repair costs caused by building damage. HAZUS sub-divides building damage into five categories; No Damage (N), Slight Damage (S), Moderate Damage (M), Extensive Damage (E) and Complete Damage (C) (Tantala, 2007).

To obtain reliable loss estimates, a tremendous amount of data collection needs to take place beforehand. Data collection is typically the most intensive step of the loss estimation process, but is a wise investment as the reliability of loss estimations is dependent on the quality and quantity of the data collected. For the loss estimates, the replacement value of the building inventory was estimated.

Monetary loss estimation

Monetary loss is determined by the amount of structural and non-structural damage to each building. Non-structural damage has a larger impact than structural damage in terms of economic loss. The monetary loss for each building was determined by the amount of structural and non-structural damage multiplied by a replacement cost value per square foot of damaged structure. The percentage of building damage was calculated based on the total area of the structure (sub floors + stories * footprint area).

2.8 The Use of Remote Sensing Data and Geographic Information System (GIS)

2.8.1 Remote Sensing

Remote sensing (RS) can be described as the process of making measurements or observations without direct contact with the object being measured or observed. The output of a remote sensing system is usually an image representing the scene being observed (Weng, 2010).

Over 50,000 earthquakes occur every year on earth (Alkema, et al., 2009). A thousand of these are in over 5 of Richter magnitude and caused the damage of settlement and the built-up areas. The remote sensing data like aerial photography and high-resolution satellite images are used to observe and locate the built-up areas. The generation of a building inventory can be obtained using remotely sensed imagery such as high-resolution satellite imagery (e.g. IKONOS or QUICKBIRD). The analysis of heights, textures, patterns, tones, size and shadows can be combined with local knowledge to identify homogeneously built areas (Montoya, 2002).

Generally, on the local scale, high spatial resolution imagery such as IKONOS and Quick-bird is more effective. Quick-bird satellite provides high resolution panchromatic and multispectral imagery. The panchromatic sensor has 0.6 m ground resolution. It has only single spectral band and the image is in black and white. While the multispectral sensor has 4.0 m ground resolution and four individual spectral bands namely blue, green, red and near infrared.

In order to obtain the object of settlement and built up areas using Quick-bird imagery, first it has to be digitally processing, namely *pan-sharpening*. The Pan-sharpen algorithm applies an automatic image fusion that increases the resolution of multispectral (color) image data by using a high-resolution panchromatic (black and white) image. Most of the satellite imagery provides a multispectral images at a lower spatial resolution and panchromatic images at a higher spatial resolution.

Digital Globe as the provider of Quick-bird data imagery offers different image data products with various corrections applied. Basic imagery, Ortho-rectified imagery and Standard imagery were provided by them. Basic imagery is the least processed image product of *Digital Globe* product which only corrections for radiometric distortions have been performed on each scene ordered while the Ortho-rectified imagery products are designed for users who require an imagery product that is GIS ready. Standard Imagery products are designed for users with has knowledge of remote sensing applications that require data of modest absolute geometric accuracy and large coverage area.

2.8.2 Geographic Information System (GIS)

A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. Formally defined a GIS is a computer-based system that provides for input, management (data storage and retrieval), manipulation/analysis and output of geo-referenced data. GIS technology can be used for scientific investigations, resource management, and development planning. For instance, a GIS might allow emergency planners to easily calculate emergency response times in the event of a natural disaster like earthquake. The basic components of GIS are illustrated in Figure 12 below.

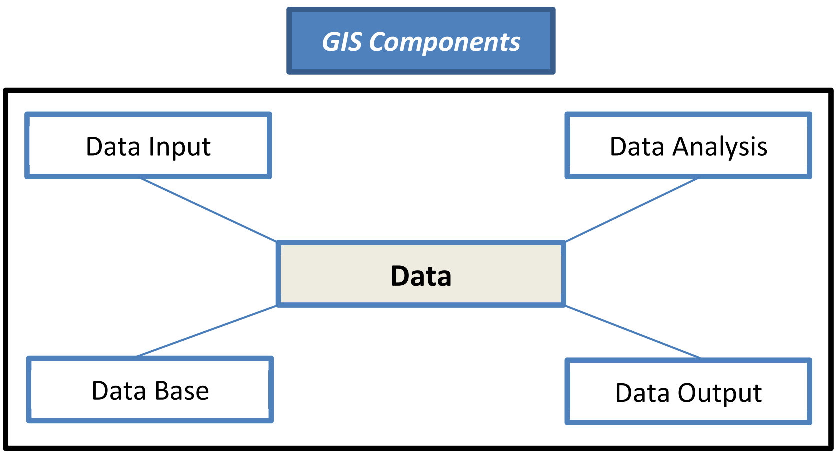


Figure 12 Components of GIS (Weng, 2010)

From the definition, it becomes clear that GIS provides geographic data which are includes both spatial data and attribute data that explain geographic features. The basic concept of GIS is one of location and its spatial distribution and the spatial relationship. Within a GIS, a database is directly connected to the graphical mapped information and so data can be manipulated and mapped or a user can interact with the map to retrieve data and also incorporates analytical functions.

GIS data can be used to enhance the functions of remote sensing image processing at various stages: selection of the area of interest for processing, preprocessing, and image classification. Wilkinson in (Weng, 2010) summarized three main ways in which remote sensing and GIS technologies can be combined to enhance each other: (1) remote sensing is used as a tool for gathering data for use in GIS, (2) GIS data are used as ancillary information to improve the products derived from remote sensing, and (3) remote sensing and GIS are used together for modeling and analysis.

The integration of remote sensing and GIS technologies has been applied widely and is recognizing as an effective tool in disaster management. Remotely sensed derived variables, GIS thematic layers and census data are three essential data sources for risk assessment analysis. The GIS-based software can help and be applied to develop plans and strategies for reducing risk. HAZUS as a software for calculating loss estimation is based on GIS that provided a tool for displaying outputs to see the effects of earthquake scenarios and assumptions. Basis on input data of GIS, it can be used to evaluate and to identify the buildings under vulnerable condition, the structures that resist on earthquake damage and the element at risk which can help in developing an emergency planning (Gulati, 2006). One of the benefit using a GIS technology is the output of the system can be used as mitigation planning for such local authorities in developing disaster emergency plan.

2.9 Summary

The chapter gives the reviews of earthquake hazard and general terms used in seismic risk assessment. It also gives an overview in seismic zoning of Indonesia based on SNI-03-1726-2002 which was developed by Indonesian Public Works. The basic concept and the study of building replacement cost in HAZUS were explained in this chapter together with the review of various approaches towards seismic risk assessment for loss estimation. The use of remote sensing (RS) and geographic information system (GIS) play an important role in seismic risk assessment of buildings. The advance of RS - GIS technology can effectively decrease the impact of earthquake especially in urban areas and built mitigation planning for the local authorities in developing disaster emergency plan.

3. STUDY AREA: BANTUL SUB-DISTRICT

This chapter gives an overview of the study area - Bantul City. It also gives a general idea about its geographical location, geological and hydrological conditions, land use patterns, Yogyakarta earthquake on May 2006 and building characteristic in study area

3.1 Introduction

Bantul Sub-district is an ideal study area for an earthquake loss estimation research due to its experienced earthquake event on 27 May 2006 and status as the hazard of earthquakes pose to the area. The area affected by earthquake is geographically small but densely populated.

3.2 General Information of Bantul District

Bantul District is part of Special Region of Yogyakarta Province that located on the south of Yogyakarta with area 50,685 hectares and almost 831,200 of the number of population (BPS, 2008). The geographic region of Bantul District is lies between 110° 12‟ 34‟‟‟‟and 110° 31‟ 08‟‟‟ east longitude and between 7° 44‟ 04‟‟‟‟and 8° 00‟ 27‟‟‟‟south latitude of Greenwich and the topography is relatively flat.

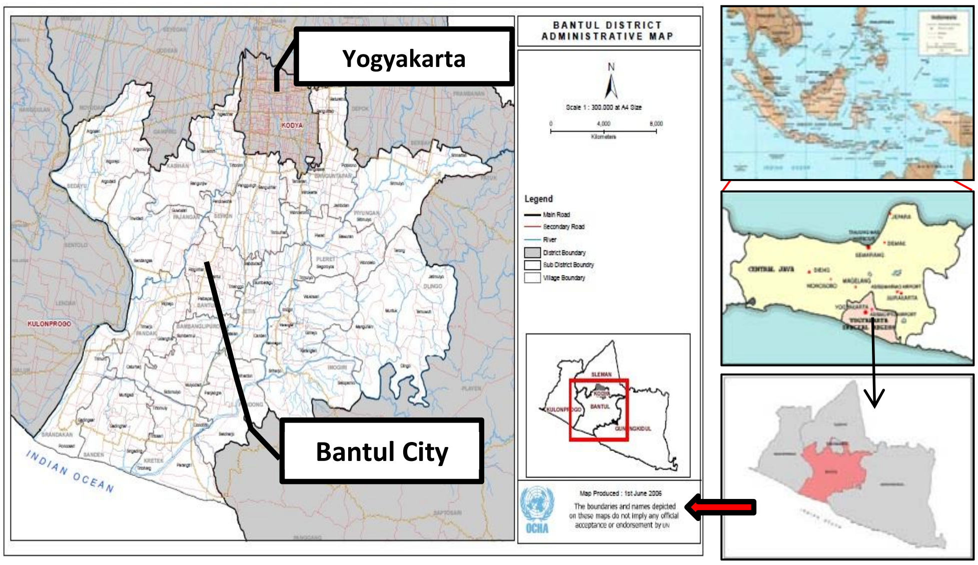


Figure 13 Study Area

Bantul District is one of 5 Districts/Cities of Daerah Istimewa Yogyakarta (DIY) Province and lies in Java. Bantul District is bordered by Yogyakarta City and Sleman District in the north, Gunungkidul District in the east, Kulonprogo District in the west and Indonesian Ocean in the south. The Bantul District consists of 17 sub-districts, 75 villages and 933 sub-villages, which one of the sub-district is Bantul Sub-district, the study area.

3.2.1 Geological Conditions

The city and the province are considered as a system where the geological phenomena distinctively dominate all the natural processes (Karnawati et al, 2006). A continued subduction of the Indo-Australia Plate from the south in the direction below the Eurasian Plate not only resulted in the formation of the active Merapi Volcano but also brought the formation of mountainous morphology of volcanic and carbonate rocks.

There is such a complex geological in Yogyakarta region which structurally consists of folds and faults. The anticline and synclinal on the folds seen on the east side of Semilir and Kepek formation and the breaking antithetic fault shaped created Bantul Graben that was actually filled by Merapi laharic flows. To the west, a dome of andesitic breccia and lava flows with the intensive fault formation occurred. Meanwhile at the eastern part of the province, steep mountains of carbonaceous-volcanic rocks as well as limestone with karst landscape are exposed (Karnawati et al, 2006).The earthquake biggest impact was on the anticline and synclinal areas which are in Semilir Formation, Andesit and Graben Bantul (SDC, 2006). The geological conditions in study area were mostly consists of the young volcanic deposits of Merapi volcano.

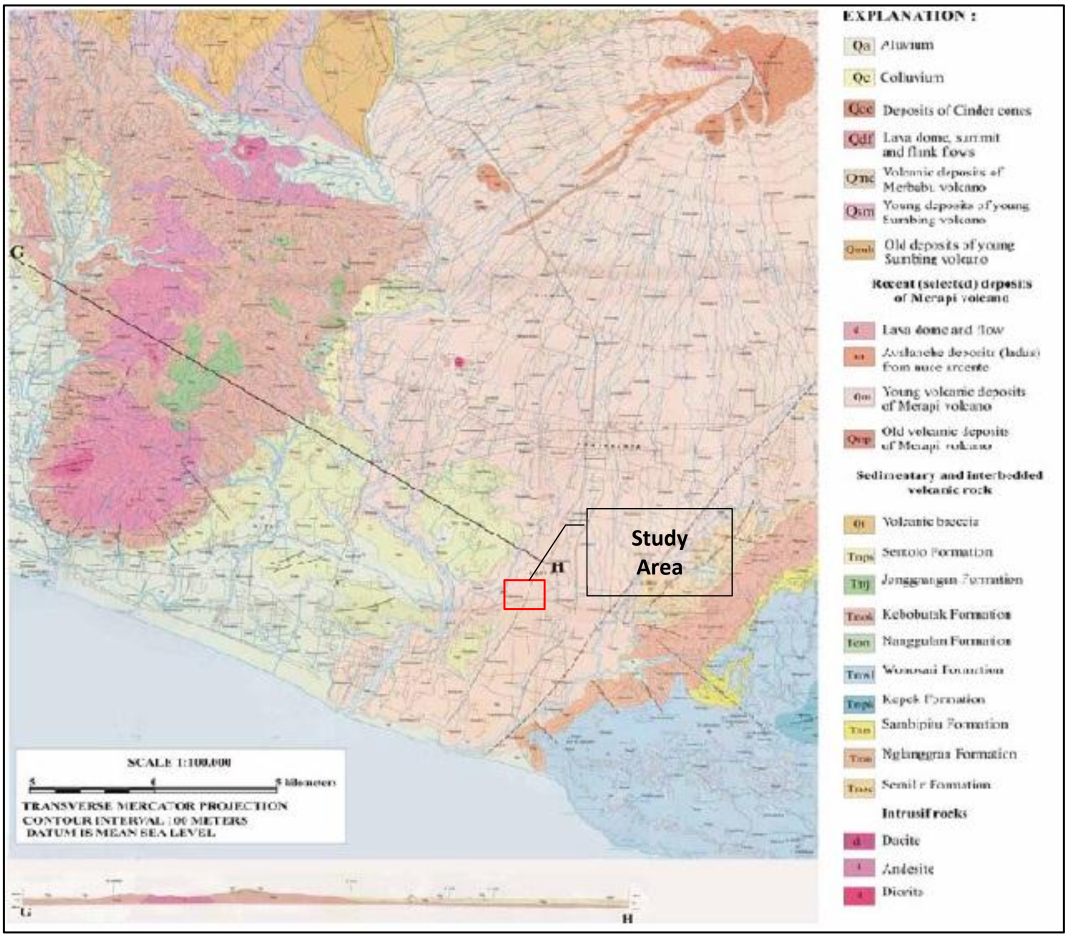


Figure 14 Geology of Yogyakarta and surroundings (Rahardjo et al, 1995 in Karnawati et al, 2006)

3.2.2 Hydrological Conditions

Bantul Region is a downstream of Merapi zone consists of many river catchment areas such as *Progo, Bedog, Winongo, Code, Opak Hulu* and *Oyo*. Moreover there is also underground water which flows through an aquifer system (SDC, 2006). The groundwater depth is a quiet shallow less than 10 m. The average rainfall is on between 1500-2500 mm/year with the wet months from November to April and dry months from June to September.

3.2.3 Land Use Pattern

Almost a half of Bantul area is cultivated land with high fertility and supported by irrigation system. Land use of Bantul in 2009 included mixed plantation 16,602

Ha (32.76%), rice field/agriculture 16,046 Ha (31.66%), dry land 6,637 (13.10%), settlement 3,810 Ha (7.52%), forest 1,385 Ha (2.73%), barren land 573 Ha (1.13%) and the others of land use are 5,630 Ha (11.11%)(BAPPEDA, 2010).

As seen in land use composition above, rice field/agriculture and mixed plantation have the highest proportion of land use in Bantul which are 16,046 Ha and 16,602 Ha. It shows that rice field/agriculture and mixed plantation played an important sector of livelihood for people of Bantul District.

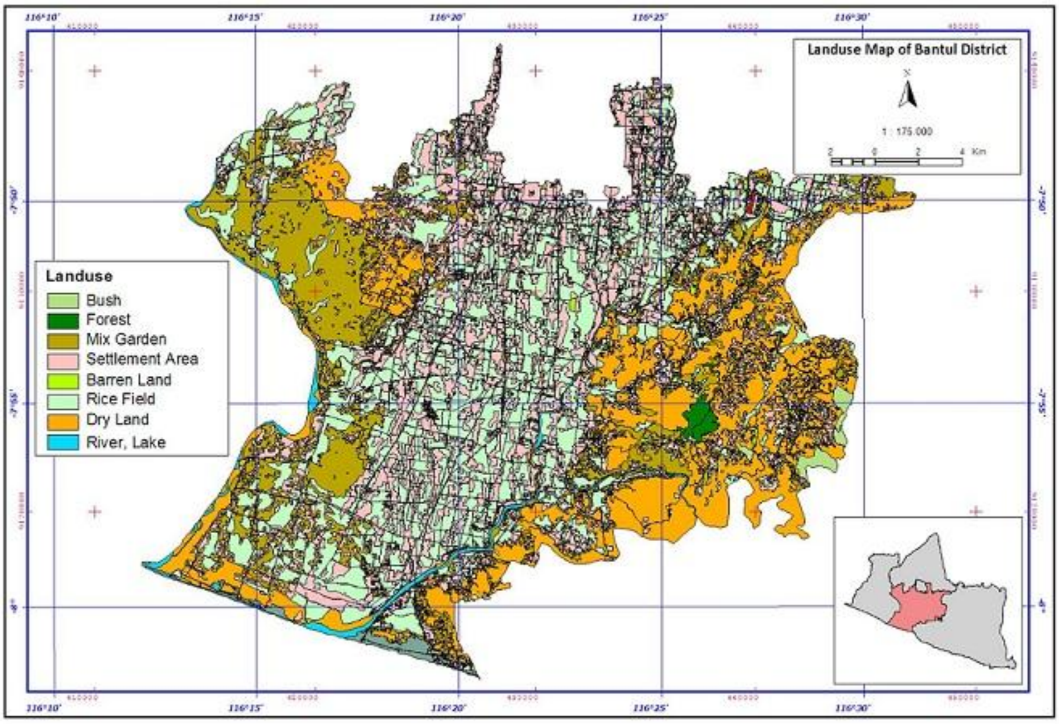


Figure 15 Landuse of Bantul (Bappeda Bantul, 2010)

Bantul Sub-district is consists of 5 villages which are Bantul, Sabdodadi, Ringinharjo, Trirenggo and Palbapang. This study was conducted in Palbapang Village (Kelurahan) of Bantul Sub-district. Palbapang was selected as a study area due to the densely populated mix of urban and rural communities. According to (DMC, 2006), the level of building damaged in Palbapang varies from collapsed and heavy damaged. 1,784 and 1,430 buildings were collapsed and heavy damaged with the total of buildings is 3,214. This is a highest number of damaged buildings in Bantul Sub-district.

Based on (BPS, 2008), Palbapang has an area of 552.38 hectares and consists of 10 Sub-village (Dukuh) and 81 RT. The number of population in Palbapang is 14,192, consists of 6,331 males and 6,698 females. The composition of land use in Palbapang Village in 2009 included settlement area 198.09 Ha, rice field 208 Ha, dry land 51.8 Ha, mixed plantation 5.71 Ha, Commercial and service area 64.66 and the rest of land use is 3.96 Ha (DMC-DIY, 2009).

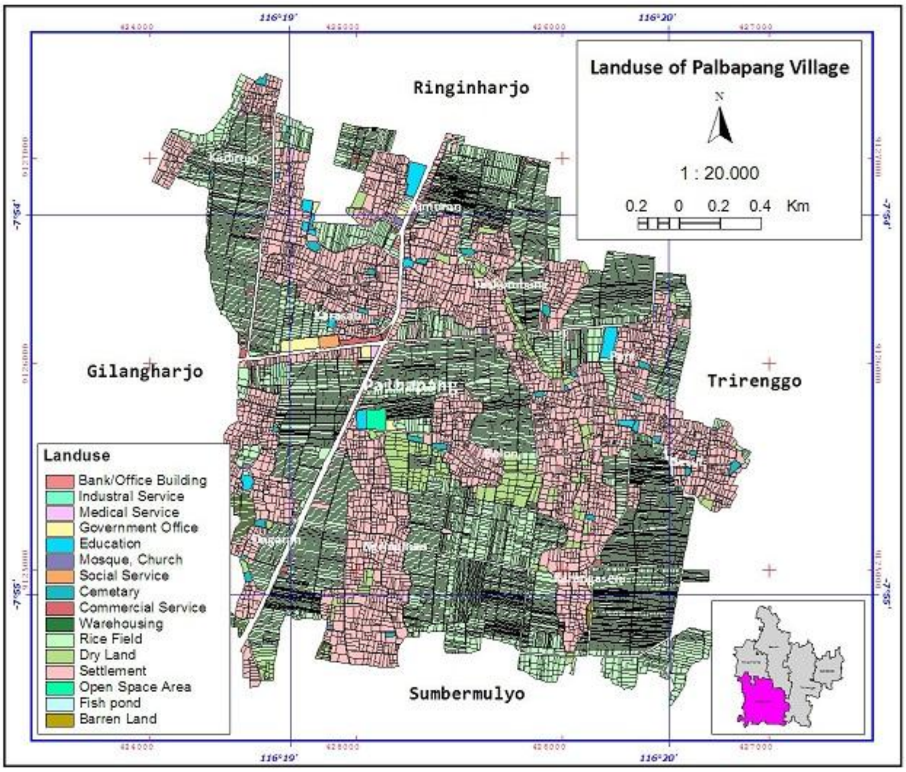


Figure 16 Land use of Palbapang Village (Source: Data Analysis, 2010)

3.3 Yogyakarta Earthquake May 27, 2006

On May 27, 2006 at 5:54 am local time, a Magnitude Mw 6.3 earthquake struck the island of Java, Indonesia, about 20 km from Yogyakarta. The affected area is a densely populated mix of urban and rural communities on the southern slope of Mount Merapi, an active volcano (EERI, 2006).According to the U.S. Geological Survey, the epicenter of the earthquake was onshore at latitude 7.962° and longitude 110.458°, in 20 km SSE of Yogyakarta with a fairly shallow focal depth (± 10 km).

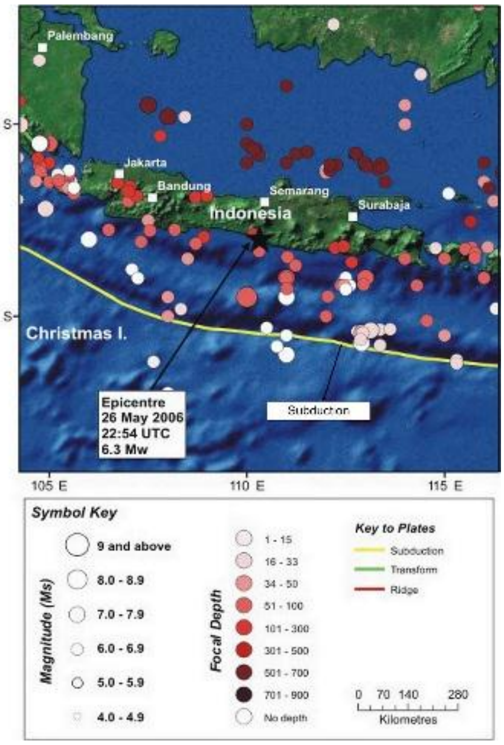


Figure 17 Seismicity Map of Java, Indonesia (With magnitude above 6.0)

Bantul District is the most destroyed area by the last earthquake, destruction were almost flatten especially in some certain areas such as Imogiri, Jetis, Pleret and Pundong as estimated those certain area located on Opak River fault region. Most of destructed residences generally were non-structural earthquake buildings.

3.4 Building Characteristic

(Boen, 2006) has been classified the building characteristic in the Provinces of Yogyakarta and Central of Java into two main categories, engineered buildings and non-engineered buildings. The non-engineered buildings are buildings that are built by local builders and/or structure owners using traditional approach, while engineered buildings are buildings that designed, built, and supervised using engineering approach by participation of professional engineers. Buildings that were damaged or collapsed during the May 27, 2006 Yogyakarta earthquake were mostly non-engineered buildings, consisting of one or two stories house, house shops, religious and school buildings. Some engineered buildings were also severely damaged or collapsed but the number is small compared to the non-engineered ones.

(Sarwidi & Winarno, 2006) classified the building type based on the construction of its building in Yogyakarta City into mud bricks, bricks, reinforced bricks and reinforced concrete (RC). In preliminary report of UGM, in cooperation with ITC, seem that almost building in Bantul that damaged during the earthquake was built without reinforcement. HAZUS classified those types of building into Unreinforced Masonry (URM).

According to (D. Kusumastuti, 2008), problems for non-engineered buildings are mainly due to minimum reference standards/codes. The structures are built by local workers using traditional construction methods, while engineers are not involved in the design process. Therefore, these buildings are frequently found to have poor detailing, wide variety of quality of materials, and wide variety of construction methods. Consequently the structures are more susceptible to damage during earthquake due to poor quality and high vulnerability.

3.5 Summary

The chapter provides the overview of Bantul District in terms of geographical location, geological and hydrological conditions, land use patterns and building characteristic. The general information of the study ward which is Palbapang Village was also reviewed in this chapter. The recent earthquake in Yogyakarta and surrounding was describes in detailed in order to give an overview of the lately earthquake events in Java region.

4. RESEARCH METHODOLOGY

This chapter describes general processes of the main works with flowchart to give clear overviews of each of the works. Data requirements, the source of each data and the processes applied upon them will be detail explained in this chapter.

4.1 Introduction

The research consists of three stages; pre-field work, fieldwork and post-fieldwork. It involves several works in order to reach the objectives. Selection of study ward, reconnaissance survey, seismic hazard identification, collection of satellite data and ancillary data; Administrative Map of Bantul; were carried out in pre-field work phase. Secondary data and primary data are collected during field work phase and will be carried out using survey method to obtain building inventory using *stratified purposive sampling* in a homogeneous unit under mapping unit class. Replacement cost for building damage was conducted in the post-field work phase. The research activities can be shown and illustrates in Figure 18.

4.2 Field Work Stage

4.2.1 Pre-field Work

In the first stage, the researcher collects literature reviews including journals, reports, books, and previous studies that related to the information about data needs and methods. Available satellite images, topographical maps and other GIS maps of the study area were collected and studied, as shown in Table 6. The information will be used during field work and data analysis stage. In this part, the researcher formulated the questionnaires and designed a sampling study area using *stratified purposive sampling* in the homogeneous unit class in a mapping unit area and using census tract level, an occupancy class can be derived.

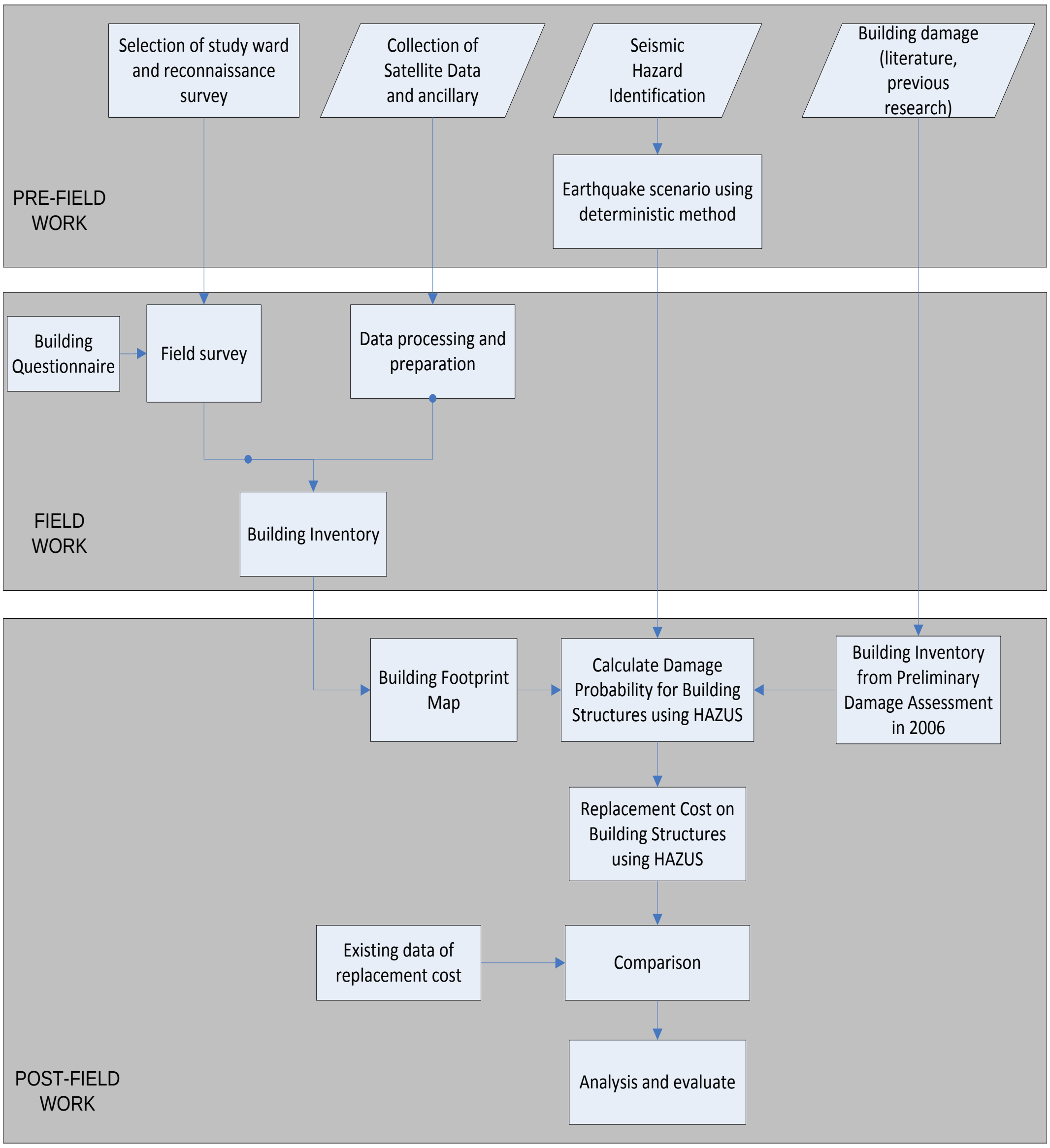


Figure 18 Research Framework

Earthquake scenario which refers to May 27 2006-Yogyakarta Earthquake was established using deterministic method in order to define seismic design. Equations for single earthquake or for earthquake of approximately have the same size was derived using *attenuation function*. Attenuation function is a function to figure out the correlation between intensity of ground motion (i) in a certain area with certain magnitude (m) and hypocenter distance (r) resulted from an earthquake source (Haifani, 2008).

Attenuation Functions is chosen and accommodated with tectonic condition or earthquake sources zone model in Indonesia. Still referred to Haifani (2008), for the given magnitude of Yogyakarta earthquake with shallow crustal source mechanism, equation from Boore, Joyner & Fumal (1997) was defined. A software which were built by USGS namely Attenuation Relationship Plotter (Version 0.10.24) was used in order to obtained the curve between *Spectral Acceleration* (g) and *Spectral Period* (second) period.

Table 6 Data Availability

No	Data	Sources	Research Activity
1.	Quick-bird Images with 0.6 m spatial resolution (1 June 2006 and 22 April 2010)	- BAPPEDA Bantul - Bakosurtanal - Digital Globe	To create building foot-print
2.	Building Inventory which are obtained during the field work	- ITC and UGM (after earthquake using preliminary rapid damage assessment) - Field survey 2010	Creating building data-base for building replacement cost in HAZUS
3.	Administrative Map 1 : 25.000 in scale	- BAPPEDA Bantul - Palbapang Village Office - Bakosurtanal	Creating census tract
4.	Questionnaire	-	Creating building inventory
5.	Earthquake scenario	- Previous research (Haifani, 2008)	Creating scenario of hazard using deterministic method

4.2.2 Field Work

In the next stages, Field work, inventorying of general building stock (GBS): building structural; building age; building occupancy; building stories based on census track level (Dukuh) and using a questionnaire to obtain building information related to price from the owner. Building inventory aimed to gain building information for database and to verify the respondents" answer during interview. In order to do so, based on data building foot-print derived from imagery, the researcher will invent general building stock in study area with the aim of determining sample. *Stratified purposive sampling* will be used which consider to the building type in a mapping unit. This type of sampling method was conducted in order to get the sample of building based on the house that rebuilt by vary of NGO such as JRF and POKMAS and also that rebuilt by their own money (self-supporting). Using GPS Handheld, census track level can be carried out to get the sample data.

A primary data collection related to the price of building will be derive using interviews and questionnaire survey by measuring and recording the building inventory in the field with various types of building damage characteristic. (Dowrick & Rhodes, 2001) state that the replacement values of the buildings were based on their floor areas and unit building costs. The question about owner status of building, price of building, the respondent data, building occupancy and physical data of building etc. will be collected during the field work.

4.2.3 Post-field Work

The last stage is Post-field work. It is a data analysis stage. All of data information gathered from field work will be tabulated, analyzed, corrected and adjusted to form a building database of study area using software such as ArcGIS, ArcView and HAZUS methodology as shown in Table 7. The HAZUS methodology will be used as a method for carrying out the loss estimation of buildings. The result analysis which can be derived from HAZUS method is building loss estimation in each census tract. The previous report on building damage assessment in Yogyakarta areas will be used as a comparison in order to analyze and to validate the building replacement cost and its correlation using Pearson Correlation Analysis (Sarwidi & Winarno, 2006).

Pearson correlation values / r (Pearson product moment correlation) is reflecting the value of linear relationship between two sets of data. In this case will be tested the correlation between building loss estimation using HAZUS methodology and actual data of loss estimation from previous report. Pearson correlation values will be calculated using this equation below.

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

Where: X_i = data values X towards i

Y_i = data values Y towards i

$\bar{x}$ = average value of x data set

$\bar{y}$ = average value of y data set

The correlation coefficient determines the extent to which values of two variables are "proportional" to each other. (http://www.statsoft.com/textbook/statistics-glossary/p/button/p/)

Table 7 Tools for Data Analysis

No	Tools	Type	Usefulness
1.	GPS	Both Handheld and RTK-GPS (Javad RTK)	Locating the buildings in point and geo-referencing the satellite imagery
2.	Questionnaire		Built the building inventory database
3.	Software	- Attenuation Relationship Plotter (Version 0.10.24) - ArcGIS and ArcView	- Built attenuation function - To map the buildings inventory
4.	Literature	HAZUS manual user book	Building loss estimation

4.3 Summary

The research consists of three stages; pre-field work, fieldwork and post-fieldwork. It involves several works in order to reach the objectives. Selection of study ward, reconnaissance survey, seismic hazard identification, collection of satellite data and ancillary data were carried out in pre-field work phase. Secondary data and primary data are collected during field work phase and will be carried out using survey method to obtain building inventory using *stratified purposive sampling* in a homogeneous unit under mapping unit class. Replacement cost for building damage was conducted in the post-field work phase.

5. DATABASE PREPARATION

This chapter describes all of the data needed in HAZUS methodology. The inventory of building in study area, the questionnaire design, homogeneous unit area mapping, the use of satellite imagery, characteristic of building type in study area and HAZUS works for building loss estimation are explain in detailed in this chapter

5.1 Building Inventory

Building inventory is conducted during the field work. It includes residential, commercial, industrial, religious, government and educational building. The limitation on building inventory was carried out only for the residential building in this study. The inventory information required for the analysis to evaluate the probability of damage to occupancy classes in the relationship between the specific occupancy class and the structure of building type.

The generation of building inventory can be achieved using remotely sensed imagery such as high-resolution satellite imagery (QUICKBIRD image). Remote sensing data are used to observe and locate the built-up areas. Analyzing the different texture and pattern, the area can be delineated to form clusters of homogeneous units. Later on, mapping of homogeneous unit will be describes in detail.

Analysis of building inventory is needed to modified building types from HAZUS model to the Indonesian practice. Building similarity approach is playing an important role to modified building characteristic in study area. In this part, together with the other researcher on HAZUS topics, it can be done together to prepare the dataset for building inventory. A building-by-building data-base was assembled for Palbapang Village. This building data-base at the individual building level was assembled using local building base maps. The developed building inventory map (building type, year built, stories, etc.) were essential for calculating economic losses and estimating damages. The Palbapang inventories were conducted by field survey of the building in select census tract.

As a mention in the previous chapter, (Boen, 2006) already classified the building characteristic in the Provinces of Yogyakarta and Central of Java into two main categories, engineered buildings and non-engineered buildings. The engineered building consist mostly of reinforced concrete structure, on the other hand the non-engineered building is divided into two main categories, which are: a).one (one and half) brick thick masonry building without reinforcement and b).half brick thick masonry building with or/and without reinforcement. Buildings that were damaged or collapsed during the May 27, 2006 Yogyakarta earthquake were mostly non-engineered buildings, consisting of one or two stories house, house shops, religious and school buildings. Some engineered buildings were also severely damaged or collapsed but the number is small compared to the non-engineered ones.

After-shock events in Bantul region, most type of building were built in this area is mostly half brick thick masonry building with reinforcement that built by NGO/Consultative consultant namely JRF (Java Reconstruction Funds). The construction of buildings/houses was supervised directly by them in order to fulfill the seismic building codes that required in Indonesia by that time. Another funding for reconstruction of buildings was come from government funds, which is doing by POKMAS (Society Groups).

The database of building was prepared using existing and collected information of the buildings in study ward. The selective respondents were selected by using *stratified purposive sampling*. This type of sampling method was conducted in order to get the sample of building based on the house that rebuilt by vary of NGO such as JRF and POKMAS and also that rebuilt by their own money (self-supporting). The sample of 20-45 representative buildings was taken from each census tract (Dukuh). The building information was collected on the basis of data collection form prepared for the survey by the researcher. The buildings were selected with the assumption that a selected building represents the construction practice that is prevalent in the selected study ward. The type of building structure in study area was dominated by Unreinforced Masonry with low rise (URML), Reinforced Masonry with low rise (RM2L), Steel Moment Frame with low rise (S1L) and Wood (W1) as shown in Figure 19 below.

Figure 19 Building types in study ward area in Palbapang Village, Bantul. RM2L type (top left), URML type (top right), S1L type (down right) and Wood type, W1 (down left)

The discussions with the owners were also carried out during the commencement of field survey, included the general condition of their house in last earthquake, the elements of construction used in their house, the quality of material that were used for construction such as cement, brick etc.

5.2 Questionnaire Design

As an earlier discussion, the general building stock was obtained during the field survey. The field survey dealt with the selection of building samples of selected building types and structures existing in the study ward. The questionnaire was tested for 10 census tract in 1 ward within Palbapang Village.

The design of questionnaire is to derive a building inventory and to calculate loss estimation is the first and foremost step in seismic risk analysis. A good questionnaire can assist in collecting the building information in a systematic way. The main objective of preparing a questionnaire was to get the building information regarding its building type, occupancy class, stories, year built, building price, etc.

Figure 20 Interview with the owner and sample of JRF House in Palbapang

In general, the questionnaire was composed of three main sections; data identification, building specifications-structures and building price. Data identifications are related to the general building information like the owner of the house, its address and geographical position and photographs to keep the record of physical condition of the building. Building specifications and structures includes the building type and occupancy; foundation; general condition of floors, walls and roofs; building size and building stories. Building price was derived based on the funds that come from government and NGO. For instance the POKMAS (Government Funds) contributes IDR 15 million for each built house while JRF (NGO Funds) contributes IDR 20 million for each built house. Else the owner of the house can also contribute for additional cost in built the house for better structure construction.

Related the building price in Bantul District, the value of residential building price in m2 has been regulated by Peraturan Bupati Bantul No. 62 Tahun 2009 (Head Officer of Bantul District Regulation Number 62 in 2009) about Value of Commodities and Services Standardization of Bantul District. The maximum residential building price in m2 is IDR 3.467.000 (PEMDA Bantul, 2009).

The data collection was prepared taking into consideration of three main types of construction practice within the ward which are RC (Reinforced Concrete), brick and wood (see Table 8). The data collection form was prepared in Microsoft Excel and converted into GIS framework. The example of questionnaire data for each of identify building can be seen in Figure 21 below

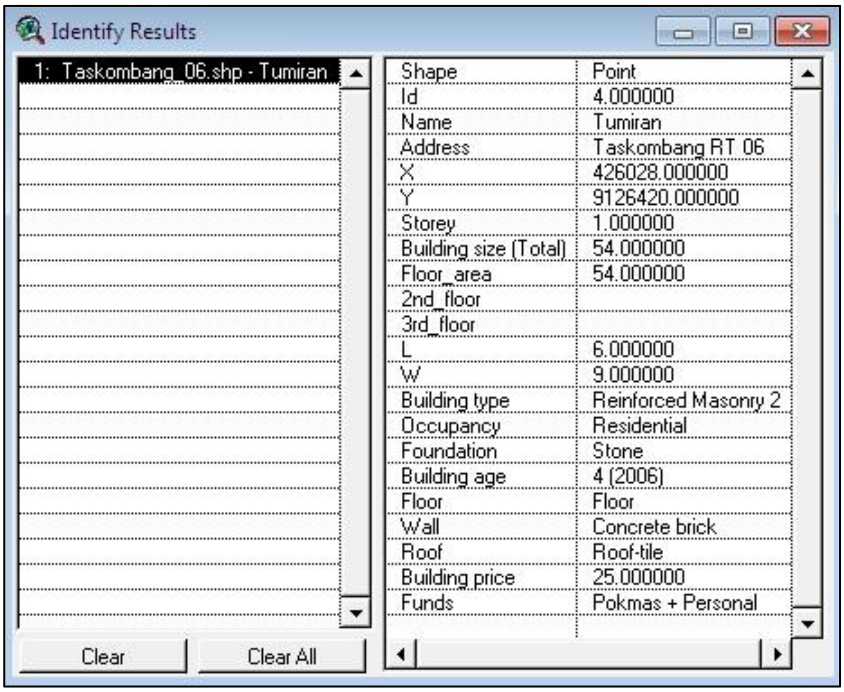


Figure 21 Example of identify result in questionnaire data of building inventory

Figure 22 shows the building samples distribution map in each census tract in the study ward. Around 300 buildings were considered as a buildings sample.

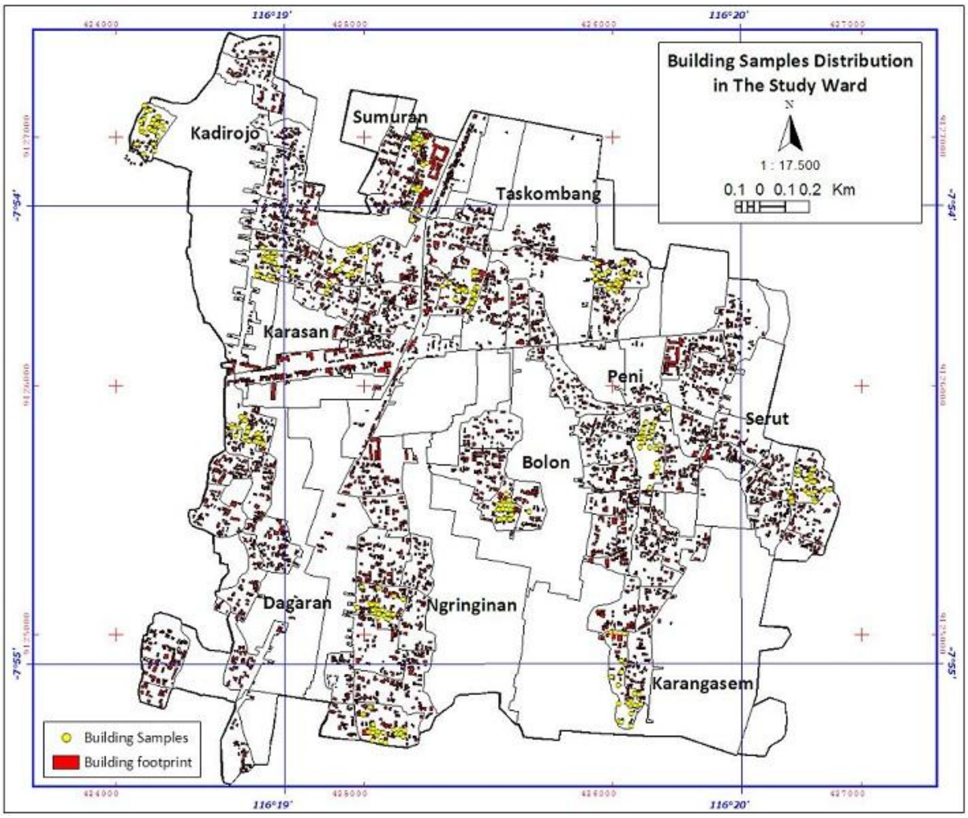


Figure 22 Building samples distribution in each census tract in The study ward

5.3 Homogeneous Unit Area Mapping

Mapping of homogeneous unit using HAZUS in Indonesia will be slightly different than in United States. HAZUS in United States tends to have similar houses within a zone. It requires some modification in the application of HAZUS model for implementation in Indonesia. Using the existing Sub-village as based for census tract level can be defined as a homogeneous unit.

The main idea of homogeneous area mapping was to divide the Bantul Sub-district into smaller units which are smaller than wards, and due to the limited time, are not into individual building level. The concept of homogeneous unit in this study is to have a similar building type and occupancy class (Figure 23). Most of the buildings in this study area have been constructed after the earthquake occurs in 2006. It tends to have similar type of construction that built by NGO called JRF and government funds through POKMAS. It is also quite common to use the same building for different building uses giving a heterogeneous building character. Therefore, divided the area based on building occupancies/building uses - building type and take the information in percentage among them was decided as shown in Figure 23 below.

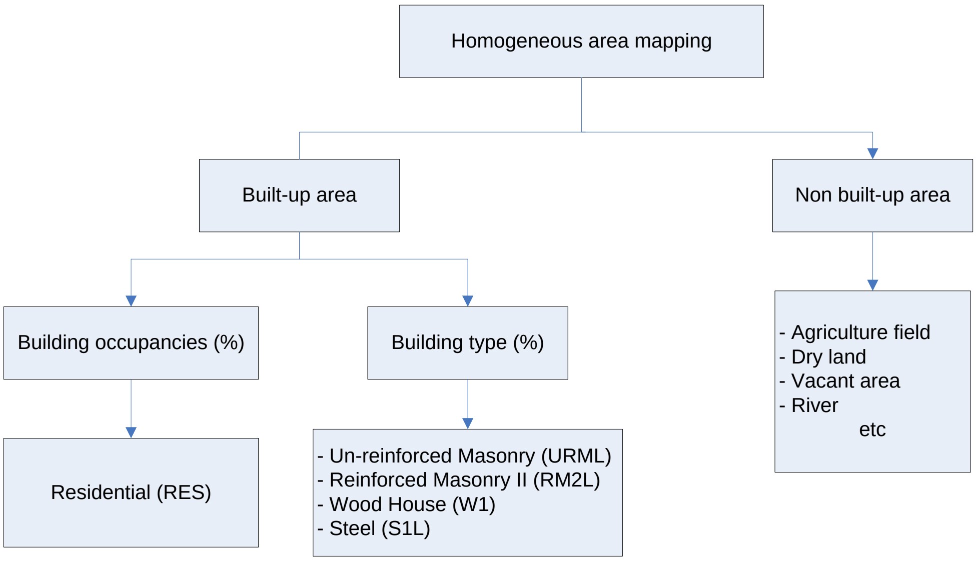


Figure 23 Homogeneous area mapping (modified from Guragain, 2004)

5.4 Geo-referencing The Satellite Imagery

A quick-bird imagery which has 0.6 m spatial resolution is used in this study. A geometrical correction need to assess in order to fulfill the requirements of the positional accuracy of image data. The corrected imagery will be used as the primary image to generate the building foot print.

Coordinates of ground control points (GCPs) can be derived from existing maps or through measurements. Ground control points are required to validate and to correct the Quick-bird imagery. Using the differential GPS (DGPS) RTK, measurement was conducted during the field work. TRIUMPH-1 JAVAD GNSS receiver was used as a RTK GPS for survey measurement. The base station is also JAVAD GNSS which is located at the Bantul Land National Agency in Bantul, approximately 1 km from Palbapang.

Figure 24 Field survey measurement using DGPS RTK Triumph-1 JAVAD GNSS

There were 8 points measured during the field work which are used as Ground Control Points (GCPs) in study area, the distribution of each point were apportionment in the whole of Palbapang region as shown in Appendix 2.

The measured of GCPs were used as the bench mark in validating the positional accuracy of the imagery data. To judge whether the positional accuracy was accurate or not, a simple method was taken to comparing the GCPs coordinates to the corresponding points of an image. At least 4 GCPs are required in geo-referencing the satellite imagery, but it is good to provide more than 4 GCPs to have a better geometrical control. 8 GCPs, as used for on screen geo-referencing of Quick-bird imagery, the same GCPs as used before in field measurement. The GCP coordinates and its corresponding points on the Quick-bird imagery are shown in Appendix 3.

Considering the 0.01905 m of RMSE (Root Mean Square Error), it can be concluded that the Quick-bird imagery does meet the requested of positional accuracy which is below of 0.6 m.

5.5 Building Characteristic

The HAZUS methodology classified the model building types into 36 categories based on their structural components and height range (Table 8). The five structural types of building used in HAZUS are wood frame, steel frame, concrete frame, RCC frame and masonry frames. In order to adopt and define this classification for the study ward it needs some discussion with the building structural experts. (Sarwidi & Winarno, 2006) has been classified the building type based on the construction of its building in Yogyakarta City into mud bricks, bricks, reinforced bricks and reinforced concrete (RC). Table 8 shows the building characteristic in Bantul with some modifications in HAZUS method.

Table 8 Building structures in Bantul and its characteristic

Type of Building in Bantul	Characteristic (Sarwidi and Winarno 2006)	Type of Building in HAZUS	Characteristic
Mud Brick	(1) Brick house with mud cemented (2) unreinforced Brick house older than 50 year in bad condition (3) ancient building with unreinforced brick in bad condition	Unreinforced Masonry (URM)	(1) 1900, the majority of floor and roof construction consists of wood framing. (2) Large buildings have floors with cast-in-place concrete supported by the unreinforced masonry walls and/or steel or concrete interior framing. (3) After 1950 have plywood and more recently include floor and roof framing that consists of metal deck and concrete fill supported by steel framing elements. (4) The perimeter walls, and possibly some interior walls, are unreinforced masonry. The walls not anchor to the diaphragms. Ties between the walls and diaphragms are more common for the bearing walls than for walls that are parallel to the floor framing.
Brick	(1) one storey building without sloof column and roof joint (2) ancient building with unreinforced brick well condition.		
Reinforced Brick	(1) 1-3 storey building from brick with sloof, column and roof joint but without lintel joint (2) 1-3 stories building that not costructed by an expert (3) reinforeced ancient building from bricks in well condition		
Reinforced Concrete	(1) reinforce concrete building that construct by the expert (2) 1-3 stories brick houses that reinforced by sloof, column, roof joint and lintel	Reinforced Masonry II (RM2)	Reinforced masonry bearing wall structures precast concrete elements such as planks or tee-beams and the precast roof and floor elements are supported on interior beams and columns of steel or concrete.
Wood House 1	unreinforced bamboo /wood house bad condition or with bad quality of material	Wood House (W1)	(1) Essential building structural feature is repetitive framing by wood rafters or joists on wood

			stud walls. Loads are light and spans are small. (2) Some have heavy masonry chimneys with partially or fully covered with masonry veneer. (3) Classified as not engineered but some are constructed in conventional construction provisions of building codes

5.6 HAZUS Methodology for Seismic Risk Assessment

One of the major components of HAZUS methodology is a comprehensive database of hazard and element at risk that are required for risk assessment. In this methodology, database inventory are obtained from general building stock which is calculating total area of groups of buildings with specific characteristic of occupancy class based on a census tract. A census tract is therefore based on the smallest group geographical unit.

As mentioned in previous chapter, contributions to loss estimates come from damage to both the structural system and non-structural elements. In order to estimate losses, the structural system must be known for all the buildings in the inventory. Since much of the inventory that is available is based on occupancy class, it needs to convert occupancy class inventory to model building types. The relationship between structural type and occupancy class will form a homogeneous unit for each census tract.

Occupancy class inventory in the HAZUS is setting up on the basis of its general and specific building occupancy. The main idea by creating a building inventory is to grouped with similar characteristic and classify into their components of building classification based on construction type, material type and structural type.

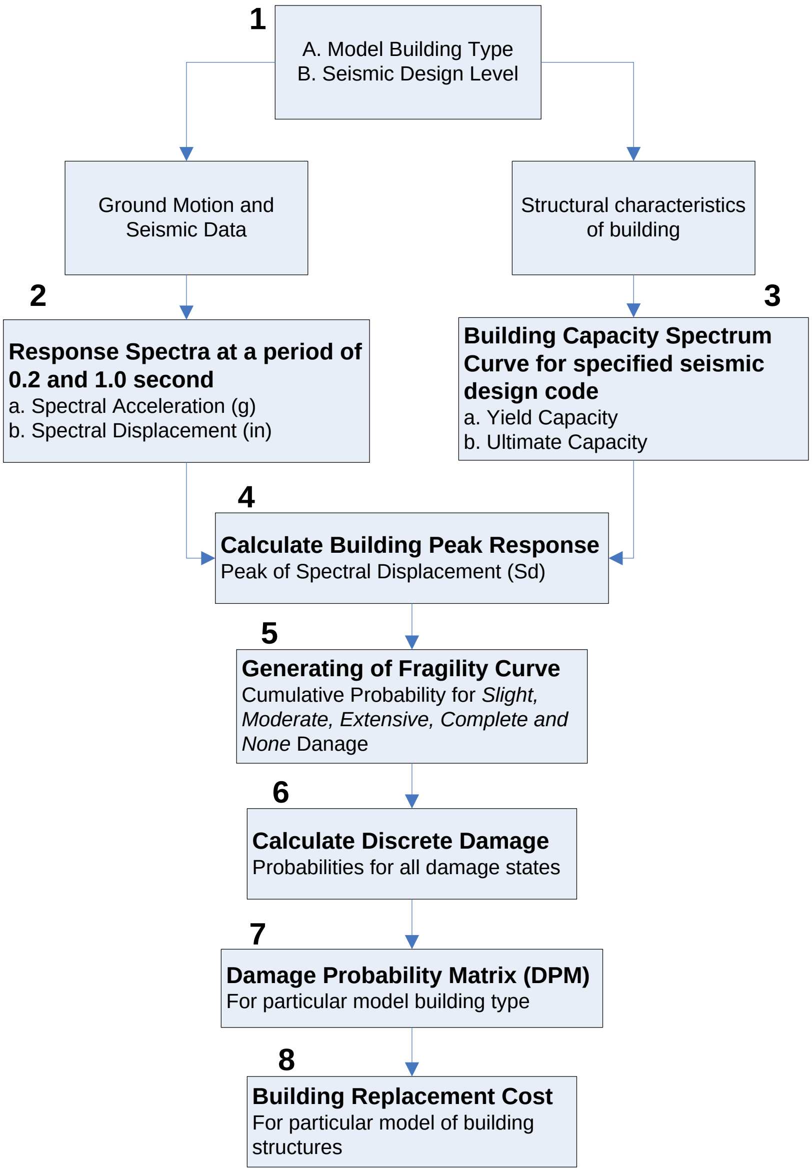


Figure 25 Flowchart of HAZUS Methodology (modified from Gulati, 2006)

Figure 25 illustrates the flow chart of HAZUS methodology for seismic risk assessment of model building type. The methodology consists of eight steps. The first step is input requirements for model building type and its design level. The second and third steps shows the parameters that required to generate the building capacity spectrum and ground motion spectrum, the output from those steps is building peak response. It is calculated from the intersection of these two curves, called spectral displacement (Sd). The output of fourth step is used to calculate the cumulative probabilities of model building type as shown in step five. The sixth step shows the calculation of discrete probabilities for all four damage states and finally the damage matrix is developed in step seven. The last step is calculated building replacement cost in census tract level for particular model building type.

The flow chart of HAZUS methodology can be clearly describes as follows,

 # Step 1.Selecting of model building type and the seismic design level for study area

Selecting model building type in study ward using HAZUS methodology, in this case were predominantly by URML, RM2L, S1 and W1. The seismic level design was based on the resistant of building characteristic due to earthquake according to SNI-03-1726-2002 which was established by Public Works.

 # Step 2.Generating response spectra

The demand spectrum is a plot of spectral acceleration, which is a function of spectral displacement. Parameters for Response Curve are:

- Soil Class
- Spectral Acceleration, S_A
- Soil amplification factor for given spectral acceleration
- Spectral Displacement using equation,

$$\mathbf{S_D = 9.8 * S_A * T^2} \quad \ldots\ldots (1)$$

Where: S_A = Amplified Spectral Acceleration (g)

T = Time Period (sec)

S_D = Spectral Displacement (inches)

 # Step 3.Generating Building Capacity Spectrum Curve

The building capacity curve is represents the characteristic of a structure, which is a plot of lateral resistance of a building as a function of characteristics lateral displacement. Design capacity, yield capacity and ultimate capacity points define the shape of building capacity curves.

Parameters for Building Capacity Curve are:

- Yield Capacity Point
- Ultimate Capacity Point

\# **Step 4**.Calculating Peak Building Response

Peak Building Response (S_d) is derived from the intersection of Building Capacity Curve and Demand Spectra. Peak building response (either spectral displacement or spectral acceleration) at the point of intersection of the capacity curve and demand spectrum is the parameter used with fragility curves to estimate damage state probabilities.

\# **Step 5**.Calculating Cumulative Damage Probabilities

- From HAZUS table, find the median value of Spectra Displacement (S_d) for model building type, design code and damage state.
- From HAZUS table, find value of lognormal standard deviation (β) for model building type, design code and damage state.
- Calculating cumulative probabilities for given damage state(ds); *Slight, Moderate, Extensive and Complete Damage*; is modeled as:

$$\mathbf{P[ds|S_d] = \phi[1/\beta ds\ Ln(S_d/S_{d},ds)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where: Sd, ds = the median value of spectral displacement at which the building reaches the threshold of the damage state, ds

Bds = the standard deviation of the natural logarithm of spectral displacement of damage state, ds

ϕ = the standard normal cumulative distribution function

\# **Step 6**.Calculating the discrete damage probabilities from Cumulative Damage Probabilities

Damage estimates are expressed in terms of probabilities of reaching or exceeding discrete states of damage for a given level of ground motion or failure. These estimates are provided for representative building categories and types.

- Probability of Complete damage, P(C) = $P[C|S_d]$
- Probability of Extensive damage, P(E) = $P[E|S_d] - P[C|S_d]$
- Probability of Moderate damage, P(M) = $P[M|S_d] - P[E|S_d]$
- Probability of Slight damage, P(S) = $P[S|S_d] - P[M|S_d]$
- Probability of No damage, P(None) = $1 - P[S|S_d]$

Step 7.Developing Mean Damage Ratio (MDR)

The mean damage ratio was defined using Hwang (1994) approach in Syamsudin (2010) which can be describes using equation below.

$$MDR = \Sigma P_{ds} * CDR \quad \text{.....} \quad (3)$$

Where: P_{ds} = Discrete probabilities in each level of damage

CDR = Central damage ratio in each level of damage that can be seen in Table 9 below

Table 9 Example of MDR

Level of Damage	Damage Ratio (%)	Central Damage Ratio (%)
Non Structural Damage	0.05 – 1.25	0.3
Slight Structural Damage	1.25 – 7.50	3.5
Moderate Structural Damage	7.50 – 20	10
Severe/Extensive Structural Damage	20 - 90	65
Complete Structural Damage/Collapse	90 – 100	95

Step 8.Building Replacement Cost

From Damage Probability Matrix, the percentage of Mean Damage Factor used as a basic to find out the damage of building and multiply it with the value of model building type per meter square.

5.6.1 Site Class

Soil class was defined using boring information collected by UGM and geology agency. Knowing the local soil conditions in a region is critical for assessing earthquake losses (Tantala, 2007). This part of the study will be doing by other researcher. This study derived a standard profile of soil stiffness as a function of soil depth, then the depth to bedrock boring directly translates into a class from A (rock at very shallow depth or outcropping) to E (with very large depth to bedrock). Mostly site class in Palbapang Village is stiff soils (D) which lies in lowland area of Bantul District. Table 10 describes the site classes that commonly used in HAZUS methodology for loss estimation.

Table 10 Site classes from 1997 NEHRP Provisions (FEMA, 2003)

Site Class	Site Class Description	Shear Wave Velocity (m/sec)	
		Minimum	Maximum
A	**HARD ROCK** Eastern United States sites only	1500	
B	**ROCK**	760	1500
C	**VERY DENSE SOIL AND SOFT ROCK** Untrained shear strength $u_s \geq 2000$ psf ($u_s \geq 100$ kPa) or $N \geq 50$ blows/ft	360	760
D	**STIFF SOILS** Stiff soil with undrained shear strength 1000 psf $\leq u_s \leq 2000$ psf (50 kPa $\leq u_s \leq 100$ kPa) or $15 \leq N \leq 50$ blows/ft	180	360
E	**SOFT SOILS** Profile with more than 10 ft (3 m) of soft clay defined as soil with plasticity index PI > 20, moisture content w > 40% and undrained shear strength u_s < 1000 psf (50 kPa) (N < 15 blows/ft)		180
F	**SOILS REQUIRING SITE SPECIFIC EVALUATIONS** **1. Soils vulnerable to potential failure or collapse under seismic loading:** e.g. liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. **2. Peats and/or highly organic clays** (10 ft (3 m) or thicker layer) **3. Very high plasticity clays:** (25 ft (8 m) or thicker layer with plasticity index >75) **4. Very thick soft/medium stiff clays:** (120 ft (36 m) or thicker layer)		

5.6.2 The Study Ward

The Palbapang Village ward has been taken as a study area in Bantul Sub-district. Based on (BPS, 2008), Palbapang has an area around 552.38 hectares and consists of 10 Sub-village (Dukuh) and 81 RT. The characteristic of Palbapang Village is a densely populated mix of urban and rural communities. Hospital, government buildings, high school buildings, bus station and commercial building are found along the main road in this area.

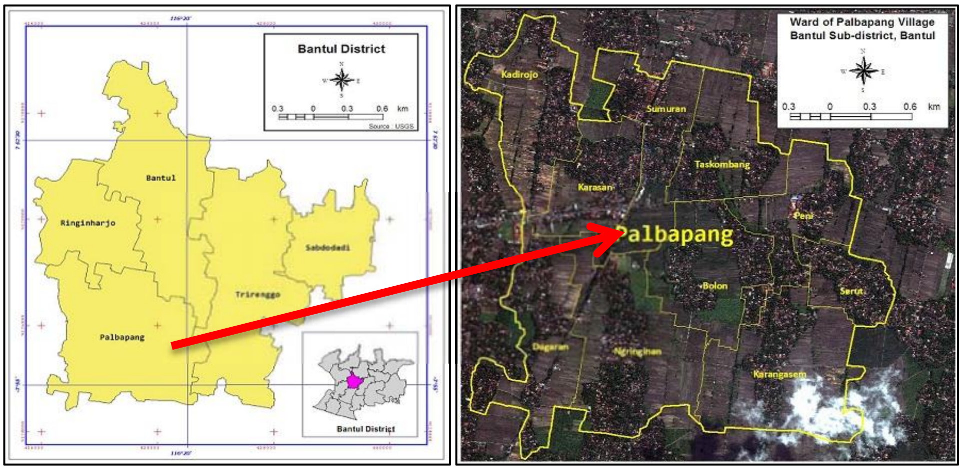


Figure 26 Location of study ward in Palbapang Village (Data Analysis)

The ward was sub divided into 10 census tract based on Dukuh boundaries. The main idea by sub dividing the ward was to identify the buildings inventory on a block basis.

Figure 27 Sub-division of study ward into census tract (Data Analysis)

5.6.3 Building Footprint

After selected the study ward and creating a census tract, digitizing on building using visualization on screen was made. All of buildings in Palbapang village were digitized and unique ID"s were assigned on census tract to each building for field data collection.

Figure 28 Digitization of buildings in overlay with April 22nd 2010 Quick-bird image

The Figure 28 above shows the digitization of buildings on census tract in overlay with quick-bird image. The digitization was made by using the building information collected from field trough data entry form within a building sample from field survey.

5.6.4 Building Damage in Study Ward

Building damage in study ward was derived from previous report of rapid damage assessment on buildings after earthquake 2006 by Kerle and Widartono (2006). Damage assessment divided into 3 class which are complete damage, medium damage and light damage that contains various of occupancy class type which are government buildings, educational buildings, commercial buildings and residential. Among all 3014 buildings were surveyed using rapid survey and 2513 residential buildings are in between. The rest of occupancy types were commercial, educational and government buildings. Percentage of complete damage is higher among medium and light damage was 78% as shown in Table 11 and Table 12 below.

Table 11 Percentage of building damage types in ward

	URML	RM2L	W1	Total
RES1	2380	126	7	2513
Percentage	95	5	0	100

Table 12 Percentage of building damage types in ward

	Complete	Moderate	Light	Total
RES1	1969	184	360	2513
Percentage	78	7	15	100

Figure 29 shows the distribution of rapid damage assessment in one of block in study ward that represents 3 level of damage assessment.

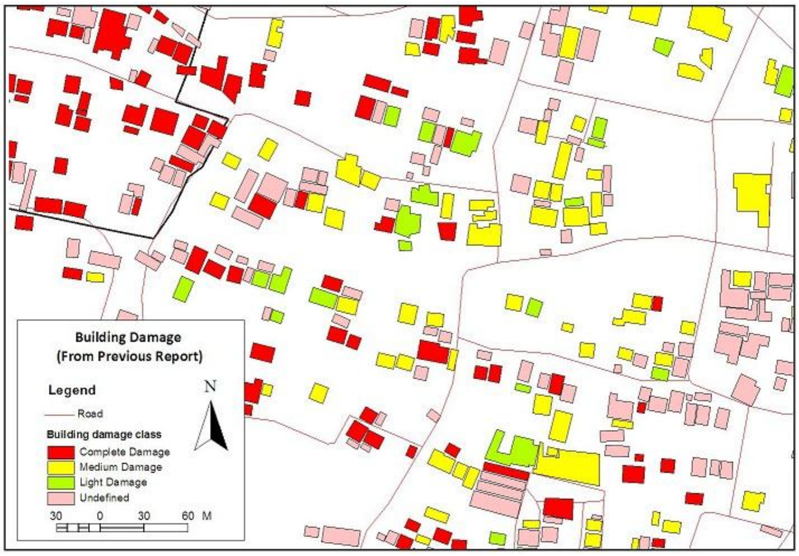


Figure 29 Distribution of building damage in study ward according to rapid damage assessment by Kerle and Widartono (2006)

5.6.5 Building Occupancy in Study Ward

Since the occupancy class in this research only considered with residential (RES1), which are became the predominant occupancy in the study ward, the government buildings, commercial buildings and other type of occupancy class will not taking into account on risk calculation. Figure 30 shows the building foot print map and occupancy class in one of census tract in Kadirojo Sub-village.

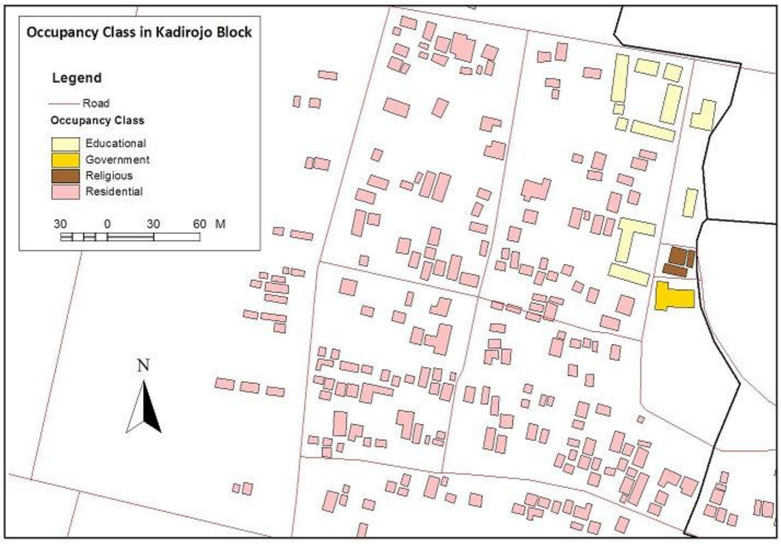


Figure 30 Example of Occupancy Class in Kadirojo Block

5.6.6 Building Structures in Study Ward

Based on previous research by (Kerle & Widartono, 2008), the predominant building structures using rapid damage assessment after the earthquake of May27th 2010 in the study ward is *Unreinforced Masonry* with low rise (URML). Among all 2513residential buildings were surveyed using rapid survey in the ward. The number of Unreinforced Masonry type has 2380 building structures which is almost 95% of the total buildings.

In 2010, 4 years after the earthquake, The *Reinforced Masonry* with low rise (RM2L) has the prime share of 98% among 300 buildings which were surveyed by researcher during the field work. The number of RM2L structure has 293 buildings and mostly the residential buildings that spread over the ward is predominant by *Reinforced Masonry*. Figure 31 shows the building foot print map and structure type before and after earthquake in one of census tract in Karasan Sub-village.

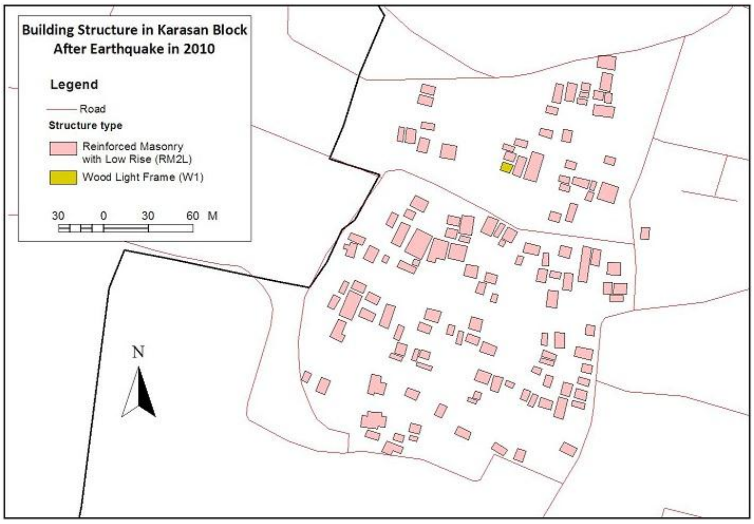


Figure 31 Example of Building Structure types in Karasan Block

5.7 Summary

This chapter describes the method of data collection trough field survey of study ward. The field work stages and data preparation for methodology was also discussed in this chapter. It is also included the process of preparing the data source using Quick-bird image and the process of preparing the building foot print map of the study ward. The outcome and results of this data will be discussed in the next chapter.

6. RESULT AND DISCUSSION: BUILDING REPLACEMENT COST

This chapter presents the result of building replacement cost for seismic risk assessment in study ward of Palbapang Village, Bantul using HAZUS methodology in different model building type for different kinds of data input, preliminary damage assessment 2006 and during field survey 2010

6.1 Result of Seismic Design

The seismic design represented the earthquake scenario. The earthquake scenario was selected using deterministic method which is refers to the May 27 2006-Yogyakarta earthquake with 6.3 in magnitude. Deterministic method implements several attenuation function which appropriate with seismic criteria of earthquake source and correlates with numerous destruction point as impact on Yogyakarta. Haifani (2008) states that based on deterministic computation, the sub-surface fault that has 6.3 Mw and lies on 10 km of shallow depth will potentially generated the intensity of earthquake with 8.1 of MMI as illustrates in the Figure 32 below.

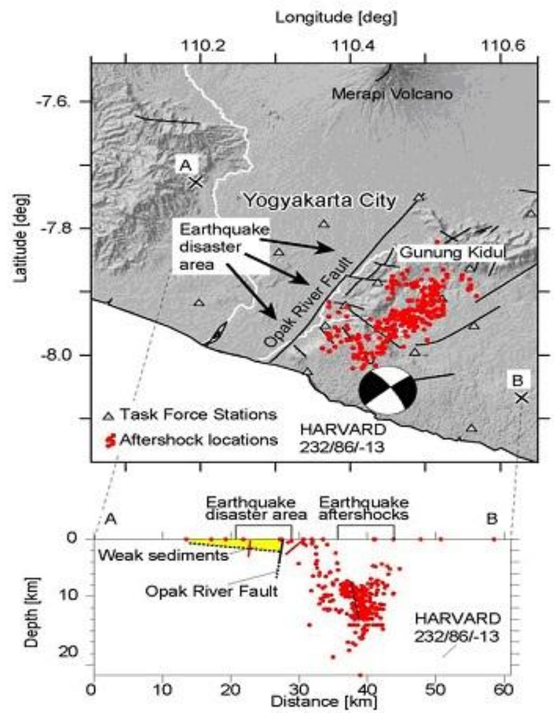


Figure 32 The epicenter of earthquake near Opak River with fault line trending SW-NE (Haifani, 2008)

Aftershocks are shown by red circles, seismometer stations by black triangles. The cross section shows the location of the aftershocks, and the distance to the earthquake disaster area.

Attenuation Functions is chosen and accommodated with earthquake sources zone model in Indonesia. For the given magnitude of Yogyakarta earthquake with shallow crustal source mechanism, equation from Boore, Joyner & Fumal (1997) was defined (Douglas, 2004). This attenuation function was assumed the earthquake source as a strike slip fault for shallow crustal earthquakes (*i.e.* epicenter depth 10 km) and estimated using aftershock data with closest distance to surface projection of fault which is 10 - 15 km length to study area (Haifani, 2008).

Types of fault	Strike-slip Fault
Length of the fault	15 km
Wide of the fault	10 km
Deep of the fault	10 km
Magnitude	6.3 Mw
Sub-surface rupture	8 km

(Sources: USGS; Haifani, 2008; Karnawati et al, 2008)

Figure 33 illustrates the relationship of *Spectral Acceleration* and *Spectral Period* using a specific attenuation function with a given magnitude in earthquake deterministic scenario.

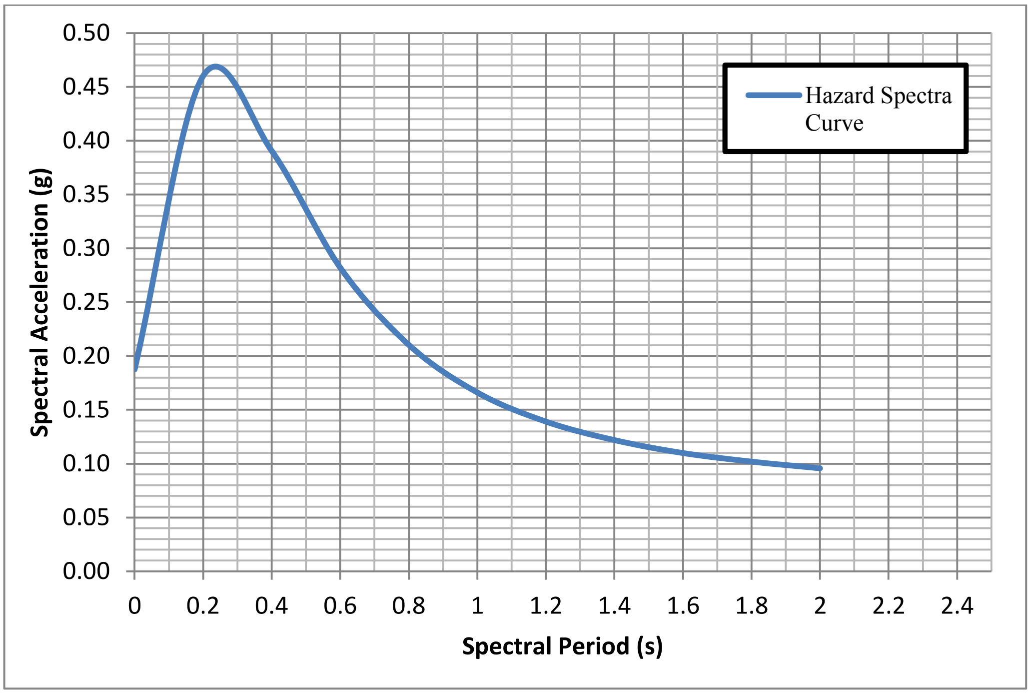


Figure 33 The relation between Spectral Acceleration (g) and Spectral Period (s)

Based on deterministic computation using Boore, Joyner & Fumal (1997), the ground motion reached until 0.19 g.

6.2 Building Classification

The two most building structure which exists in the study ward are wood frame and masonry frames. With the approaches in HAZUS methodology and discussing a model of building types in Bantul region, there are four types of building structure were selected for this research; Wood Light Frame (W1), Reinforced Masonry Bearing Wall with Precast Concrete Diaphragms (RM2), Unreinforced Masonry Bearing Walls (URM) and Steel Moment Frame (S1).

Wood Light Frame (W1) often can be seen in almost rural area in Yogyakarta and Bantul City. These are typically a single-family or small. Most of the buildings built mix with bamboo and constructed in accordance with conventional construction provisions of building codes and mostly non-engineered building.

There is one building surveyed during the field work which have a slightly different type of building compared with the other type of building structures. The building was not built by the government or any NGO like POKMAS or JRF. It was built personally from the assistance funds. The structure is steel. HAZUS grouped this model building into *Steel Moment Frame* (S1). These buildings have a frame of steel columns and beams. The structure is concealed on the outside by exterior non-structural walls, which can be of almost any material. In this case is gypsum. Steel moment frame buildings are typically more flexible than shear wall buildings.

Unreinforced Masonry (URM) buildings were spread almost in rural area of Bantul City. The collapse of such buildings was responsible for most of the deaths and injuries in almost affected area of Bantul. This type of building will be detailed explain in the next discussion.

Nowadays the *Reinforced Masonry* (RM2) can be found mostly in Bantul area and surrounding. After the 2006 earthquake, a good performance of confined fired brick, solid concrete block and stone masonry were scattered throughout the heavily affected areas.

6.3 Result of Building Replacement Cost

HAZUS subdivides building damages into five categories: No Damage (N), Slight Damage (S), Moderate Damage (M), Extensive Damage (E) and Complete Damage (C). The calculation was done both of using data of preliminary damage assessment in 2006 and building inventory during field survey 2010.

6.3.1 Building Structures based on Preliminary Damage Assessment 2006

According to the previous research of preliminary damage assessment by (Kerle & Widartono, 2008), building replacement cost was calculated to define the cost of building using HAZUS method. The predominant building structures using rapid damage assessment after the earthquake of May 27 2006 in the study ward is *Unreinforced Masonry* with low rise (URML). Among all 2513 residential buildings were surveyed using rapid survey in the ward. The number of Unreinforced Masonry type has 2380 building structures which is almost 95% of the total buildings.

The URML represents the old construction and not resistance with earthquake and also have a poor maintenance. This model building type was constructed without reinforcement and generally more vulnerable into earthquake. URM failures were associated with poor quality materials and lack of wall integrity in the transverse direction for out-of-plane forces and no mechanical connection between the top of the wall and the roof or floor. There is no steel reinforced concrete foundation beams, columns or ring beams were used in older house. The Figure 34 gives the example of URM model building type in ward. The perimeter walls in some cases were constructed of reinforced masonry ancient building from bricks. The assumption was taken and put the class in URM class in HAZUS(Table 8).

Figure 34 Example of URML building in study ward

Figure 35 shows the likely distribution of building types in 10 census tract of Palbapang as the study ward.

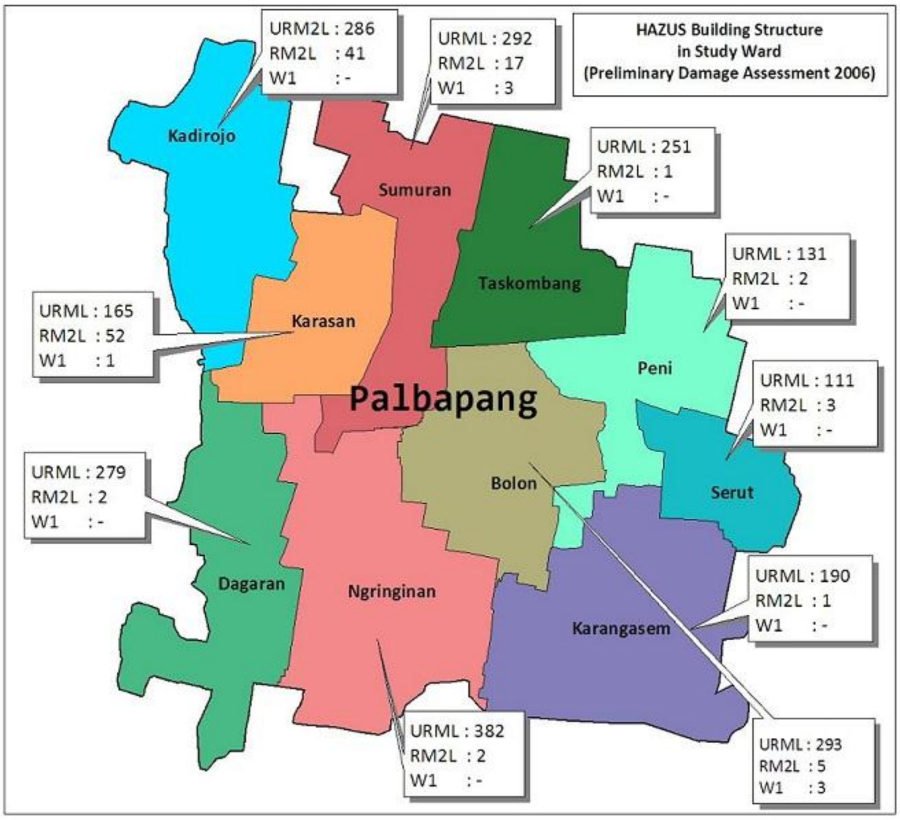


Figure 35 Building Structures in study ward 2006

6.3.1.1 Assessment on Building Type

The assessment on building type was calculated in HAZUS methodology for a different model building type which defined in the study area; RM2L, URML and W1.

Example in Calculation of Unreinforced Masonry with Low Rise (URML)

Figure 36 shows the example of building structure URML in Bolon block

Figure 36 Example of building structure URML in Bolon Sub-village

Model building type is URML and seismic design level is Pre-Code Seismic Design

General Information	
Location	Bolon Sub-village
Structure Type	URML
Soil Class	D (Stiff soil)
Building sq meter	109.69 m^2
Building value per m2	IDR 264,000
Building value	IDR 28,957,394

Mean Damage Ratio for the URML model building type

Mean Damage Ratio				
Level of Damage	**Cumulative Probabilities**	**Discrete Damage Probabilities**	**Median Damage Ratio**	**Damage Ratio**
Complete	0.07301	0.07301	95	6.936%
Extensive	0.23471	0.16170	65	10.511%
Moderate	0.51512	0.28041	10	2.804%
Slight	0.74391	0.22879	3.5	0.801%
No damage	1.0000	0.25609	0.3	0.077%
		MDR		21.129%
		Level of Damage =		**Extensive Damage**

From Damage Probability Matrix, the percentage of Mean Damage Factor used as a basic to find out the damage of building and multiply it with the value of model building type per meter square.

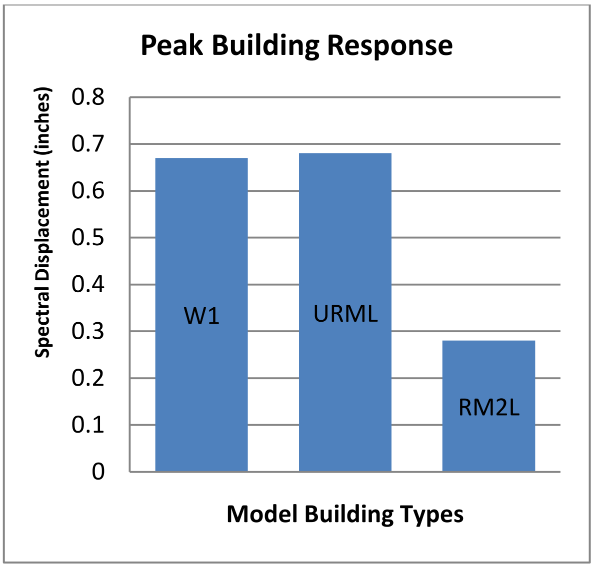
Building Replacement Cost	
Hazard Probability	10%
Exposure Period (Year)	50
Return Period (Year)	475
Mean Damage Ratio (MDR)	21.129%
Building Value (IDR)	28,957,394
Damage Value (IDR)	6,118,408
Replacement Cost for Building Structure URML (IDR)	**IDR 6,118,408**

Table 13 shows the replacement cost for each census tract and the average replacement cost in the study area using preliminary rapid damage assessment in 2006.

Table 13 Building Replacement Cost in each of Census Tract Level in the study ward (Preliminary damage assessment 2006)

DUKUH	**MEAN DAMAGE RATIO**				**REPLACEMENT COST (IDR)**			
	URML	**W1**	**RM2L**	**S1L**	**URML**	W1	RM2L	**S1L**
KARASAN	21.13%	9.35%	1.57%		6,337,652	616,430	623,636	
BOLON	21.13%	9.35%	1.57%		6,118,408	735,231	719,893	
SERUT	21.13%	9.35%	1.57%		7,025,431		434,431	
PENI	21.13%	9.35%	1.57%		6,343,395		694,330	
TASKOMBANG	21.13%	9.35%	1.57%		7,262,278		481,196	
KADIROJO	21.13%	9.35%	1.57%		6,641,021		558,351	
DAGARAN	21.13%	9.35%	1.57%		8,679,681		475,557	
NGRINGINAN	21.13%	9.35%	1.57%		8,319,151		1,318,064	
KARANGASEM	21.13%	9.35%	1.57%		6,400,085		1,306,738	
SUMURAN	21.13%	9.35%	1.57%		6,215,091	2,621,035	5,88,692	
				Mean	**6,934,219**	**1,324,232**	**720,089**	

6.3.1.2 Summary



The values of peak building response of all three model building types showed that Unreinforced Masonry with Low Rise (URML) has the higher peak building response. The selection of Pre-code Seismic Design of HAZUS in URML was also affirmed that the URML represents the old construction, not resistance with earthquake and also have a poor maintenance.

The damage probability matrix was derived for all model building types for all damage states using damage algorithm which describes in Step 5. The graphic of mean damage ratio shows the comparative analysis of damage cumulative probabilities which calculated by HAZUS method of three model building types in the ward. URML building type showing a higher risk for all damage states that have been given on URML model building type.

Table 14 Cumulative Probabilities of Three Model Building Types in Preliminary Damage Assessment 2006

	Cumulative Probabilities			
Model Type	Slight	Moderate	Extensive	Complete
W1	0.69522	0.35415	0.07655	0.01112
URML	0.74391	0.51512	0.23471	0.07301
RM2L	0.14967	0.05956	0.00736	0.00008

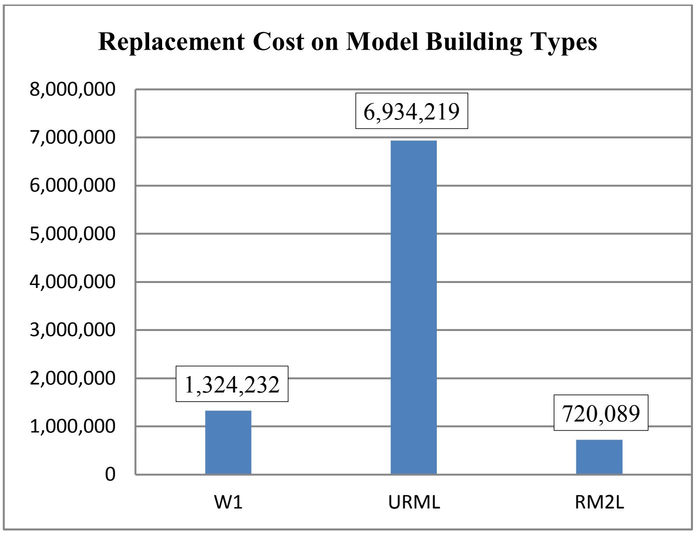
Table 15 Discrete Damage Probabilities of Three Model Building Types in Preliminary Damage Assessment 2006

	Discrete Probabilities			
Model Type	Slight	Moderate	Extensive	Complete
W1	0.34377	0.27490	0.06543	0.01112
URML	0.22879	0.28041	0.16170	0.07301
RM2L	0.09010	0.05220	0.00728	0.00008

Table 16 Summary of Model Building Type Damaged in the Study Ward

Model Building Types	**Building Response Spectra**	**Mean Damage Ratio (MDR)**	**Replacement Cost (IDR)**
W1	0.670	9.353% (Moderate Damage)	1,324,232
URML	0.680	21.129% (Extensive Damage)	6,934,219
RM2L	0.230	1.573% (Light Damage)	720,089

Table 14 shows the values of cumulative probabilities of three model building types. Using the equation 2 was given to determine the damage probabilities for each damage state in HAZUS methodology. Table 15 provides the discrete damage probabilities which obtained from cumulative probabilities given in Table 14. The calculation of discrete probabilities based on the formulation given in step 6 (page 42). Table 16 describes the summary of each type of building damaged in each of census tract level (Dukuh) in the study ward, Palbapang Village. It is also describes the mean damage ratio and mean building value in every block/Dukuh (Appendix 4).



The graphic of building replacement cost shows that Unreinforced Masonry with Low Rise (URML) has a highest on replacement cost of model building damage which calculated using HAZUS. The loss on building reached IDR 6,934,219 using pre-code seismic level design. Pre-code seismic design was chosen because of its characteristic on URML which represented the old building construction and poor maintenance and mostly built before the Indonesian Building Regulation was established.

6.3.2 Building Structures (During field survey 2010)

Building inventory was obtained during the field survey. The database of building was prepared using existing and collected information of the buildings in study ward. The selective respondents were selected by using *stratified purposive sampling*. This type of sampling method was conducted in order to get the sample of building based on the house that rebuilt by vary of NGO such as JRF and POKMAS and also that rebuilt by their own money (self-supporting). The buildings were selected with the assumption that a selected building represents the construction practice that is prevalent in the selected study ward. Figure 37 and Figure 38 show the distribution of building sampling in 10 census track the study ward.

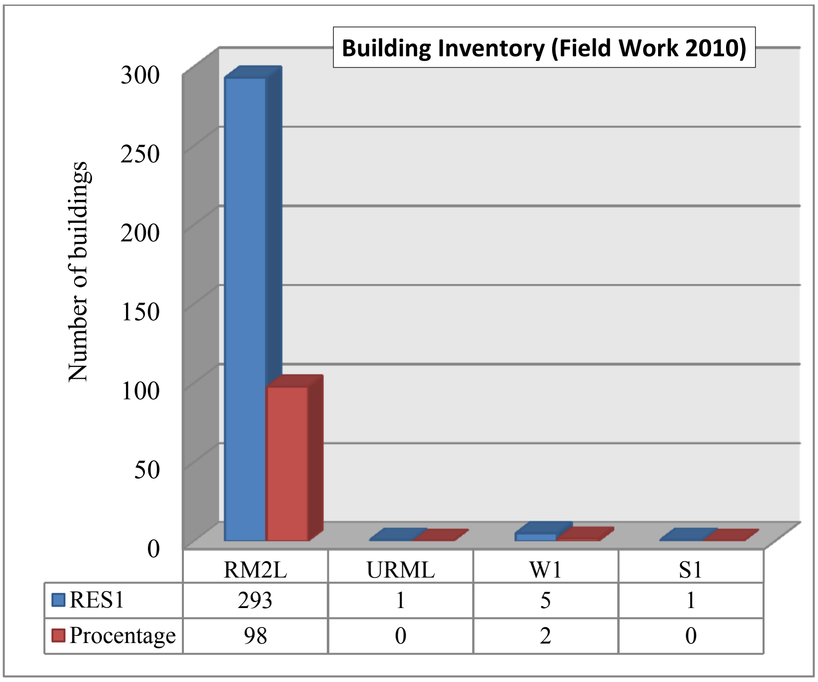


Figure 37 Distribution of model building types in Study Ward

Figure 37 showing that the predominant building structures during the field survey in the study ward is *Reinforced Masonry* with low rise (RM2L). Among all 300 residential buildings were surveyed using rapid survey in the ward, the number of Reinforced Masonry type has 293 building structures which is almost 98% of the total buildings. The RM2L represents the new construction that resistance to the quake and most of the structures have good maintenance.

The structural characteristic of RM2 in HAZUS methodology is these types of buildings have bearing walls similar to the reinforced masonry bearing wall structures with metal deck diaphragms with the roof and floor elements are supported on interior beams and columns of concrete. Most of building that built after earthquake 2006 was in Reinforced Masonry type. Many newly built confined masonry houses performed well due to their reinforced concrete tie columns and bond beams at the plinth and roof levels.

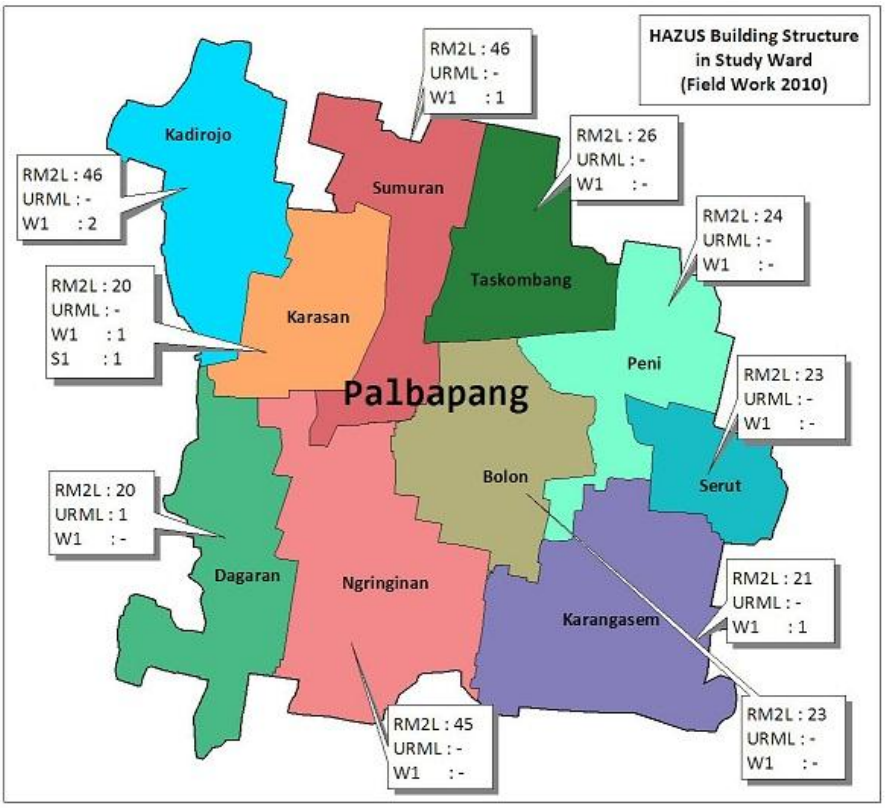


Figure 38 Building Structures in the study ward 2010

Figure 38 shows the distribution of a building sample in 10 census tract in the study ward. Most of the building surveyed was built by government funds and non-government organization such as JRF and POKMAS.

6.3.2.1 Assessment on Building Type

The assessment on building type was calculated in HAZUS methodology for a different model building type which defined in the study area; RM2L, URML, W1 and S1.

Example in Calculation of Reinforced Masonry with low rise (RM2L)

Figure 39 shows the example of building structure RM2L in Peni block.

Figure 39 Example of building structure RM2L in Peni Sub-village

Model building type is RM2L and seismic design level is High Code Seismic Design. Moderate code seismic design has been chosen because the building properties and characteristic is quiet suitable with building resistance due to earthquake.

General Information	
Location	Karasan Sub-village
Structure Type	RM2L
Soil Class	D (Stiff soil)
Building in sq.meter (Mean)	45.70 m^2
Building value per m2	688,585 IDR
Building value	31,468,343 IDR

Mean Damage Ratio for the RM2L model building type

Mean Damage Ratio				
Level of Damage	**Cumulative Probabilities**	**Discrete Damage Probabilities**	**Median Damage Ratio**	**Damage Ratio**
Complete	0.00003	0.00003	95	0.003%
Extensive	0.00424	0.00421	65	0.274%
Moderate	0.03892	0.03468	10	0.347%
Slight	0.10491	0.06599	3.5	0.231%
No damage	1.00000	0.89509	0.3	0.269%
		MDR		1.123%
		Level of Damage =		**Non-structural Damage**

From Damage Probability Matrix, the percentage of Mean Damage Factor used as a basic to find out the damage of building and multiply it with the value of model building type per meter square.

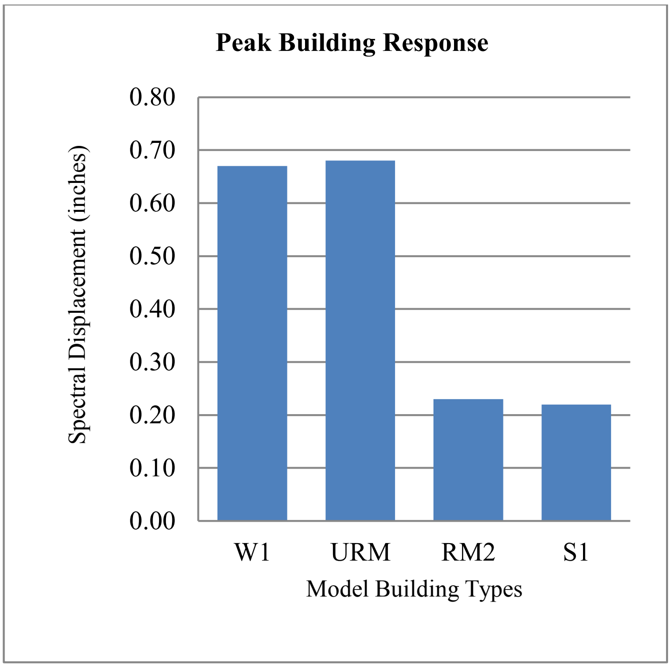
Building Replacement Cost	
Hazard Probability	10%
Exposure Period (Year)	50
Return Period (Year)	475
Mean Damage Ratio (MDR)	1.123%
Building Value (IDR)	31,468,335
Damage Value (IDR)	362,401
Replacement Cost for Building Structure RM2L (IDR)	**IDR 362,401**

Table 17 shows the result of replacement cost for each census tract and the average replacement cost in the study area during the field survey 2010. The result of replacement cost varies for each model building type. The unreinforced masonry has the highest replacement cost; IDR 5,282,250 while the steel moment frame has the lowest replacement cost which is IDR 103,800.

Table 17 Building Replacement Cost in each of Census Tract Level (During field survey 2010)

DUKUH	MEAN DAMAGE RATIO				REPLACEMENT COST			
	URML	W1	RM2L	S1L	URML	W1	RM2L	S1L
KARASAN	21.13%	9.35%	1.12%	0.35%		1,870,600	423,371	103,800
BOLON	21.13%	9.35%	1.12%	0.35%			375,473	
SERUT	21.13%	9.35%	1.12%	0.35%			301,257	
PENI	21.13%	9.35%	1.12%	0.35%			362,401	
TASKOMBANG	21.13%	9.35%	1.12%	0.35%			348,346	
KADIROJO	21.13%	9.35%	1.12%	0.35%		444,268	314,660	
DAGARAN	21.13%	9.35%	1.12%	0.35%	5,282,250		332,970	
NGRINGINAN	21.13%	9.35%	1.12%	0.35%			323,449	
KARANGASEM	21.13%	9.35%	1.12%	0.35%		3,273,550	329,146	
SUMURAN	21.13%	9.35%	1.12%	0.35%		2,244,720	366,196	
				Mean	**5,282,250**	**1,958,284**	**347,727**	**103,800**

6.3.2.2 Summary



The values of peak building response of all four model building types showed that Unreinforced Masonry with Low Rise (URML) has the higher peak building response. It has the same value with the previous one cause there is no difference in characteristic and properties of building. The selection of Pre-code Seismic Design of HAZUS in URML was also affirmed that the URML represents the old construction and not resistance with earthquake and also have a poor maintenance.

Table 18 shows the values of cumulative probabilities of four model building types. It shows the comparative analysis of damage cumulative probabilities which calculated by HAZUS method of four model building types in the ward. Still the URML building type showing a higher risk for all damage states that have been given on URML model building type. Using the equation 2 was given to determine the damage probabilities for each damage state in HAZUS methodology. Table 19 provides the discrete damage probabilities which obtained from cumulative probabilities given in Table 18.

Table 18 Cumulative Probabilities of four model building types During the field work

	Cumulative Probabilities			
Model Type	Slight	Moderate	Extensive	Complete
W1	0.70034	0.35670	0.07856	0.01154
URM	0.74391	0.51512	0.23471	0.07301
RM2	0.10491	0.03892	0.00424	0.00003
S1	0.01319	0.00059	0.00000	0.00000

Table 19 Discrete Damage Probabilities of four model building types During the field work

	Discrete Probabilities			
Model Type	Slight	Moderate	Extensive	Complete
W1	0.34364	0.27813	0.06703	0.01154
URM	0.22879	0.28041	0.16170	0.07301
RM2	0.06599	0.03468	0.00421	0.00003
S1	0.01260	0.00059	0.00000	0.00000

Table 20 Summary of Model Building Type Damaged in the Study Ward

Model Building Types	Building Response Spectra	Mean Damage Ratio (MDR)	Replacement Cost (IDR)
W1	0.670	9.353% (Moderate Damage)	1,958,284
URML	0.680	21.129% (Extensive Damage)	5,282,250
RM2L	0.230	1.123% (Non-structural Damage)	347,727
S1L	0.220	0.346% (Non-structural Damage)	103,800

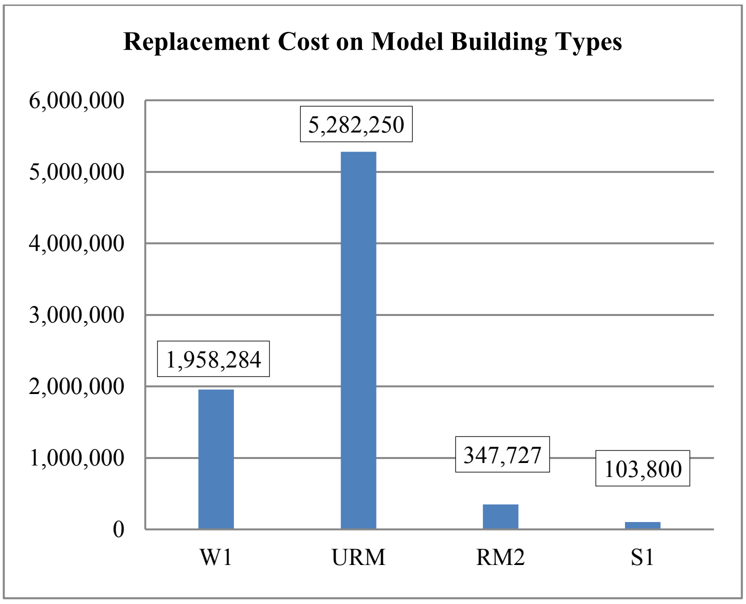


Table 20 describes the summary of each type of building damaged in each of census tract level (Dukuh) in the study ward. It is also describes the mean damage ratio and mean building value in every Dukuh (Appendix 5).The graphic of building replacement cost shows that URML has a highest on replacement cost of model building damage which calculated using HAZUS. The loss on building reached IDR 5,282,250 using pre-code seismic level design. Pre-code is chosen because of its characteristic on URML which represented the old building construction and poor maintenance and mostly built before the Indonesian Building Regulation was established. The S1 shows a lowest on building replacement cost due to its resistance to the earthquake and grouped into moderate code seismic level.

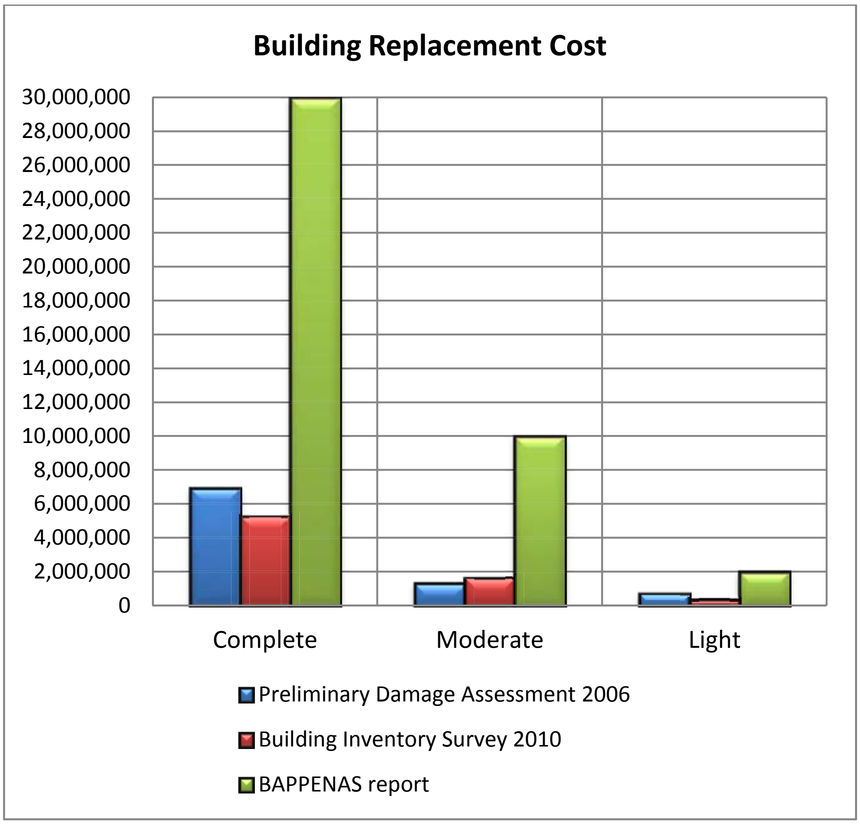
6.4 Discussion

The results concluded that the damage probability determined by HAZUS methodology does not gives the realistic results in terms of monetary loss on building damage for risk assessment in the study ward. The difference in building properties and characteristic of Wood Light Frame (W1), Reinforced Masonry (RM2), Unreinforced Masonry (URM) and Steel Light Frame (S1) with structural properties of framed, brick and masonry buildings in study area could be the one of the reason for getting inaccurate results of building assessment.

Building inventory in 2006 preliminary damage assessment showing URM has a highest replacement cost while RM2 has a lowest cost. This shows that URM has a very poor construction and maintenance. The selection of pre-code seismic design for URM indicates the structures not resistance with an earthquake.

Building inventory during the field survey in August – October 2010 period shows that RM2 has a highest number in each census tract. It is related to the recent building codes regulated by Law (SNI-03-1726-2002) that every building must resistance to the earthquake. In the result of building replacement cost, the URM shows the highest in replacement cost, same with the 2006 building damaged while the S1 has a lowest cost in building assessment.

The government report from BAPPENAS (2006) announced that IDR 30 million will be provided for each destroyed house, IDR 10 million for damaged house and IDR 2 million for a light damaged house. The assumption was taken in order to compare the existing data with HAZUS result. A destroyed house is represent the extensive and complete damaged in HAZUS, a damaged house similar with moderate damaged while light damaged house represent the light damaged and non-structural damaged in HAZUS.



The calculation of Pearson correlation value (r) shows the positive correlation between the resulted of building loss estimation from Government report (BAPPENAS, 2006) with the preliminary report in rapid damage assessment of 2006, which have 0.98 of Pearson value while the correlation between building loss resulted during the field work in 2010 and total building damaged shows 0.91 in Pearson value which mean have the positive or strong correlation between estimation resulted and the number of building damaged in study area. This indicates that the more numbers of building damage, the higher of loss estimation in building risk assessment.

7. CONCLUSION AND RECOMMENDATION

This chapter concludes this study and also some recommendations have been given for further studies and also for local authorities. The research questions were answered to give the research conclusion

7.1 Conclusion

The works conducted in the research have met the research objectives and also have answered the research questions which stated in first chapter. The main objective of the research is analyzing the replacement cost of buildings using HAZUS methodology for seismic risk assessment in Palbapang Village of Bantul Sub-district. The conclusion in detailed regarding for each specific objective can be explained as follows:

1. *Identify and modify the parameters of seismic risk assessment that are required in HAZUS for building loss estimation in the Indonesian practice.*

   The parameter used in HAZUS for seismic risk assessment consists of various parameters which can be classified into four main components which are: seismic hazard characteristic, ground motion, building inventory and damage functions.

   The seismic hazard characteristic or in other words is earthquake scenario include the location of the earthquake, fault type and source information. Using deterministic method from May 27 2006 earthquake with 6.3 Mw and the epicenter lies on 10 km of shallow depth, the attenuation function was defined using Boore, Joyner & Fumal (1997) equation. The ground motion is include the soil classification, soil amplification factors, spectral displacement and spectral acceleration which also have a link with seismic hazard characteristic. Building inventory consists of building occupancy classification and building structures classification. Both derived during the field survey and using satellite imagery to obtained building foot print map. The building structure classification was taken from HAZUS methodology for particular model building type that exists in study ward. Seismic design building code was taken from Indonesian building code SNI-03-1726-2002. The building damage function in HAZUS was known as No Damage (N), Slight Damage (S), Moderate Damage (M), Extensive Damage (E) and Complete Damage (C). The damage functions or in other word fragility curves known as spectral displacement (inch) is the intersection of two curves; capacity curve and demand curve. Later on in the next objective it will be describes clearly.

HAZUS method set aside the comprehensive engineering analysis which considered the potential ground motion and building structural components behavior. HAZUS is intended for local, regional or state officials in United States (US) and includes the structural characteristic of buildings based on construction and building practice used in US. The structural characteristic of buildings within HAZUS tends to have a different in structural characteristic with the representative buildings in Indonesia, especially in the study area. The difference in this matter potentially gave great effects on building strength structures. For instance the wood type in US is slightly different with the wood type in Indonesia. The wood buildings in Indonesia tends more like in bamboo or thin wood types and mostly is not built from teak trees while in US is quiet strength made from teak or oak trees with a good structure and foundation. This could be the reasons why the result of building assessment in study area is more or less unrealistic.

2. *Estimate the building replacement costs due to the Yogyakarta earthquake of 2006 using deterministic earthquake scenarios in the HAZUS methodology.*

The purpose of a building inventory classification system is to group buildings with similar damage/loss characteristics into a set of pre-defined building classes. Seismic risk assessment under HAZUS methodology is based on basic spatial units and not done in individual building level. Therefore even at large scale risk assessment is normally carried out for groups of buildings namely homogeneous unit. HAZUS in United States tends to have similar houses within a zone while the Indonesian condition was not. It requires some modification in the application of HAZUS model for implementation in Indonesia. Using the existing Sub-village as based for census tract level can be defined as a homogeneous unit. The main idea of homogeneous area mapping was to divide the Bantul Sub-district into smaller units which are smaller than wards and the concept is to have a similar building type and occupancy class.

The damage functions is based on the intersection of two curves; capacity curves and demand spectra curves which produced peak building response and it will be used to estimates damage state probabilities. The mean damage estimates are expressed in terms of probabilities of reaching or exceeding discrete states of damage for a given level of ground motion or failure. These estimates are provided for representative building categories and types.

Building replacement cost is calculated within HAZUS at the census tract level for each occupancy class. From damage probability matrix for each of building type, the percentage of mean damage factor used as a basic to find out the level damage of building and multiply the percentage of mean damage ratio with the building value per meter square based on field survey.

3. *Evaluate the use of HAZUS methodology for seismic risk assessment in building loss estimation in the Bantul Sub-district.*

   Basically HAZUS can be applied and adopted in Bantul District for seismic risk assessment in different building structures with some modification in occupancy class and structural characteristic, but the model implementation on building structures assessment in not very accurate in Indonesian practice. The occupancy class which is residential building can be adopted in study area without difficulties but there are many mixed class of residential and commercial building which have to consider should be added in the classification. Building structures in study area also can be adopted by modifying the structural characteristic into HAZUS method. The structural characteristic of framed, brick, masonry and wood buildings in study area can be classified into Reinforced Masonry (RM2), Unreinforced Masonry (URM) and Wood Light Frame (W1).

The modification on building structures and occupancy class needed for the implementation of HAZUS in Indonesian practice. Redefining the model building types and occupancy class will be considered as the components to be change in Indonesian building practice.

7.2 Recommendation

7.2.1 Recommendation for Bantul District

Overall the HAZUS methodology can be applied and adopted in Indonesia especially in Bantul District with some modification in parameter input and building structures, but the unrealistic result in building replacement cost considered taking into account that HAZUS method seems not to be very accurate in Indonesian implementation. It needs to be redefining the HAZUS model building types into Indonesian building practice.

The large number of structural building database was required within HAZUS method. It is rather difficult to collect and generating building inventory in short period of research without the involvement of the related institution which dealt with the land and building policy and disaster emergency plan. The involvement of agencies or institution like BPN, Tax Office, BAPPEDA, BNPB and PEMDA/Local Government in earthquake risk reduction can effectively work in this area. HAZUS requires large building inventory and complex of building structural calculations. The availability of building database inventory is very important in building the mitigation planning.

7.2.2 Recommendation for Further Research

- The further research on building fragility curves in Indonesia is needed and could be very helpful for building damaged assessment due to earthquake disaster. The database created and building information collected to use in HAZUS can be incorporated in identifying the building damaged assessment.

- The calculation of building replacement cost should use the market values instead of the values available in the document of the Tax Office. The prices of building in taxation purpose do not represent the actual values as the market values do.

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APPENDIX

Appendix 1.Distribution of housing damage (BAPPENAS, 2006)

	Totally Destroyed	Damaged	Total Housing Damage	Human Death Toll
Yogyakarta Province	**88,249**	**98,343**	**186,592**	**4,659**
Bantul	46,753	33,137	79,890	4,121
Sleman	14,801	34,231	49,032	240
Gunung Kidul	15,071	17,967	33,038	81
Yogyakarta City	4,831	3,591	8,422	195
Kulonprogo	6,793	9,471	16,210	22
Central Java Province	**68,415**	**103,689**	**172,104**	**1,057**
Klaten	65,849	100,817	166,666	1,041
Sukoharjo	1,185	488	1,673	1
Magelang	499	729	1,228	10
Purworejo	144	760	904	1
Boyolali	715	825	1,540	4
Wonogiri	23	70	93	-
TOTAL	**156,664**	**202,032**	**358,696**	**5,716**

Appendix 2.Coordinates of GCPs that were distributed over Bantul Sub-district (Source: Data Analysis, 2010)

Point	X (TM3)	Y (TM3)	Hgt(ell)	HRMS	Latitude	Longitude	X (UTM)	Y (UTM)
P1	292537.421	625730.19	61.788	0.00881	7 54' 21.87"	110 20' 21.32"	427168.37	9126027.91
P2	291494.229	624300.062	56.802	0.01175	7 55' 8.49"	110 19' 47.36"	426130.82	9124594.52
P3	290110.569	624971.119	60.244	0.02119	7 54' 46.74"	110 19' 2.14"	424745.14	9125260.23
P4	290501.685	625819.074	63.974	0.0112	7 54' 19.10"	110 19' 14.86"	425133.23	9126109.71
P5	289863.372	625785.557	64.903	0.01117	7 54' 20.24"	110 18' 54.02"	424495.17	9126073.65
P6	290617.998	626308.385	64.621	0.01734	7 54' 3.17"	110 19' 18.62"	425247.57	9126599.12
P7	290615.814	626311.911	64.818	0.02399	7 54' 3.06"	110 19' 18.55"	425245.42	9126602.49
P8	291866.92	626588.802	65.335	0.02351	7 53' 53.96"	110 19' 59.38"	426495.19	9126883.97
P9	289852.053	624400.534	58.102	0.03992	7 55' 5.32"	110 18' 53.74"	424488.87	9124689.20

Appendix 3.Coordinates of GCPs and its corresponding points on the image (Source: Data Analysis, 2010)

ID	X Source (GCP)	Y Source (GCP)	X Map	Y Map	Residual
P1	427166.017779	9126032.494565	427168.495499	9126027.930193	0.017920
P2	425131.567343	9126113.117264	425133.136999	9126109.455375	0.021750
P3	426494.215385	9126887.840743	426495.136569	9126883.832986	0.021590
P4	425246.768630	9126602.528646	425247.649724	9126599.019230	0.016040
P5	424742.492369	9125264.152378	424745.206920	9125260.378113	0.023290
P6	426126.581760	9124599.142509	426130.815735	9124594.536525	0.003620
P7	424493.795312	9126076.992183	424495.159855	9126073.651892	0.028300
P8	424485.377982	9124692.889413	424488.834457	9124689.053244	0.005560

Appendix 4.Mean Damage Ratio and Level of Damage (Preliminary Damage Assessment 2006)

DUKUH	MEAN DAMAGE RATIO			LEVEL OF DAMAGE			MEAN BUILDING VALUE		
	URML	W1	RM2L	URML	W1	RM2L	URML	W1	RM2L
KARASAN	21.13%	9.35%	1.57%	Extensive	Moderate	Light	29,995,040	6,590,720	39,646,269
BOLON	21.13%	9.35%	1.57%	Extensive	Moderate	Light	28,957,394	7,860,907	45,765,600
SERUT	21.13%	9.35%	1.57%	Extensive	Moderate	Light	33,250,182		27,618,000
PENI	21.13%	9.35%	1.57%	Extensive	Moderate	Light	30,022,221		44,140,500
TASKOMBANG	21.13%	9.35%	1.57%	Extensive	Moderate	Light	34,371,138		30,591,000
KADIROJO	21.13%	9.35%	1.57%	Extensive	Moderate	Light	31,430,834		35,495,927
DAGARAN	21.13%	9.35%	1.57%	Extensive	Moderate	Light	41,079,469		30,232,500
NGRINGINAN	21.13%	9.35%	1.57%	Extensive	Moderate	Light	39,373,140		83,793,000
KARANGASEM	21.13%	9.35%	1.57%	Extensive	Moderate	Light	30,290,526		83,073,000
SUMURAN	21.13%	9.35%	1.57%	Extensive	Moderate	Light	29,414,979	28,023,467	37,424,824

Appendix 5.Mean Damage Ratio and Level of Damage (During Field Survey 2010)

DUKUH	MEAN DAMAGE RATIO				LEVEL OF DAMAGE				MEAN BUILDING VALUE			
	URML	W1	RM2L	S1L	URML	W1	RM2L	S1L	URML	W1	RM2L	S1L
KARASAN	21.13%	9.35%	1.12%	0.35%	Extensive	Moderate	Non-structural	Non-structural		20,000,000	37,700,000	30,000,000
BOLON	21.13%	9.35%	1.12%	0.35%	Extensive	Moderate	Non-structural	Non-structural			33,434,783	
SERUT	21.13%	9.35%	1.12%	0.35%	Extensive	Moderate	Non-structural	Non-structural			26,826,087	
PENI	21.13%	9.35%	1.12%	0.35%	Extensive	Moderate	Non-structural	Non-structural			32,270,833	
TASKOMBANG	21.13%	9.35%	1.12%	0.35%	Extensive	Moderate	Non-structural	Non-structural			31,019,231	
KADIROJO	21.13%	9.35%	1.12%	0.35%	Extensive	Moderate	Non-structural	Non-structural		4,750,000	28,019,565	
DAGARAN	21.13%	9.35%	1.12%	0.35%	Extensive	Moderate	Non-structural	Non-structural	25,000,000		29,650,000	
NGRINGINAN	21.13%	9.35%	1.12%	0.35%	Extensive	Moderate	Non-structural	Non-structural			28,802,222	
KARANGASEM	21.13%	9.35%	1.12%	0.35%	Extensive	Moderate	Non-structural	Non-structural		35,000,000	29,309,524	
SUMURAN	21.13%	9.35%	1.12%	0.35%	Extensive	Moderate	Non-structural	Non-structural		24,000,000	32,608,696	

Appendix 6.Soil Amplification Factors

Site Class B Spectral Acceleration	Site Class				
	A	B	C	D	E
Short-Period, S_{AS} (g)	Short-Period Amplification Factor, F_A				
≤ 0.25	0.8	1.0	1.2	1.6	2.5
0.50	0.8	1.0	1.2	1.4	1.7
0.75	0.8	1.0	1.1	1.2	1.2
1.0	0.8	1.0	1.0	1.1	0.9
≥ 1.25	0.8	1.0	1.0	1.0	0.8*
1-Second Period, S_{A1} (g)	1.0-Second Period Amplification Factor, F_V				
≤ 0.1	0.8	1.0	1.7	2.4	3.5
0.2	0.8	1.0	1.6	2.0	3.2
0.3	0.8	1.0	1.5	1.8	2.8
0.4	0.8	1.0	1.4	1.6	2.4
≥ 0.5	0.8	1.0	1.3	1.5	2.0*

Appendix 7.Code Building Capacity Curves – High Code Seismic Design Level

Building Type	Yield Capacity Point		Ultimate Capacity Point	
	D_y (in.)	A_y (g)	D_u (in.)	A_u (g)
W1	0.48	0.400	11.51	1.200
W2	0.63	0.400	12.53	1.000
S1L	0.61	0.250	14.67	0.749
S1M	1.78	0.156	28.40	0.468
S1H	4.66	0.098	55.88	0.293
S2L	0.63	0.400	10.02	0.800
S2M	2.43	0.333	25.88	0.667
S2H	7.75	0.254	61.97	0.508
S3	0.63	0.400	10.02	0.800
S4L	0.38	0.320	6.91	0.720
S4M	1.09	0.267	13.10	0.600
S4H	3.49	0.203	31.37	0.457
S5L				
S5M				
S5H				
C1L	0.39	0.250	9.39	0.749
C1M	1.15	0.208	18.44	0.624
C1H	2.01	0.098	24.13	0.293
C2L	0.48	0.400	9.59	1.000
C2M	1.04	0.333	13.84	0.833
C2H	2.94	0.254	29.39	0.635
C3L				
C3M				
C3H				
PC1	0.72	0.600	11.51	1.200
PC2L	0.48	0.400	7.67	0.800
PC2M	1.04	0.333	11.07	0.667
PC2H	2.94	0.254	23.52	0.508
RM1L	0.64	0.533	10.23	1.066
RM1M	1.38	0.444	14.76	0.889
RM2L	0.64	0.533	10.23	1.066
RM2M	1.38	0.444	14.76	0.889
RM2H	3.92	0.338	31.35	0.677
URML				
URMM				
MH	0.18	0.150	2.16	0.300

Appendix 8.Code Building Capacity Curves – Moderate Code Seismic Design Level

Building Type	Yield Capacity Point		Ultimate Capacity Point	
	D_y (in.)	A_y (g)	D_u (in.)	A_u (g)
W1	0.36	0.300	6.48	0.900
W2	0.31	0.200	4.70	0.500
S1L	0.31	0.125	5.50	0.375
S1M	0.89	0.078	10.65	0.234
S1H	2.33	0.049	20.96	0.147
S2L	0.31	0.200	3.76	0.400
S2M	1.21	0.167	9.70	0.333
S2H	3.87	0.127	23.24	0.254
S3	0.31	0.200	3.76	0.400
S4L	0.19	0.160	2.59	0.360
S4M	0.55	0.133	4.91	0.300
S4H	1.74	0.102	11.76	0.228
S5L				
S5M				
S5H				
C1L	0.20	0.125	3.52	0.375
C1M	0.58	0.104	6.91	0.312
C1H	1.01	0.049	9.05	0.147
C2L	0.24	0.200	3.60	0.500
C2M	0.52	0.167	5.19	0.417
C2H	1.47	0.127	11.02	0.317
C3L				
C3M				
C3H				
PC1	0.36	0.300	4.32	0.600
PC2L	0.24	0.200	2.88	0.400
PC2M	0.52	0.167	4.15	0.333
PC2H	1.47	0.127	8.82	0.254
RM1L	0.32	0.267	3.84	0.533
RM1M	0.69	0.222	5.54	0.444
RM2L	0.32	0.267	3.84	0.533
RM2M	0.69	0.222	5.54	0.444
RM2H	1.96	0.169	11.76	0.338
URML				
URMM				
MH	0.18	0.150	2.16	0.300

Appendix 9.Code Building Capacity Curves – Low Code Seismic Design Level

Building Type	Yield Capacity Point		Ultimate Capacity Point	
	D_y (in.)	A_y (g)	D_u (in.)	A_u (g)
W1	0.24	0.200	4.32	0.600
W2	0.16	0.100	2.35	0.250
S1L	0.15	0.062	2.29	0.187
S1M	0.44	0.039	4.44	0.117
S1H	1.16	0.024	8.73	0.073
S2L	0.16	0.100	1.57	0.200
S2M	0.61	0.083	4.04	0.167
S2H	1.94	0.063	9.68	0.127
S3	0.16	0.100	1.57	0.200
S4L	0.10	0.080	1.08	0.180
S4M	0.27	0.067	2.05	0.150
S4H	0.87	0.051	4.90	0.114
S5L	0.12	0.100	1.20	0.200
S5M	0.34	0.083	2.27	0.167
S5H	1.09	0.063	5.45	0.127
C1L	0.10	0.062	1.47	0.187
C1M	0.29	0.052	2.88	0.156
C1H	0.50	0.024	3.77	0.073
C2L	0.12	0.100	1.50	0.250
C2M	0.26	0.083	2.16	0.208
C2H	0.74	0.063	4.59	0.159
C3L	0.12	0.100	1.35	0.225
C3M	0.26	0.083	1.95	0.188
C3H	0.74	0.063	4.13	0.143
PC1	0.18	0.150	1.80	0.300
PC2L	0.12	0.100	1.20	0.200
PC2M	0.26	0.083	1.73	0.167
PC2H	0.74	0.063	3.67	0.127
RM1L	0.16	0.133	1.60	0.267
RM1M	0.35	0.111	2.31	0.222
RM2L	0.16	0.133	1.60	0.267
RM2M	0.35	0.111	2.31	0.222
RM2H	0.98	0.085	4.90	0.169
URML	0.24	0.200	2.40	0.400
URMM	0.27	0.111	1.81	0.222
MH	0.18	0.150	2.16	0.300

Appendix 10.Code Building Capacity Curves – Pre-Code Seismic Design Level

Building Type	Yield Capacity Point		Ultimate Capacity Point	
	D_y (in.)	A_y (g)	D_u (in.)	A_u (g)
W1	0.24	0.200	4.32	0.600
W2	0.16	0.100	2.35	0.250
S1L	0.15	0.062	2.75	0.187
S1M	0.44	0.039	5.33	0.117
S1H	1.16	0.024	10.48	0.073
S2L	0.16	0.100	1.88	0.200
S2M	0.61	0.083	4.85	0.167
S2H	1.94	0.063	11.62	0.127
S3	0.16	0.100	1.88	0.200
S4L	0.10	0.080	1.30	0.180
S4M	0.27	0.067	2.46	0.150
S4H	0.87	0.051	5.88	0.114
S5L	0.12	0.100	1.20	0.200
S5M	0.34	0.083	2.27	0.167
S5H	1.09	0.063	5.45	0.127
C1L	0.10	0.062	1.76	0.187
C1M	0.29	0.052	3.46	0.156
C1H	0.50	0.024	4.52	0.073
C2L	0.12	0.100	1.80	0.250
C2M	0.26	0.083	2.60	0.208
C2H	0.74	0.063	5.51	0.159
C3L	0.12	0.100	1.35	0.225
C3M	0.26	0.083	1.95	0.188
C3H	0.74	0.063	4.13	0.143
PC1	0.18	0.150	2.16	0.300
PC2L	0.12	0.100	1.44	0.200
PC2M	0.26	0.083	2.08	0.167
PC2H	0.74	0.063	4.41	0.127
RM1L	0.16	0.133	1.92	0.267
RM1M	0.35	0.111	2.77	0.222
RM2L	0.16	0.133	1.92	0.267
RM2M	0.35	0.111	2.77	0.222
RM2H	0.98	0.085	5.88	0.169
URML	0.24	0.200	2.40	0.400
URMM	0.27	0.111	1.81	0.222
MH	0.18	0.150	2.16	0.300

Appendix 11.Structural Fragility Curve Parameters – High Code Seismic Design Level

Building Properties			Interstory Drift at Threshold of Damage State				Spectral Displacement (inches)							
Type	Height (inches)						Slight		Moderate		Extensive		Complete	
	Roof	Modal	Slight	Moderate	Extensive	Complete	Median	Beta	Median	Beta	Median	Beta	Median	Beta
W1	168	126	0.0040	0.0120	0.0400	0.1000	0.50	0.80	1.51	0.81	5.04	0.85	12.60	0.97
W2	288	216	0.0040	0.0120	0.0400	0.1000	0.86	0.81	2.59	0.88	8.64	0.90	21.60	0.83
S1L	288	216	0.0060	0.0120	0.0300	0.0800	1.30	0.80	2.59	0.76	6.48	0.69	17.28	0.72
S1M	720	540	0.0040	0.0080	0.0200	0.0533	2.16	0.65	4.32	0.66	10.80	0.67	28.80	0.74
S1H	1872	1123	0.0030	0.0060	0.0150	0.0400	3.37	0.64	6.74	0.64	16.85	0.65	44.93	0.67
S2L	288	216	0.0050	0.0100	0.0300	0.0800	1.08	0.81	2.16	0.89	6.48	0.94	17.28	0.83
S2M	720	540	0.0033	0.0067	0.0200	0.0533	1.80	0.67	3.60	0.67	10.80	0.68	28.80	0.79
S2H	1872	1123	0.0025	0.0050	0.0150	0.0400	2.81	0.63	5.62	0.63	16.85	0.64	44.93	0.71
S3	180	135	0.0040	0.0080	0.0240	0.0700	0.54	0.81	1.08	0.82	3.24	0.91	9.45	0.90
S4L	288	216	0.0040	0.0080	0.0240	0.0700	0.86	0.89	1.73	0.89	5.18	0.98	15.12	0.87
S4M	720	540	0.0027	0.0053	0.0160	0.0467	1.44	0.77	2.88	0.72	8.64	0.70	25.20	0.89
S4H	1872	1123	0.0020	0.0040	0.0120	0.0350	2.25	0.64	4.49	0.66	13.48	0.69	39.31	0.77
S5L														
S5M														
S5H														
C1L	240	180	0.0050	0.0100	0.0300	0.0800	0.90	0.81	1.80	0.84	5.40	0.86	14.40	0.81
C1M	600	450	0.0033	0.0067	0.0200	0.0533	1.50	0.68	3.00	0.67	9.00	0.68	24.00	0.81
C1H	1440	864	0.0025	0.0050	0.0150	0.0400	2.16	0.66	4.32	0.64	12.96	0.67	34.56	0.78
C2L	240	180	0.0040	0.0100	0.0300	0.0800	0.72	0.81	1.80	0.84	5.40	0.93	14.40	0.92
C2M	600	450	0.0027	0.0067	0.0200	0.0533	1.20	0.74	3.00	0.77	9.00	0.68	24.00	0.77
C2H	1440	864	0.0020	0.0050	0.0150	0.0400	1.73	0.68	4.32	0.65	12.96	0.66	34.56	0.75
C3L														
C3M														
C3H														
PC1	180	135	0.0040	0.0080	0.0240	0.0700	0.54	0.76	1.08	0.86	3.24	0.88	9.45	0.99
PC2L	240	180	0.0040	0.0080	0.0240	0.0700	0.72	0.84	1.44	0.88	4.32	0.98	12.60	0.94
PC2M	600	450	0.0027	0.0053	0.0160	0.0467	1.20	0.77	2.40	0.81	7.20	0.70	21.00	0.82
PC2H	1440	864	0.0020	0.0040	0.0120	0.0350	1.73	0.64	3.46	0.66	10.37	0.68	30.24	0.81
RM1L	240	180	0.0040	0.0080	0.0240	0.0700	0.72	0.84	1.44	0.86	4.32	0.92	12.60	1.01
RM1M	600	450	0.0027	0.0053	0.0160	0.0467	1.20	0.71	2.40	0.81	7.20	0.76	21.00	0.75
RM2L	240	180	0.0040	0.0080	0.0240	0.0700	0.72	0.80	1.44	0.81	4.32	0.91	12.60	0.98
RM2M	600	450	0.0027	0.0053	0.0160	0.0467	1.20	0.71	2.40	0.79	7.20	0.70	21.00	0.73
RM2H	1440	864	0.0020	0.0040	0.0120	0.0350	1.73	0.66	3.46	0.65	10.37	0.66	30.24	0.72
URML														
URMM														
MH	120	120	0.0040	0.0080	0.0240	0.0700	0.48	0.91	0.96	1.00	2.88	1.03	8.40	0.92

Appendix 12.Structural Fragility Curve Parameters – Moderate Code Seismic Design Level

Building Properties			Interstory Drift at Threshold of Damage State				Spectral Displacement (inches)							
Type	Height (inches)						Slight		Moderate		Extensive		Complete	
	Roof	Modal	Slight	Moderate	Extensive	Complete	Median	Beta	Median	Beta	Median	Beta	Median	Beta
W1	168	126	0.0040	0.0099	0.0306	0.0750	0.50	0.84	1.25	0.86	3.86	0.89	9.45	1.04
W2	288	216	0.0040	0.0099	0.0306	0.0750	0.86	0.89	2.14	0.95	6.62	0.95	16.20	0.92
S1L	288	216	0.0060	0.0104	0.0235	0.0600	1.30	0.80	2.24	0.75	5.08	0.74	12.96	0.88
S1M	720	540	0.0040	0.0069	0.0157	0.0400	2.16	0.65	3.74	0.68	8.46	0.69	21.60	0.87
S1H	1872	1123	0.0030	0.0052	0.0118	0.0300	3.37	0.64	5.83	0.64	13.21	0.71	33.70	0.83
S2L	288	216	0.0050	0.0087	0.0233	0.0600	1.08	0.93	1.87	0.92	5.04	0.93	12.96	0.93
S2M	720	540	0.0033	0.0058	0.0156	0.0400	1.80	0.70	3.12	0.69	8.40	0.69	21.60	0.89
S2H	1872	1123	0.0025	0.0043	0.0117	0.0300	2.81	0.66	4.87	0.64	13.10	0.69	33.70	0.80
S3	180	135	0.0040	0.0070	0.0187	0.0525	0.54	0.88	0.94	0.92	2.52	0.97	7.09	0.89
S4L	288	216	0.0040	0.0069	0.0187	0.0525	0.86	0.96	1.50	1.00	4.04	1.03	11.34	0.92
S4M	720	540	0.0027	0.0046	0.0125	0.0350	1.44	0.75	2.50	0.72	6.73	0.72	18.90	0.94
S4H	1872	1123	0.0020	0.0035	0.0093	0.0262	2.25	0.66	3.90	0.67	10.50	0.70	29.48	0.90
S5L														
S5M														
S5H														
C1L	240	180	0.0050	0.0087	0.0233	0.0600	0.90	0.89	1.56	0.90	4.20	0.90	10.80	0.89
C1M	600	450	0.0033	0.0058	0.0156	0.0400	1.50	0.70	2.60	0.70	7.00	0.70	18.00	0.89
C1H	1440	864	0.0025	0.0043	0.0117	0.0300	2.16	0.66	3.74	0.66	10.08	0.76	25.92	0.91
C2L	240	180	0.0040	0.0084	0.0232	0.0600	0.72	0.91	1.52	0.97	4.17	1.03	10.80	0.87
C2M	600	450	0.0027	0.0056	0.0154	0.0400	1.20	0.81	2.53	0.77	6.95	0.73	18.00	0.91
C2H	1440	864	0.0020	0.0042	0.0116	0.0300	1.73	0.66	3.64	0.68	10.00	0.70	25.92	0.87
C3L														
C3M														
C3H														
PC1	180	135	0.0040	0.0070	0.0187	0.0525	0.54	0.89	0.94	0.92	2.52	0.97	7.09	1.04
PC2L	240	180	0.0040	0.0069	0.0187	0.0525	0.72	0.96	1.25	1.00	3.37	1.03	9.45	0.88
PC2M	600	450	0.0027	0.0046	0.0125	0.0350	1.20	0.82	2.08	0.79	5.61	0.75	15.75	0.93
PC2H	1440	864	0.0020	0.0035	0.0094	0.0263	1.73	0.68	3.00	0.69	8.08	0.77	22.68	0.89
RM1L	240	180	0.0040	0.0069	0.0187	0.0525	0.72	0.96	1.25	0.99	3.37	1.05	9.45	0.94
RM1M	600	450	0.0027	0.0046	0.0125	0.0350	1.20	0.81	2.08	0.82	5.61	0.80	15.75	0.89
RM2L	240	180	0.0040	0.0069	0.0187	0.0525	0.72	0.91	1.25	0.96	3.37	1.02	9.45	0.93
RM2M	600	450	0.0027	0.0046	0.0125	0.0350	1.20	0.81	2.08	0.80	5.61	0.75	15.75	0.88
RM2H	1440	864	0.0020	0.0035	0.0094	0.0263	1.73	0.67	3.00	0.69	8.08	0.70	22.68	0.86
URML														
URMM														
MH	120	120	0.0040	0.0080	0.0240	0.0700	0.48	0.91	0.96	1.00	2.88	1.03	8.40	0.92

Appendix 13.Structural Fragility Curve Parameters – Low Code Seismic Design Level

Building Properties			Interstory Drift at Threshold of Damage State				Spectral Displacement (inches)							
Type	Height (inches)						Slight		Moderate		Extensive		Complete	
	Roof	Modal	Slight	Moderate	Extensive	Complete	Median	Beta	Median	Beta	Median	Beta	Median	Beta
W1	168	126	0.0040	0.0099	0.0306	0.0750	0.50	0.93	1.25	0.98	3.86	1.02	9.45	0.99
W2	288	216	0.0040	0.0099	0.0306	0.0750	0.86	0.97	2.14	0.90	6.62	0.89	16.20	0.99
S1L	288	216	0.0060	0.0096	0.0203	0.0500	1.30	0.77	2.07	0.78	4.38	0.78	10.80	0.96
S1M	720	540	0.0040	0.0064	0.0135	0.0333	2.16	0.68	3.44	0.78	7.30	0.85	18.00	0.98
S1H	1872	1123	0.0030	0.0048	0.0101	0.0250	3.37	0.66	5.37	0.70	11.38	0.76	28.08	0.92
S2L	288	216	0.0050	0.0080	0.0200	0.0500	1.08	0.96	1.73	0.89	4.32	0.86	10.80	0.98
S2M	720	540	0.0033	0.0053	0.0133	0.0333	1.80	0.70	2.88	0.73	7.20	0.85	18.00	0.98
S2H	1872	1123	0.0025	0.0040	0.0100	0.0250	2.81	0.66	4.49	0.67	11.23	0.74	28.08	0.92
S3	180	135	0.0040	0.0064	0.0161	0.0438	0.54	0.98	0.87	0.99	2.17	1.01	5.91	0.90
S4L	288	216	0.0040	0.0064	0.0161	0.0438	0.86	1.05	1.38	0.98	3.47	0.89	9.45	0.98
S4M	720	540	0.0027	0.0043	0.0107	0.0292	1.44	0.76	2.31	0.78	5.78	0.90	15.75	0.99
S4H	1872	1123	0.0020	0.0032	0.0080	0.0219	2.25	0.70	3.60	0.75	9.01	0.90	24.57	0.98
S5L	288	216	0.0030	0.0060	0.0150	0.0350	0.65	1.11	1.30	1.04	3.24	0.99	7.56	0.95
S5M	720	540	0.0020	0.0040	0.0100	0.0233	1.08	0.77	2.16	0.79	5.40	0.87	12.60	0.98
S5H	1872	1123	0.0015	0.0030	0.0075	0.0175	1.68	0.70	3.37	0.73	8.42	0.89	19.66	0.97
C1L	240	180	0.0050	0.0080	0.0200	0.0500	0.90	0.95	1.44	0.91	3.60	0.85	9.00	0.97
C1M	600	450	0.0033	0.0053	0.0133	0.0333	1.50	0.70	2.40	0.74	6.00	0.86	15.00	0.98
C1H	1440	864	0.0025	0.0040	0.0100	0.0250	2.16	0.70	3.46	0.81	8.64	0.89	21.60	0.98
C2L	240	180	0.0040	0.0076	0.0197	0.0500	0.72	1.04	1.37	1.02	3.55	0.99	9.00	0.95
C2M	600	450	0.0027	0.0051	0.0132	0.0333	1.20	0.82	2.29	0.81	5.92	0.81	15.00	0.99
C2H	1440	864	0.0020	0.0038	0.0099	0.0250	1.73	0.68	3.30	0.73	8.53	0.84	21.60	0.95
C3L	240	180	0.0030	0.0060	0.0150	0.0350	0.54	1.09	1.08	1.07	2.70	1.08	6.30	0.91
C3M	600	450	0.0020	0.0040	0.0100	0.0233	0.90	0.85	1.80	0.83	4.50	0.79	10.50	0.98
C3H	1440	864	0.0015	0.0030	0.0075	0.0175	1.30	0.71	2.59	0.74	6.48	0.90	15.12	0.97
PC1	180	135	0.0040	0.0064	0.0161	0.0438	0.54	1.00	0.87	1.05	2.17	1.12	5.91	0.89
PC2L	240	180	0.0040	0.0064	0.0161	0.0438	0.72	1.08	1.15	1.03	2.89	0.98	7.88	0.96
PC2M	600	450	0.0027	0.0043	0.0107	0.0292	1.20	0.81	1.92	0.79	4.81	0.84	13.12	0.99
PC2H	1440	864	0.0020	0.0032	0.0080	0.0219	1.73	0.71	2.77	0.75	6.93	0.89	18.90	0.98
RM1L	240	180	0.0040	0.0064	0.0161	0.0438	0.72	1.11	1.15	1.10	2.89	1.10	7.88	0.92
RM1M	600	450	0.0027	0.0043	0.0107	0.0292	1.20	0.87	1.92	0.84	4.81	0.79	13.12	0.96
RM2L	240	180	0.0040	0.0064	0.0161	0.0438	0.72	1.05	1.15	1.07	2.89	1.09	7.88	0.91
RM2M	600	450	0.0027	0.0043	0.0107	0.0292	1.20	0.84	1.92	0.81	4.81	0.77	13.12	0.96
RM2H	1440	864	0.0020	0.0032	0.0080	0.0219	1.73	0.69	2.77	0.72	6.93	0.87	18.90	0.96
URML	180	135	0.0030	0.0060	0.0150	0.0350	0.41	0.99	0.81	1.05	2.03	1.10	4.73	1.08
URMM	420	315	0.0020	0.0040	0.0100	0.0233	0.63	0.91	1.26	0.92	3.15	0.87	7.35	0.91
MH	120	120	0.0040	0.0080	0.0240	0.0700	0.48	0.91	0.96	1.00	2.88	1.03	8.40	0.92

Appendix 14.Structural Fragility Curve Parameters – Pre-Code Seismic Design Level

Building Properties			Interstory Drift at Threshold of Damage State				Spectral Displacement (inches)							
Type	Height (inches)						Slight		Moderate		Extensive		Complete	
	Roof	Modal	Slight	Moderate	Extensive	Complete	Median	Beta	Median	Beta	Median	Beta	Median	Beta
W1	168	126	0.0032	0.0079	0.0245	0.0600	0.40	1.01	1.00	1.05	3.09	1.07	7.56	1.06
W2	288	216	0.0032	0.0079	0.0245	0.0600	0.69	1.04	1.71	0.97	5.29	0.90	12.96	0.99
S1L	288	216	0.0048	0.0076	0.0162	0.0400	1.04	0.85	1.65	0.82	3.50	0.80	8.64	0.95
S1M	720	540	0.0032	0.0051	0.0108	0.0267	1.73	0.70	2.76	0.75	5.84	0.81	14.40	0.98
S1H	1872	1123	0.0024	0.0038	0.0081	0.0200	2.70	0.69	4.30	0.71	9.11	0.85	22.46	0.93
S2L	288	216	0.0040	0.0064	0.0160	0.0400	0.86	1.01	1.38	0.96	3.46	0.88	8.64	0.98
S2M	720	540	0.0027	0.0043	0.0107	0.0267	1.44	0.73	2.30	0.75	5.76	0.80	14.40	0.98
S2H	1872	1123	0.0020	0.0032	0.0080	0.0200	2.25	0.70	3.59	0.70	8.99	0.84	22.46	0.91
S3	180	135	0.0032	0.0051	0.0128	0.0350	0.43	1.06	0.69	1.03	1.73	1.07	4.73	0.89
S4L	288	216	0.0032	0.0051	0.0128	0.0350	0.69	1.11	1.11	1.03	2.77	0.99	7.56	0.98
S4M	720	540	0.0021	0.0034	0.0086	0.0233	1.15	0.81	1.85	0.80	4.62	0.94	12.60	1.00
S4H	1872	1123	0.0016	0.0026	0.0064	0.0175	1.80	0.73	2.88	0.75	7.21	0.90	19.66	0.97
S5L	288	216	0.0024	0.0048	0.0120	0.0280	0.52	1.20	1.04	1.11	2.59	1.08	6.05	0.95
S5M	720	540	0.0016	0.0032	0.0080	0.0187	0.86	0.85	1.73	0.83	4.32	0.94	10.08	0.99
S5H	1872	1123	0.0012	0.0024	0.0060	0.0140	1.35	0.72	2.70	0.75	6.74	0.92	15.72	0.96
C1L	240	180	0.0040	0.0064	0.0160	0.0400	0.72	0.98	1.15	0.94	2.88	0.90	7.20	0.97
C1M	600	450	0.0027	0.0043	0.0107	0.0267	1.20	0.73	1.92	0.77	4.80	0.83	12.00	0.98
C1H	1440	864	0.0020	0.0032	0.0080	0.0200	1.73	0.71	2.76	0.80	6.91	0.94	17.28	1.01
C2L	240	180	0.0032	0.0061	0.0158	0.0400	0.58	1.11	1.10	1.09	2.84	1.07	7.20	0.93
C2M	600	450	0.0021	0.0041	0.0105	0.0267	0.96	0.86	1.83	0.83	4.74	0.80	12.00	0.98
C2H	1440	864	0.0016	0.0031	0.0079	0.0200	1.38	0.73	2.64	0.75	6.82	0.92	17.28	0.97
C3L	240	180	0.0024	0.0048	0.0120	0.0280	0.43	1.19	0.86	1.15	2.16	1.15	5.04	0.92
C3M	600	450	0.0016	0.0032	0.0080	0.0187	0.72	0.90	1.44	0.86	3.60	0.90	8.40	0.96
C3H	1440	864	0.0012	0.0024	0.0060	0.0140	1.04	0.73	2.07	0.75	5.18	0.90	12.10	0.95
PC1	180	135	0.0032	0.0051	0.0128	0.0350	0.43	1.14	0.69	1.14	1.73	1.17	4.73	0.98
PC2L	240	180	0.0032	0.0051	0.0128	0.0350	0.58	1.14	0.92	1.10	2.31	1.10	6.30	0.93
PC2M	600	450	0.0021	0.0034	0.0086	0.0233	0.96	0.87	1.54	0.83	3.85	0.91	10.50	1.00
PC2H	1440	864	0.0016	0.0026	0.0064	0.0175	1.38	0.74	2.21	0.75	5.55	0.91	15.12	0.96
RM1L	240	180	0.0032	0.0051	0.0128	0.0350	0.58	1.20	0.92	1.17	2.31	1.17	6.30	0.94
RM1M	600	450	0.0021	0.0034	0.0086	0.0233	0.96	0.91	1.54	0.89	3.85	0.89	10.50	0.96
RM2L	240	180	0.0032	0.0051	0.0128	0.0350	0.58	1.14	0.92	1.10	2.31	1.15	6.30	0.92
RM2M	600	450	0.0021	0.0034	0.0086	0.0233	0.96	0.89	1.54	0.87	3.85	0.87	10.50	0.96
RM2H	1440	864	0.0016	0.0026	0.0064	0.0175	1.38	0.75	2.21	0.75	5.55	0.84	15.12	0.94
URML	180	135	0.0024	0.0048	0.0120	0.0280	0.32	1.15	0.65	1.19	1.62	1.20	3.78	1.18
URMM	420	315	0.0016	0.0032	0.0080	0.0187	0.50	0.99	1.01	0.97	2.52	0.90	5.88	0.88
MH	120	120	0.0032	0.0064	0.0192	0.0560	0.38	1.11	0.77	1.10	2.30	0.95	6.72	0.97

Appendix 15.Assessment on Building Type (using preliminary damage assessment 2006)

The assessment on building type was calculated in HAZUS methodology for a different model building type which defined in the study area; RM2L, URML and W1.

Example in Calculation of Unreinforced Masonry with Low Rise (URML)

Figure 36 shows the example of building structure URML in Bolon block

Figure 40 Example of building structure URML in Bolon Sub-village

 # Step 1.Selecting of model building type and the seismic design level for study area

Model building type is URML and seismic design level is Pre-Code Seismic Design

General Information	
Location	Bolon Sub-village
Structure Type	URML
Soil Class (a)	D (Stiff soil)
Building sq meter (b)	109.69 m^2
Building value per m2 (c)	IDR 264,000
Building value	IDR 28,957,394

(a). Taken from Table 10 Site classes from 1997 NEHRP Provisions (FEMA, 2003)
(b). Estimation of building square meter was taken from the mean square meter of URML in Peni Sub-village from Kerle and Widartono (2006)
(c). Building value for calculating building replacement cost using rapid damage assessment data was taken from the price that come from The Tax Office data

 # Step 2.Generating response spectra

The demand spectrum is a plot of spectral acceleration, which is a function of spectral displacement. Parameters for Response Curve are:

- Soil Class
- Spectral Acceleration, S_A
- Soil amplification factor for given spectral acceleration
- Spectral Displacement using equation,

………………………………………………………………………………………… $\mathbf{S_D = 9.8*S_A*T^2}$(1)

Where: S_A = Amplified Spectral Acceleration (g)
T = Time Period (sec)
S_D = Spectral Displacement (inches)

Ground Motion Spectrum with 475 years of return period probabilities (10% in 50 years)					
Period (T)(d)	**Acceleration in bed rock (g)(e)**	**Soil amplification factor (f)**	**Building shaking reduction factor (g)**	**Inelastic acceleration (g)**	**Displacement (inch)(h)**
0	0.19	1.6	1.60	0.19	0.000
0.2	0.46	1.6	1.60	0.46	0.180
0.4	0.39	1.4	1.60	0.34	0.535
0.6	0.28	1.2	1.60	0.21	0.741
0.8	0.21	1.1	1.60	0.14	0.906
1.0	0.17	1.1	1.60	0.12	1.145
1.2	0.14	1.1	1.60	0.10	1.358
1.4	0.12	1.0	1.60	0.08	1.441
1.6	0.11	1.0	1.60	0.07	1.725
1.8	0.10	1.0	1.60	0.06	1.985
2.0	0.10	1.0	1.60	0.06	2.450

(d). Taken from graphic of Hazard Spectra Curve in Figure 33
(e). Taken from graphic of Hazard Spectra Curve in Figure 33
(f). Taken from amplification factor which is used by HAZUS for spectral short period, Table 4.9 technical manual of HAZUS page 4-16 (appendix 6)
(g). Taken from Reduction factor of building (Rm), 2.4, Table 2 and 3 of SNI 1726-2002 page 15-16 (appendix)
(h). Calculating Spectral Displacement using equation 1

 # Step 3.Generating Building Capacity Spectrum Curve

The building capacity curve is represents the characteristic of a structure, which is a plot of lateral resistance of a building as a function of characteristics lateral displacement. Design capacity, yield capacity and ultimate capacity points define the shape of building capacity curves. Parameters for Building Capacity Curve are:

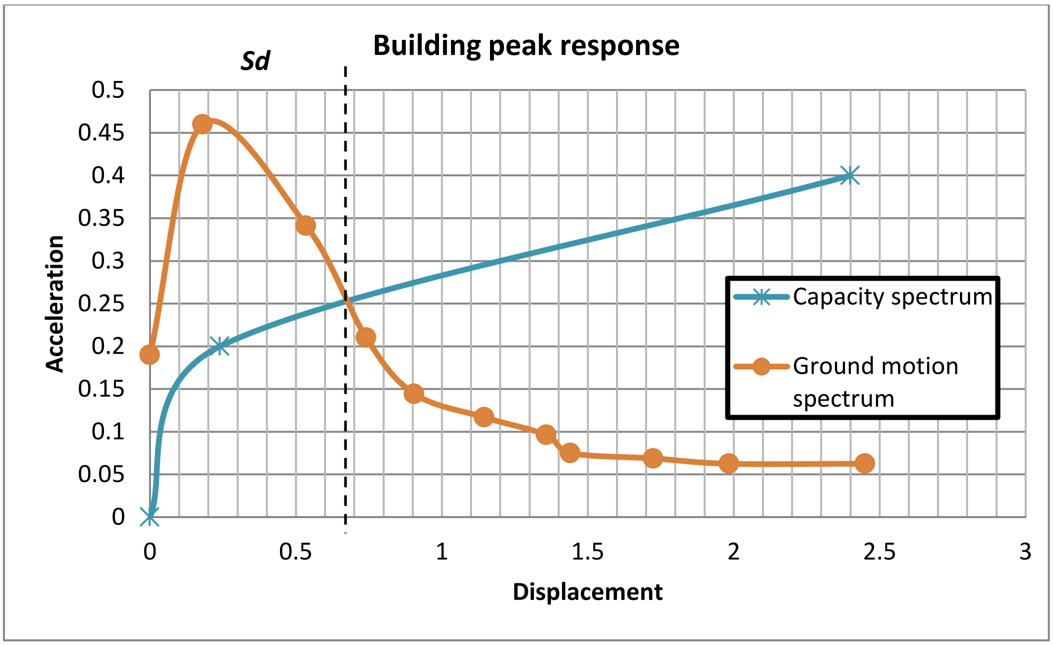
- Yield Capacity Point
- Ultimate Capacity Point

Building Capacity Spectrum		
Status	**HAZUS median value(i)**	
	Displacement	**Acceleration**
Begin	0	0
Yield	0.240	0.200
Ultimate	2.400	0.400

(i). Taken from HAZUS capacity curve for Pre-Code Seismic Design, Table 5.7d technical manual of HAZUS MR4, structure URML (appendix 10)

 # Step 4.Calculating Peak Building Response

Peak Building Response (S_d) is derived from the intersection of Building Capacity Curve and Demand Spectra. Peak building response (either spectral displacement or spectral acceleration) at the point of intersection of the capacity curve and demand spectrum is the parameter used with fragility curves to estimate damage state probabilities.



Peak Building Response (S_d) from graphic above is 0.68.

 # Step 5.Calculating Cumulative Damage Probabilities

- From HAZUS table, find the median value of Spectra Displacement (S_d) for model building type, design code and damage state.
- From HAZUS table, find value of lognormal standard deviation (β) for model building type, design code and damage state.
- Calculating cumulative probabilities for given damage state(ds); *Slight, Moderate, Extensive and Complete Damage*; is modeled as:

……………………………………………………………….**$P[ds|S_d] = \phi[1/\beta ds \; Ln(S_d/S_{d},ds)]$** (2)

Where: Sd,ds = the median value of spectral displacement at which the building reaches the threshold of the damage state,ds

βds = the standard deviation of the natural logarithm of spectral displacement of damage state,ds

ϕ = the standard normal cumulative distribution function

Cumulative Damage Probabilities [j]						
Damage	**Sd**	**S_{ds}** [k]	**β_{ds}** [k]	**$Ln(Sd/S_{ds})$**	**$Ln(Sd/S_{ds})/\beta_{ds}$**	**Θ(Y)**
Slight	0.68	0.32	1.15	0.754	0.655	0.74391
Moderate	0.68	0.65	1.19	0.045	0.038	0.51512
Extensive	0.68	1.62	1.20	-0.868	-0.723	0.23471
Complete	0.68	3.78	1.18	-1.715	-1.454	0.07301

(j). Calculate using equation 2

(k). Taken from Table 5-9d, Pre- Code Seismic Design, HAZUS technical manual, with structure type URML (appendix 14)

 # Step 6.Calculating the discrete damage probabilities from Cumulative Damage Probabilities

and

 # Step 7.Developing Mean Damage Ratio (MDR)

Mean Damage Ratio				
Level of Damage	**Cumulative Probabilities**	**Discrete Damage Probabilities**	**Median Damage Ratio** (I)	**Damage Ratio**
Complete	0.07301	0.07301	95	6.936%
Extensive	0.23471	0.16170	65	10.511%
Moderate	0.51512	0.28041	10	2.804%
Slight	0.74391	0.22879	3.5	0.801%
No damage	1.0000	0.25609	0.3	0.077%
		MDR		21.129%
		Level of Damage =		**Extensive Damage**

(I). Taken from Hwang (1994) page 165 in Syamsudin (2010)

 # Step 8.Building Replacement Cost

From Damage Probability Matrix, the percentage of Mean Damage Factor used as a basic to find out the damage of building and multiply it with the value of model building type per meter square.

Building Replacement Cost	
Hazard Probability	10%
Exposure Period (Year)	50
Return Period (Year)	475
Mean Damage Ratio (MDR)	21.129%
Building Value (IDR)	28,957,394
Damage Value (IDR)	6,118,408
Replacement Cost for Building Structure URML (IDR)	**IDR 6,118,408**

Appendix 16.Assessment on Building Type (during field work 2010)

The assessment on building type was calculated in HAZUS methodology for a different model building type which defined in the study area; RM2L, URML, W1 and S1.

Example in Calculation of Reinforced Masonry with low rise (RM2L)

Figure 41 shows the example of building structure RM2L in Peni block.

Figure 41 Example of building structure RM2L in Peni Sub-village

 # Step 1.Selecting of model building type and the seismic design level for study area

Model building type is RM2L and seismic design level is High Code Seismic Design.

Moderate code seismic design has been chosen because the building properties and characteristic is quiet suitable with building resistance due to earthquake.

General Information	
Location	Karasan Sub-village
Structure Type	RM2L
Soil Class [(a)]	D (Stiff soil)
Building in sq.meter [(b)](Mean)	45.70 m^2
Building value per m2 [(c)]	688,585 IDR
Building value	31,468,343 IDR

(a). Taken from Table 10 Site classes from 1997 NEHRP Provisions (FEMA, 2003)
(b). Estimation of building square meter was taken from the building inventory during field survey in Peni Sub-village
(c). Building value for calculating building replacement cost using value from building inventory during field survey 2010 in Palbapang Village

 # Step 2.Generating response spectra

The demand spectrum is a plot of spectral acceleration, which is a function of spectral displacement. Parameters for Response Curve are:

- Soil Class
- Spectral Acceleration, S_A
- Soil amplification factor for given spectral acceleration
- Spectral Displacement using equation,

……………………………………………………………………………………………. $\mathbf{S_D = 9.8*S_A*T^2}$(2)

Where: S_A = Amplified Spectral Acceleration (g)
T = Time Period (sec)
S_D = Spectral Displacement (inches)

Ground Motion Spectrum with 475 years of return period probabilities (10% in 50 years)					
Period (T)[(d)]	**Acceleration in bed rock (g)[(e)]**	**Soil amplification factor [(f)]**	**Building shaking reduction factor [(g)]**	**Inelastic acceleration (g)**	**Displacement (inch)[(h)]**
0	0.19	1.6	2.80	0.11	0.000
0.2	0.46	1.6	2.80	0.26	0.103
0.4	0.39	1.4	2.80	0.20	0.306
0.6	0.28	1.2	2.80	0.12	0.423
0.8	0.21	1.1	2.80	0.08	0.517
1.0	0.17	1.1	2.80	0.07	0.655
1.2	0.14	1.1	2.80	0.06	0.776
1.4	0.12	1.0	2.80	0.04	0.823
1.6	0.11	1.0	2.80	0.04	0.986
1.8	0.10	1.0	2.80	0.04	1.134
2.0	0.10	1.0	2.80	0.04	1.400

(d). Taken from graphic of Hazard Spectra Curve in Figure 33
(e). Taken from graphic of Hazard Spectra Curve in Figure 33
(f). Taken from amplification factor which is used by HAZUS for spectral short period, Table 4.9 technical manual of HAZUS page 4-16 (appendix 6)
(g). Taken from Reduction factor of building (Rm), 2.4, Table 2 and 3 of SNI 1726-2002 page 15-16 (appendix)
(h). Calculating Spectral Displacement using equation 1

 # Step 3.Generating Building Capacity Spectrum Curve

The building capacity curve is represents the characteristic of a structure, which is a plot of lateral resistance of a building as a function of characteristics lateral displacement. Design capacity, yield capacity and ultimate capacity points define the shape of building capacity curves. Parameters for Building Capacity Curve are:

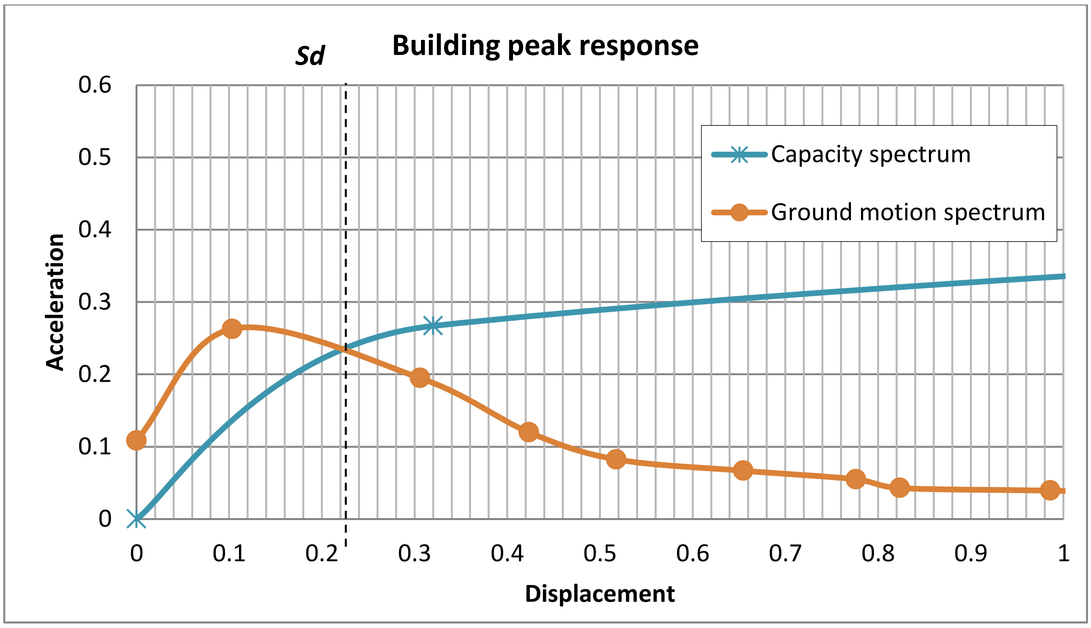
- Yield Capacity Point
- Ultimate Capacity Point

Building Capacity Spectrum		
Status	**HAZUS median value[(i)]**	
	Displacement	**Acceleration**
Begin	0	0
Yield	0.320	0.267
Ultimate	3.840	0.533

(i). Taken from HAZUS capacity curve for Moderate Code Seismic Design, Table 5.7b technical manual of HAZUS MR4, structure RM2L (appendix 8)

 # Step 4.Calculating Peak Building Response

Peak Building Response (S_d) is derived from the intersection of Building Capacity Curve and Demand Spectra. Peak building response (either spectral displacement or spectral acceleration) at the point of intersection of the capacity curve and demand spectrum is the parameter used with fragility curves to estimate damage state probabilities.



Peak Building Response (S_d) from graphic above is 0.23.

 # Step 5.Calculating Cumulative Damage Probabilities

- From HAZUS table, find the median value of Spectra Displacement (S_d) for model building type, design code and damage state.
- From HAZUS table, find value of lognormal standard deviation (β) for model building type, design code and damage state.
- Calculating cumulative probabilities for given damage state(ds); *Slight, Moderate, Extensive and Complete Damage*; is modeled as:

……………………………………………………………**$P[ds|S_d] = \phi[1/\beta ds \, Ln(S_d/S_{d},ds)]$** (2)

Where: Sd,ds = the median value of spectral displacement at which the building reaches the threshold of the damage state,ds

βds = the standard deviation of the natural logarithm of spectral displacement of damage state, ds

ϕ = the standard normal cumulative distribution function

Cumulative Damage Probabilities[j]						
Damage	**Sd**	**S_{ds}**[k]	**β_{ds}**[k]	**$Ln(Sd/S_{ds})$**	**$Ln(Sd/S_{ds})/\beta_{ds}$**	**ϴ(Y)**
Slight	0.23	0.72	0.91	-1.141	-1.254	0.10491
Moderate	0.23	1.25	0.96	-1.693	-1.763	0.03892
Extensive	0.23	3.37	1.02	-2.685	-2.632	0.00424
Complete	0.23	9.45	0.93	-3.716	-3.995	0.00003

(j). Calculate using equation 2

(k). Taken from Table 5-9b, Moderate Code Seismic Design, HAZUS technical manual, with structure type RM2L (appendix 12)

 # Step 6.Calculating the discrete damage probabilities from Cumulative Damage Probabilities

And

 # Step 7.Developing Mean Damage Ratio (MDR)

Mean Damage Ratio				
Level of Damage	**Cumulative Probabilities**	**Discrete Damage Probabilities**	**Median Damage Ratio** (I)	**Damage Ratio**
Complete	0.00003	0.00003	95	0.003%
Extensive	0.00424	0.00421	65	0.274%
Moderate	0.03892	0.03468	10	0.347%
Slight	0.10491	0.06599	3.5	0.231%
No damage	1.00000	0.89509	0.3	0.269%
		MDR		1.123%
		Level of Damage =		**Non-structural Damage**

(I). Taken from Hwang (1994) page 165 in Syamsudin (2010)

 # Step 8. Building Replacement Cost

From Damage Probability Matrix, the percentage of Mean Damage Factor used as a basic to find out the damage of building and multiply it with the value of model building type per meter square.

Building Replacement Cost	
Hazard Probability	10%
Exposure Period (Year)	50
Return Period (Year)	475
Mean Damage Ratio (MDR)	1.123%
Building Value (IDR)	31,468,335
Damage Value (IDR)	362,401
Replacement Cost for Building Structure RM2L (IDR)	**IDR 362,401**