APPLICATION OF HAZUS IN EARTHQUAKE BUILDING DAMAGE ASSESSMENT

in Palbapang Village, Bantul Yogyakarta Province, Indonesia

Thesis submitted to the Double Degree M.Sc. Programme, Gadjah Mada University and Faculty of Geo-Information Science and Earth Observation, 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

UGM

ITC

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DOUBLE DEGREE M.Sc. PROGRAMME
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THESIS

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Signed ………………

DISCLAIMER

This document describes work undertaken as part of joint education program study between Faculty of Geo-information Science and Earth Observation, University of Twente and Gadjah Mada University. All views and opinions expressed therein remain the sole responsibility of the author, and do not necessarily represent those of the institute.

ABSTRACT

Indonesia is one of the countries with a very high prone to earthquake. It has experienced several deadly earthquakes with a large number of death and property damaged. The 2006 Yogyakarta earthquake has caused highest victim from building's damage along Opak Fault line than other places in Yogyakarta Province. It is necessary to study earthquake risk assessment in building to reduce the impact of earthquake and all of the possible hazard threat.

HAZUS is a disaster risk assessment tools developed in United States. It assesses multi hazard loss estimation for the building and casualties of population. The loss estimation in HAZUS has to compare to check the validation of this result. Thus the analysis is done in adapting the application of HAZUS in Indonesia and comparing the outcome with a post disaster damage survey. Different scenario of hazard is used to estimate building damaged. The scenario of hazard is created to analyze the possibility parameter of hazard by different researcher. The scenario is based on different source of earthquake (BMG and USGS). Hazard map is based on ground motion and liquefaction potency. The data of hazard is used to generate HAZUS method in study area.

Palbapang village is taken as the study area to apply the HAZUS model in Indonesian term. The study area is taken because it represents the mixture of urban and rural area and also the heavy damaged in this area as the considering factor. Unreinforced masonry is the dominant building in this area before 2006 earthquake while reinforced masonry (RM) is dominating structural type of building after 2006 earthquake. The vulnerability function is taken from HAZUS and the research by Miura in Philippine.

The result from HAZUS has concluded that hazard maps have similarity with other result from previous research. The Intensity has estimated in VII- VIII MMI based on different scenario. The liquefaction susceptibility is categorized as moderate and high susceptibility which depends on lithology unit in this area. The building damaged probability of HAZUS method in scenario 1 gives more damages building in study area than in Scenario 2 and Miura. The distance from epicenter and liquefaction probability is the highest factor of hazard to create high damaged of building in study area. The correlation in building vulnerability has high relationship in URM but weak in RM and Wood. The modification is required in term of vulnerability function and complete data base to adapt HAZUS method In Indonesia.

Key words: ***earthquake, HAZUS, hazard, scenario, building vulnerability***.

INTISARI

Indonesia adalah salah satu negara dengan kerentanan sangat tinggi terhadap gempa. Indonesia telah mengalami beberapa gempa bumi yang mematikan dengan kerugian materi dan korban yang sangat besar. Gempa bumi Yogyakarta 2006 di sepanjang jalur Sesar Opak telah menyebabkan korban terbesar dari kerusakan bangunan daripada di tempat lain di Provinsi Yogyakarta. Untuk itu diperlukan untuk pembelajaran gempa dengan penilaian risiko di dalam bangunan untuk mengurangi dampak gempa bumi dan semua ancaman bahaya yang mungkin terjadi.

Skenario yang berbeda digunakan untuk mengestimasi bangunan yang rusak. Skenario ini didasarkan pada berbagai sumber gempa (BMG dan USGS Bahaya peta. didasarkan pada gerakan tanah dan potensi pencairan Data bahaya digunakan untuk menghasilkan metode HAZUS di wilayah studi.. Di Desa Palbapang, bangunan bata tanpa perkuatan (URM) adalah bangunan yang dominan sebelum gempa 2006 sementara bangunan bata dengan perkuatan(RM) mendominasi struktur bangunan setelah gempa 2006. Fungsi kerentanan diambil dari HAZUS dan penelitian oleh Miura di Filipina.

Hasil dari HAZUS dapat disimpulkan bahwa peta bahaya memiliki kesamaan dengan hasil lainnya dari penelitian sebelumnya. Intensitas gempa memiliki estimasi di VII-VIII MMI berdasarkan skenario yang berbeda. Kerentanan likuifaksi dikategorikan sebagai kerentanan sedang dan tinggi yang bergantung pada unit litologi di daerah ini. Metode HAZUS dalam skenario 1 memberikan kerusakan bangunan lebih besar di wilayah studi daripada Skenario 2 dan Miura. Jarak dari pusat gempa dan probabilitas likuifaksi adalah faktor yang menetukan kerusakan bangunan di wilayah studi. Korelasi dalam kerentanan bangunan memiliki hubungan yang tinggi pada struktur URM tetapi lemah dalam RM dan Kayu. diperlukan penelitian lebih lanjut dalam hal fungsi kerentanan dan kelengkapan data base untuk mengadopsi metode HAZUS di Indonesia.

Kata kunci: ***gempabumi, HAZUS, Bahaya, skenario,kerentanan bangunan***

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Bambang Sudrajat

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATION

BMKG	Meteorology, Climatology and Geophysics Agency.
BNPB	National Disaster management Agency
PBVMG	Center for Vulcanology and Geological Hazard Mitigation
HAZUS MH	Hazard United States Multi hazard
BAPPENAS	Planning and Development Board
FEMA	Federal Emergency Management Agency
NIBS	National Institute of Building Sciences
MMI	Modified Mercalli Intensity
PGA	Peak Ground Acceleration
PGV	Peak Ground Velocity
SA	Spectral Acceleration
PGD	Permanent Ground Deformation
NEHRP	National Earthquake Hazards Reduction Program
US	United States
SNI	National Standard of Indonesia
DEM	Digital Elevation Model
GIS	Geography Information System
USGS	United States Geological Survey
SPT	Standard Penetration Test
CPT	Core Penetration Test
GIS	Geography Information System
RM	Reinforced Masonry
URM	Unreinforced Masonry
Vs	Shear Wave Velocity
UGM	University of Gadjah Mada
ITC	Faculty of Geo Information Science and Earth Observation
RVS	Rapid Visual Screening

1. INTRODUCTION

1.1. Background

Indonesia has experienced several deadly earthquakes throughout its history. The deadliest earthquake which generates tsunami occurred in Sumatra in December 2004 with a total loss of over 280.000 inhabitants. These earthquakes caused damage of infrastructures and buildings, death tolls and cost trillion of Rupiah for rehabilitation and reconstruction. Within the last six years the destructive earthquake occurred in Indonesia such as Nias(2005) Yogyakarta (2006) Tasikmalaya (2009) and Padang (2009). Based on this fact, it is necessary to understand earthquake characteristics to apply earthquake risk assessment and to manage the possible hazards threats. Table 1-1 shows destructive earthquakes in Indonesia between 2000 to 2009.

Table 1-1: Destructive earthquake in Indonesia (2000 – 2009)
(http://earthquake.usgs.gov, http://dibi.bnpb.go.id)

Date	Magnitude	Region	Explanation
May 4, 2000	Mw 7.4	SULAWESI	46 people killed, 264 injured, 30,000 homeless because of tsunami
June 4, 2000	Mw 7.7	SUMATERA	103 people killed, 2,174 injured
November 2, 2002	Mw 7.4	SIMEULUE	2 people killed, 51 injured and 1,363 buildings damaged (BNPB)
February 5, 2004	Mw 7.0	PAPUA	39 people killed, 722 injured, 1,072 buildings damaged or destroyed in Nabire.(BNPB)
November 26, 2004	Mw 7.1	PAPUA	31 people killed, 228 injured, 4,847 buildings damaged (BNPB)
December 26, 2004	Mw 9.0	NORTHERN SUMATRA	283.106 people were killed or were missing
March 28, 2005	Mw 8.6	NORTHERN SUMATRA	915 people killed, 6278 injured 7,366 buildings damaged (BNPB)
May 27, 2006	Mw 6.3	JAVA	5,773 people were killed, 38,814 were injured 308,523 building were damaged.(BNPB)
July 17, 2006	Mw 7.7	SOUTH JAVA	662 people were killed, 9,275 were injured 1,623 buildings damaged
March 6, 2007	MW 6.4	SOUTHERN SUMATRA	67 people killed, 826 injured and 47,059 houses damaged or destroyed (BNPB)
September 12, 2007	MW 8.5	SOUTHERN SUMATRA	25 people killed, 92 injured, 95,589 buildings damaged or destroyed(BNPB)
November 16, 2008	MW 7.3	SULAWESI	6 people killed, 431 injured, 2,401 buildings damaged (BNPB)
January 3, 2009	MW 7.7	NORTHPAPUA	4 killed 509 people injured, 6,696 buildings damaged (BNPB)
February 11, 2009	MW 7.2	TALAUD	1 killed 74 people injured and 1,454 buildings damaged or destroyed (BNPB)
September 2, 2009	MW 7.0	JAVA	81 killed 297 people injured and 260,438 buildings damaged (BNPB)
September 30, 2009	MW 7.6	SOUTHERN SUMATRA	1,198 killed 1,824 people injured and 281,009 buildings damaged (BNPB)

Indonesia is situated in active tectonic zones. There are three major tectonic plates and nine minor tectonic plates colliding in Indonesia region. The collision between plates formed a subduction zone from West of Sumatera to North of Papua. This formed oceanic trenches, fold, ridge, distribution of volcanoes, earthquakes and the distribution of mineral resources. The mechanism of subduction beneath island is causing fault in island arc. Thus Indonesia is prone to catastrophic volcanic eruptions and earthquakes.

Yogyakarta region has experienced earthquakes from time to time. The activity of the Opak Fault as the biggest threat to Jogjakarta province has been recorded since 1867. In that year an earthquake intensity of VIII-IX MMI has killed more than 500 inhabitants. The 27 May 2006 earthquake from the movement of Opak fault has killed 5.773 inhabitants according to BNPB (National Disaster management Agency). Magnitude has been recorded of 6.3 Richter Scale ((USGS)(figure 1-1). It resulted not only in building loss but also in economic loss. The research of(Putranto 2007) shows Opak fault was active for at least 2300 to 2900 years ago.

Earthquake as the major threat does not kill people but the effect of the shake does. It might trigger tsunamis, landslides, fire and building collapse that can kill and injure people.

In this thesis a method to describe the hazard and related loss assessment as a part of risk assessment has been created. HAZUS-MH (Hazards United States Multi-Hazard) is a tool to determine multi-hazard loss estimations in the United States. Another method that is based on HAZUS is TELES (Taiwan earthquake Loss Estimation) and SELENA(Seismic Loss Estimation Using Logic Three Approach) for the Europe region.

Geoinformation of disaster management is a research field in the Gadjah Mada University that has a joint education program with natural hazard and disaster risk management in ITC. It builds an expertise in disaster management base on geographical information system and remote sensing. It handles all aspects of disasters, ranging from aspects of preparedness, rehabilitation and reconstruction after the disaster to disaster risk reduction planning prior to the disaster. Rapid damage assessment after the Jogjakarta Earthquake of 2006 has been done by UGM researchers to calculate damage of building in cooperation with ITC. For this, field work has been combined with high resolution remote sensing imagery. HAZUS as the Geography Information System (GIS) tool could do the rapid assessment of building with efficient time. In this M.Sc research, the research were divided into three fields; identification of the data base by cadastral database, modeling HAZUS for building damage assessment and replacement cost for risk assessment.

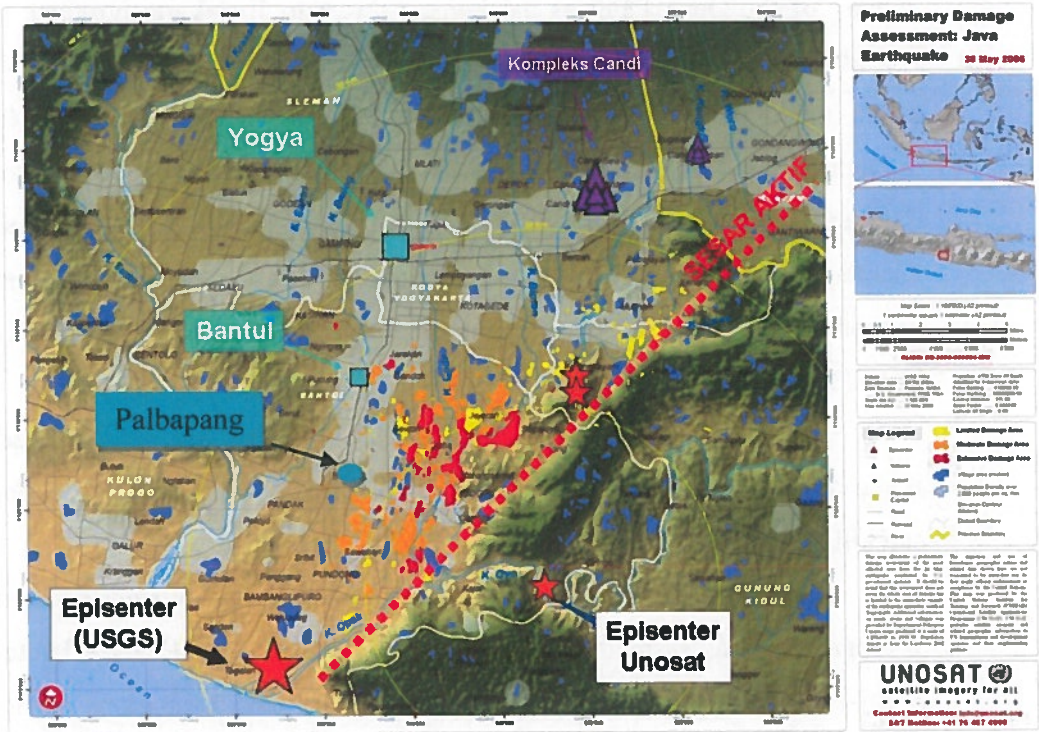


Figure 1-1: Yogyakarta Earthquake 27 May 2006 preliminary damage (UNOSAT, 2006)

The research of generated database and replacement cost are conducted by Kusmiarto (Designing Integrated Cadastre Database as a Basis For Comprehensive Element at Risk Analysis) and Bayu Aswandono (Building Replacement Cost For Seismic Risk Assessment). The location is in the same area to generate how the risk assessment in Bantul region especially in Palbapang village as an example of Indonesian characteristic building can be generated by

HAZUS. With some modification and understanding method, the implementation can be generated in Indonesian region. Thus Indonesia can build the model in Indonesian parameter.

This research is focus on the generation of earthquake risk assessment model in the village area. The estimation of building loss from scenario of hazard with modification parameter of HAZUS method and validate the application with the rapid damage assessment from previous research by UGM and ITC.

1.2. Problems Statement

The respond of society and government indicate an earthquake as the first major threat. The earthquake in Bantul regency, volcanic eruption and typhoon in Sleman regency, also tsunamis along the coast make Yogyakarta province prone to disaster. Sudibyakto, Suwahyono et al.(2009) stated that the focus to assessment of risk in disaster management is needed. The hazard assessments of earthquake in Jogjakarta has been done by many researchers such as Danny, Haifani, Karnawaty etc. after the earthquake in May 2006, but the scenario using HAZUS method for the risk assessment has not yet been done.

The 27 May 2006 earthquake damaged many building in the Yogyakarta and Central Java. BAPPENAS (2006) reported that 157,000 houses were totally destroyed and more than 202,000 more were partly damaged. Bantul district is the worst of all. Triple A(2006) stated that 45 % of all houses were damaged and destroyed in Bantul regency. This has huge impacts on the economic growth. In 2006 the economic growth was 2.02% which has depleted from 5% in 2005. In Bantul subdistrict, HRC (Housing Resources Center) reported that only 7 houses stand after the earthquake in Serut sub village of Palbapang village. DMC (2006) reported in Palbapang village 1,784 building collapsed and 1,430 heavy damaged. It is the highest damaged compared to the rest of the villages in Bantul Sub-district. For that reason, this research intends to model earthquake building damage by different scenario of hazard with the HAZUS application in Palbapang Village, Bantul region.

The challenge is to implement the HAZUS method in Indonesian although HAZUS MH was designed for the American region. The HAZUS method will have different input parameter compared to Indonesia. Therefore a modification of Indonesian will be needed. In this research, the loss estimation will focus on physical damaged; identification of hazard assessment and the vulnerability characteristics of buildings and how HAZUS might work in the Indonesia region.

1.3. Objectives and Research Question

The Main objective of this research is to adapt the input parameters of HAZUS for Indonesia and to compare the outcome with a post disaster damage survey with different scenario of hazard. The location of the study is Palbapang Village in Bantul Regency. The specific objectives of the research can be seen in the table 1-2:

Table 1-2: Specific Objectives and Research Question

To identify the parameters for Ground shaking characteristic, seismic data, building inventory and damage that required in HAZUS method for Palbapang village.	• How to modify the ground shaking parameter to be applied in HAZUS with different scenario of earthquake source? • How to fit the building inventory data of Bantul sub district to be applied in HAZUS?
To estimate ground motion and ground failure using HAZUS and validate the result with previous research	• How high the correlation between the Hazard Map resulted from HAZUS application with the hazard map resulted from previous research
To estimate damage building in HAZUS for Palbapang village and validate the output of damage building of HAZUS with damage database on Palbapang village	• How high the correlation of damage Building estimation from HAZUS application with the building damaged resulted from previous research • What is the difference of building damage before and after the earthquake in Jogjakarta with different scenario of earthquake source? • How best can HAZUS building base method to use in Indonesia region.

To analyze the applicability of HAZUS in Palbapang village.	• What is the limitation of HAZUS application in Bantul? • What modification is required in term of parameter to apply HAZUS Model in Indonesia?

1.4. Significance of the Study

This study has a contribution to access how the work of HAZUS in Indonesia region. It explains about basis of mitigation and rapid assessment of the earthquake and as the input to further study in Indonesian disaster management of earthquake hazard.

1.5. Scope and Limitations

The limitation of this research is in try to model earthquake hazard on the building in Palbapang village with HAZUS method. The research only generated structural building damage assessment.

The scope of this research is about Information:

1. Information about Building vulnerability before and after earthquake
2. Information about the hazard that happened in the area.

1.6. Thesis Structure

Chapter 1 describes about background of studies, problems, objectives, questions, significance study, the scope and limitation, and thesis structure.

Chapter 2 describes of related literatures used to support this research. It describes the hazard and vulnerability definition, about hazard assessment, seismic zone in Indonesia, building vulnerability and HAZUS method

Chapter 3 discusses about general information of study area. Discussion about study area contains the general information of Bantul district, geomorphology, hydrology, geology, characteristic of the Palbapang villages, and earthquake in Bantul district on May 27th 2006.

Chapter 4 discusses about methodology and the process used for this research. Discussion about the methodology contains 3 phases of the research; pre fieldwork, fieldwork (data collection) and post fieldwork (analysis). Discussion about creates hazard map and Building stock assessment in HAZUS.

Chapter 5 discusses about the measurement information of HAZUS in hazard assessment, about ground motion and ground failure and how to correlate it with previous research. It discusses about the information of measurement of HAZUS in Building damage assessment, and how to validate it with previous researcher from Norman Kearle and Barandi and other rapid assessment in Palbapang village. The result from this chapter will be used for the conclusion

Chapter 6 discusses about the conclusions and number of recommendations, from chapter 5, the conclusion based of objective and finding the result and discussion on the study.

2. LITERATURE REVIEW

2.1. Earthquake

Earthquake is a term used for the ground shake caused by sudden movement of tectonic (fault, subduction) or volcanic activity and other sudden stress changes in the earth. Westen,(2009) define earthquake as "Vibrations of the earth caused by the rupture and sudden movement of rocks that have been strained beyond their elastic limits". The travel of seismic wave can be generated in near surface (Rayleigh and Love waves) or through the earth interior (P and S waves)" (figure 2-1).

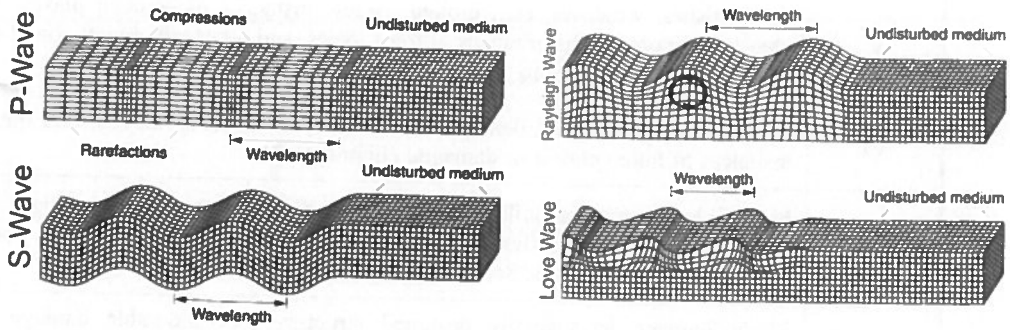


Figure 2-1: Wave propagation (USGS)

The primary damage of earthquake is caused by ground motion which depends on local geological condition, magnitude of the earthquake and closeness to the epicenter. The secondary damage of ground shaking are fault and ground rupture, aftershocks, landslides, earth cracks, liquefaction, subsidence or uplift, tsunamis and seiches, flood from dam failures and fires(Westen 2009).

The severity of an earthquake is described by both magnitude and intensity. Magnitude characterizes the size of an earthquake by measuring indirect released energy. Intensities represent severities or the effect of earthquake in each different location from epicenter. The given earthquake can be described by one magnitude, with much intensity because the effects would vary from distance to epicenter and from local soil condition. In fact, the same earthquake might have different magnitude estimates by few scales of unit depending on which magnitude scale is used and which data are included in the analysis (Day 2002).

The Intensity of damage from Modified Mercalli Intensity (MMI) can be seen in table 2-1. The 2006 Yogyakarta earthquake has recorded in scale VII to VIII MMI.

Table 2-1:Modified Mercalli Intensity Scale (Day 2002)

Intensity	Level of Damage
I	No damage
II	No damage. Delicately suspended objects may swing.
III	No damage. Standing motor cars may rock
IV	Dishes, windows, and doors are disturbed. Walls make a creaking sound. Standing motor cars rock noticeably.
V	Some dishes, windows, etc., broken. A few instances of cracked plaster and unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop
VI	There is slight structural damage. Some heavy furniture is moved, and there are a few instances of fallen plaster or damaged chimneys.
VII	Negligible damage in buildings of good design and construction, slight to moderate damage in well-built ordinary structures, and considerable damage in poorly built or badly designed structures. Some chimneys are broken.
VIII	Slight damage in specially designed structures. Considerable damage in ordinary substantial buildings, with partial collapse. Great damage in poorly built structures. Panel walls are thrown out of frame structures. There is the fall of chimneys, factory stacks, columns, monuments, and walls. Heavy furniture is overturned. Sand and mud are ejected in small amounts, and there are changes in well-water levels.
IX	Considerable damage in specially designed structures. Well-designed frame structures are thrown out of plumb. There is great damage in substantial buildings with partial collapse. Buildings are shifted off of their foundations. The ground is conspicuously cracked, and underground pipes are broken.
X	Some well-built wooden structures are destroyed. Most masonry and frame structures are destroyed, including the foundations. The ground is badly cracked. There are bent train rails, a considerable number of landslides at river banks and steep slopes, shifted sand and mud, and water is splashed over their
XI	Few, if any, masonry structures remain standing. Bridges are destroyed, and train rails are greatly bent. There are broad fissures in the ground, and underground pipelines are completely out of service. There are earth slumps and land slips in soft ground.
XII	Total damage with practically all works of construction greatly damaged or destroyed. Objects are thrown upward into the air.

The used of Magnitude is more objective than the intensity. In the catalog it has different scales that have been widely used such as:

a. Richter local Magnitude (*ML*) is the magnitude scale for shallow and local earthquakes, and the seismograph is at least 100 km away from the epicenter.
b. Surface wave Magnitude (*MS*) is the magnitude that based on amplitude of surface wave. It is typically used for moderate to large earthquakes. It has a shallow focal depth and the seismograph is at least 1000 km away from the epicenter.
c. Body wave Magnitude (*Mb*) is used for deep earthquakes and the surface magnitude is difficult to count.
d. Moment magnitude (*Mw*) is a common used method for determining the magnitude of large earthquakes..

Idriss (1985) in(Irsyam, Sengara et al. 2010) make the correlation for *Mw* with *ML*, *MS*, and *Mb* in table 2-2 :

Table 2-2 :Convert correlation of Magnitude scale in Indonesia Region(Irsyam, Sengara et al. 2010)

Convert correlation	Range of Magnitude	Regresion (R^2)
$Mw = 0.143Ms^2 - 1.051Ms + 7.285$	$4.5 \leq Ms \leq 8.6$	93.9%
$Mw = 0.114mb^2 - 0.556mb + 5.560$	$4.9 \leq mb \leq 8.2$	72.0%
$Mw = 0.787ME + 1.537$	$5.2 \leq ME \leq 7.3$	71.2%
$mb = 0.125ML^2 - 0.389x + 3.513$	$3.0 < ML < 6.2$	56.1%
$ML = 0.717MD + 1.003$	$3.0 \leq MD \leq 5.8$	29.1%

The use of magnitude scale from the catalog must be converted into one scale before making the attenuation function. BMKG (Meteorology, Climatology and Geophysics Agency) generally uses body magnitude scaled 5.9 Mb for earthquake in Yogyakarta and has to convert to moment magnitude because the tools in HAZUS use the moment magnitude.

2.1.1. Earthquake in Indonesia

Most of Indonesian archipelagos are prone to earthquake, only Borneo Island generally not prone to earthquake. In a year, earthquakes struck Indonesia one or two times and three times in two year with high magnitude. Figure 2.2 shows the epicenter and the magnitude of earthquake that struck Indonesian archipelago.

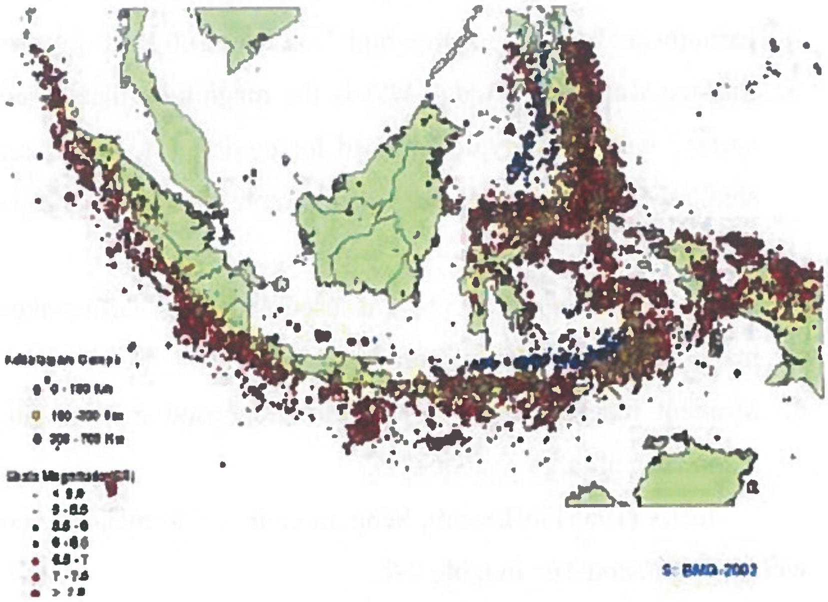


Figure 2-2:Epicenter location , magnitude and the depth of earthquake in Indonesia in 10 Year (1991-2001)(Siddiq 2006)

KIMPRASWIL(2002)created Indonesian building standard base on Indonesian hazard map. The Seismic Zones of Indonesia is divided in to 6 seismic zones as seen in figure 2-3 below. The seismic zones are based on probabilistic earthquake which has possibility occurred in Indonesia. Bantul is located in the seismic zones 3. It means that maximum peak ground acceleration reach 0.15g in rock deposit or 0.23 in medium soil.

After many earthquakes with high magnitude stroked Indonesia from Aceh with 9.0 Richter scale and Yogyakarta with 6.3 Richter scale, the need to revise Hazard Map of Indonesia is being generated in 2010. The Hazard map was not base by Seismic zone but based on the seismogenic which depends on the source of earthquake.

Irsyam et al (2010) has analyzed that earthquake source zones in Indonesia are from seismogenic and divided into three zones e.g. Fault zones, Subduction zones and Background zones.

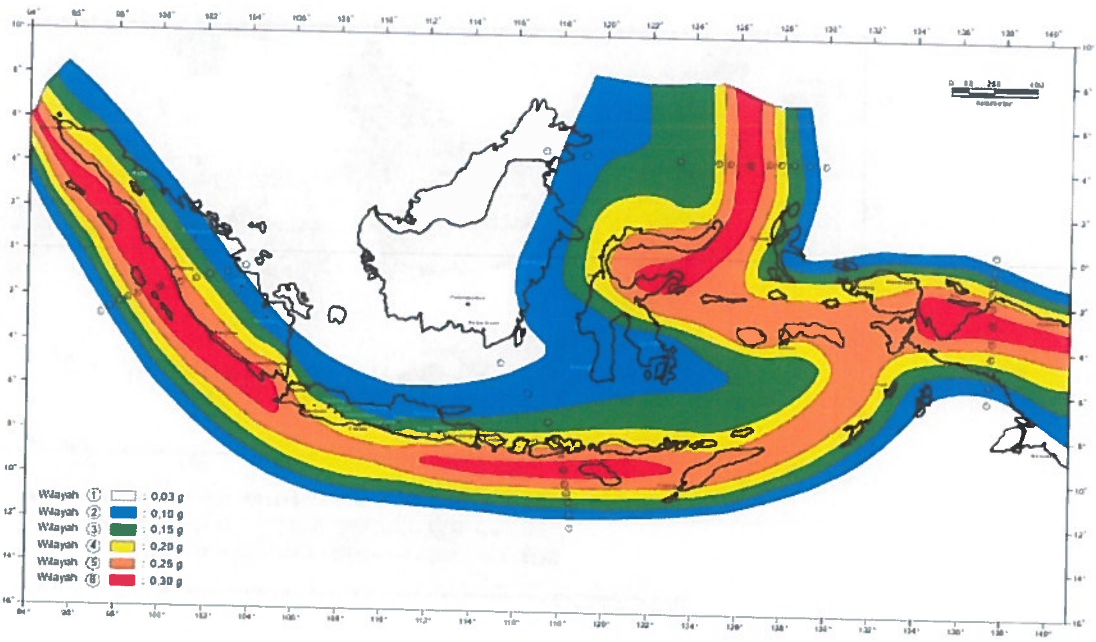


Figure 2-3: Indonesia Earthquake hazard zone Map with 500 year return period(Kimpraswil 2002)

Fault zones are called as three dimension earthquake sources. The probability of distance from site to hypocenter is also calculating the dip from fault. The parameter calculated earthquake source which includes fault trace, slip rate, dip, length and width of the fault. Subduction zones are the model from seismotectonic data from the location of subduction zones, in coordinate of latitude and longitude, b-values from historical data and depth of subduction zones. Gridded seismicity/background zones are the calculation of the model from medium earthquake that occurred from unidentified fault or local earthquake outside fault area.

The difference between earthquake hazard map in 2002 (Figure 2-3) and the new earthquake hazard map (figure 2-4) can be seen in Bantul region where the structure of fault created straight line and has higher PGA than its surrounding area. The PGA recorded 0.3-0.4 in 500 years return period. A higher PGA in Indonesian earthquake hazard zone map occurred because the revision of hazard map from earthquake which is occurred from 2002-2009.

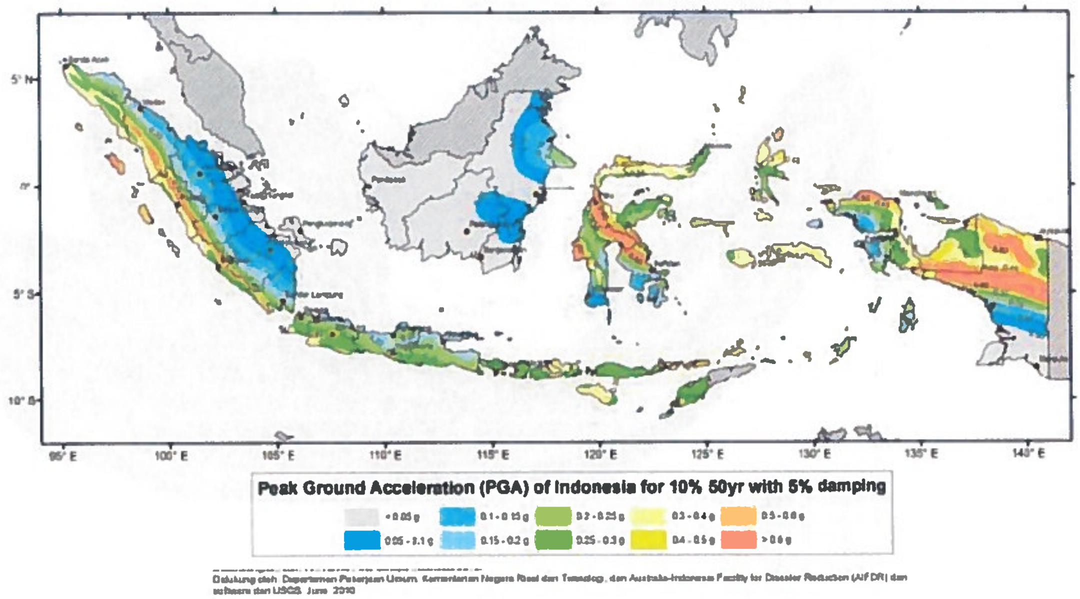


Figure 2-4:Indonesia Earthquake hazard zone Map with 10% 50 year with 5 % damping.(Irsyam, Sengara et al. 2010)

2.1.2. Earthquake in Java Island

In Java Island, Australian- Indian Ocean plate is moving and colliding beneath the Java continental crust. This subduction zone has imposed tectonic stresses on the Java Island, causing the formation of earthquake fault zones which accommodate the plate movement.

Elnashai et al(2006) has divided earthquake around Java island into two distinct features; location of epicenter in the north are in deep focus, and those in the south have shallower origins of epicenter. The earthquake potency can be seen in figure 2-5. The shallow origins of epicenter is the hypocenter of earthquake which range between 0 and 70 km deep and deep focus earthquakes is applied to earthquakes deeper than 70 km.

The 2006 Yogyakarta earthquake occurred from the shallow origins of earthquake. It occurred from fault zones. In July 2006, the earthquake occurred in the south sea of Java Island which created tsunami in Pangandaran and Cilacap. The deep of the source is 34 km. It is also shallow earthquake in the subduction zones at south Java trench. The Java earthquake that happened in 2009 has hypocenter deeper than 70 km. It is categorized as deep focus from subduction zones. It was triggering Landslide in Cianjur, West Java.

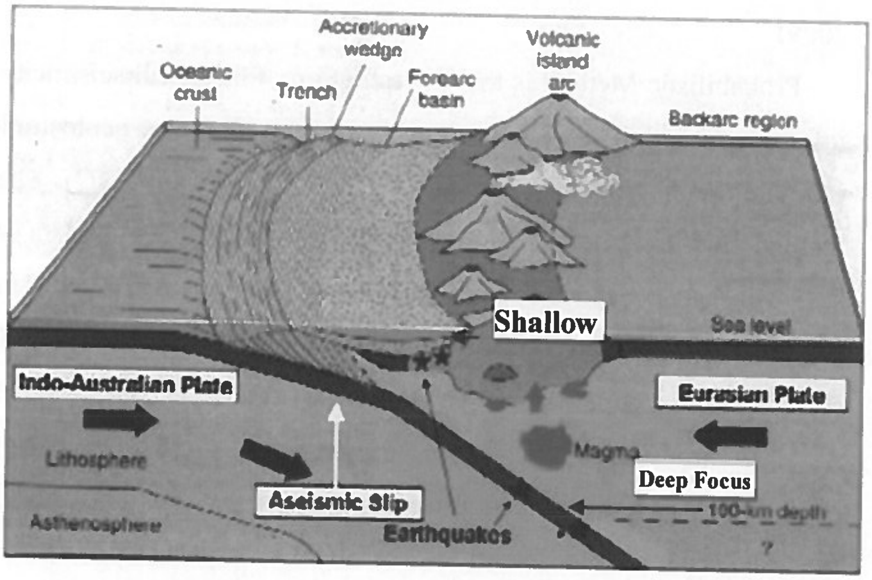


Figure 2-5:The interpolate and intraplate earthquake potential in Java (Elnashai, Kim et al. 2006)

2.2. Hazard Assessment

In generating hazard assessment, the risk as the process in disaster management has to be understood. The term risk is correlated with probability of losses. Risk defines as "probability of harmful consequences or expected losses from interaction between hazard and vulnerable conditions" (Westen, 2009)

Risk is presented by the basic equation:

RISK = HAZARD * VULNERABILITY * AMOUNT

The term Hazard is associated with time and intensity. Vulnerability is associated with degree of loss to element at risk, and amount of element at risk is defined as the number of assets (population, properties, economic activities, or any defined value), in value, area or perception. (Westen, 2009)

Hazard assessment is "an assessment of a probability of a certain magnitude of an event that causes damage or loss of live in a specific period of time". Understanding earthquake characteristic such as wave, historical activities, tectonic activity and ground motion is important to assess earthquake hazard.

Probabilistic and deterministic methods are the methods used in seismic hazard which can complement each other in term of providing of risk insight. (Westen 2009)

Probabilistic Method is the incorporation of historical seismicity and geologic information within fault zones that displays evidence of neotectonic activities to estimates probability of ground shaking levels(Westen 2009). The probabilistic method gives long live term shaking in each region/zone with data catalog needed. The data catalog can be found in BMKG (The Meteorology, Climatology and Geophysics Agency), USGS, ISC (International Seismological Centre), EHB (Enghdahl, Van der Hilst, and Buland, 1998) and Centennial.

Deterministic method based on estimation of a seismic design of a facility on the largest earthquake or ground motion at the site. This method assumes in specified scenario and determines the effect on a particular events. This scenario of earthquake creates the "what if" for a particular assumed earthquake. The stages of deterministic involves(Westen 2009):

a. Finding the nearest active fault
b. Calculating the largest earthquake that could happen on this fault
c. Assuming the largest earthquake at the closes point to the region
d. Calculating ground motion that will be achieve.

2.2.1. Fault

"Fault is the local movement between two portion of the crust in new or preexisting offsets of geological structure of the crust" (Kramer 1996). The length of fault can be several meter to hundred of kilometer and extend from ground surface to the depth below the earth.

There are three main faults from the direction of the tension to form a fault. Thrust fault/reverse fault is formed when the largest and medium main tension is the horizontal direction and the smallest is in vertical direction. Normal fault is formed when largest main tension is the vertical direction and the other tensions are medium and small in horizontal direction. In strike slip faults, the largest and smallest main tensions are in horizontal direction and the medium is in vertical direction. The figure of three main faults can be seen in the figure 2-6 below:

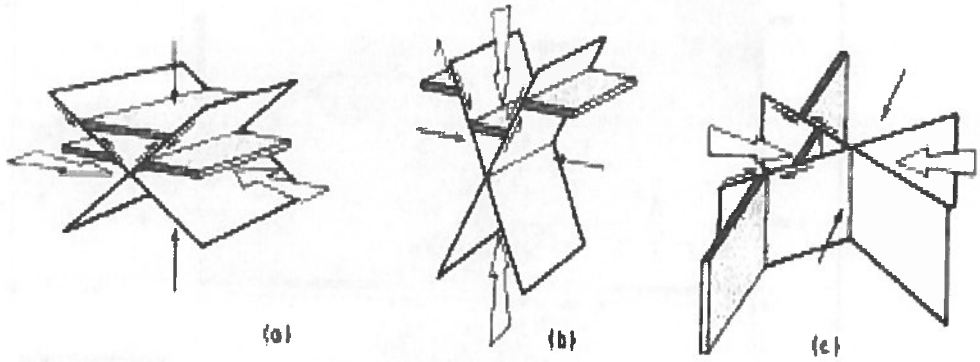


Figure 2-6:a.Thrust fault, b . Normal fault and c. strike-slip fault

Opak Fault is correlated with the earthquake of 27 May, 2006; there were researches to find the source of the earthquake by this fault. The first plot was the Opak fault from geological mapping which concludes that the fault is a normal fault. This hypothesis appears from the geomorphology view. The difference offset from Wonosari hill and Bantul Basin in the lower flat area created suggested line as fault. Danny H Natawidjaya in (Abidin, Andreas et al. 2009) has conclude that the left lateral movement of Opak Fault from Parangtritis beach into eastern Yogyakarta city is the source of 2006 Yogyakarta earthquake. The movement influenced by the subduction of Australian plate that collided Eurasia plate. Rovicky concluded Opak Fault has dip 45^0 .The dip based on plotting in aftershocks data (figure 2-7). The locations of damage map in Opak fault area which were not in the hypocenter can be explained from the movement of the rock and/or soil is different from Nglanggran formation and from Young Merapi Volcanic Formation. Nglanggran formation has low amplification. It formed in tertiary age which has solidified the rock while Young Merapi deposit is formed in quaternary age which is still unsolidified. It amplifies ground shake more than in the bed rock.

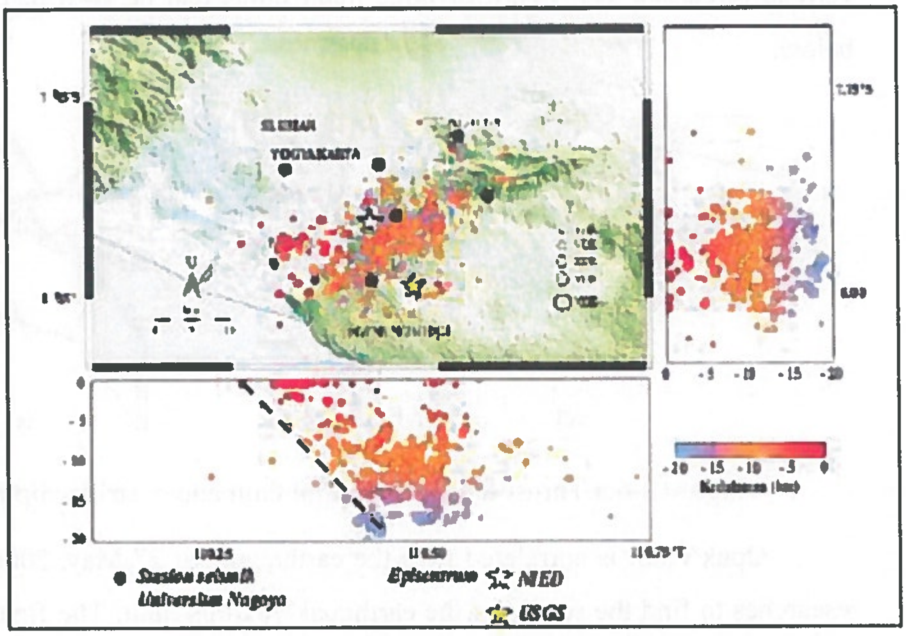


Figure 2-7:The aftershocks data of Yogyakarta earthquake(Abidin, Andreas et al. 2009)and hypothetical dip of fault.

The interpretation of this fault has supported by the research of (Widarto, Andriansyah et al. 2007). They used Audio Magneto Telluric (AMT). AMT is a higher frequency magneto telluric technique for shallow investigations to measure rock resistivity. This distribution model was concluded from rock resistivity. It measures from west-east direction which cut Opak Fault. Low resistivity associated with loose sediment and no water (west and central), and high resistivity associated with limestone and old volcanic Nglanggran (east). The model indicates a low resistivity zones suspected of reflection from a tilted fault Opak eastward (figure 2.8).

Abidin et al(2009)has concluded from GPS surveys. It derived displacement vectors and depths of aftershocks which has suggested the existence of left-lateral fault, with strike and dip angles of about 48° and 89°, located at about 5-10 km east of Opak Fault which is usually drawn along the Opak River.

Tsuji, Yamamoto et al (2009) analyzed the source of the epicenter with synthetic aperture radar interferometry (InSAR). It is associated with the earthquake in Yogyakarta and the result of the fault location and geometry has not been clearly determined. However they suggested the source of earthquake from the surface deformation that occurred in 10 km east of Opak fault.

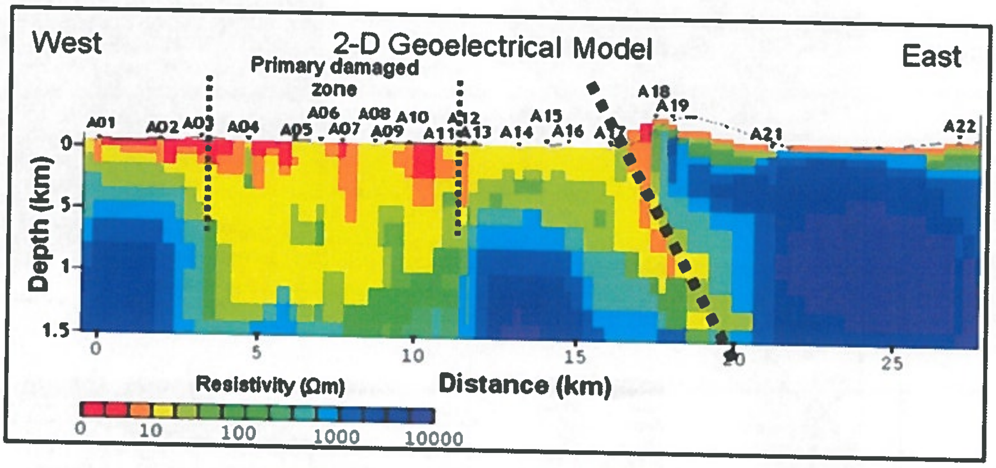
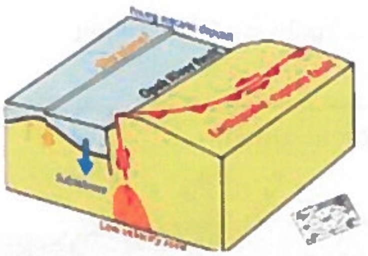


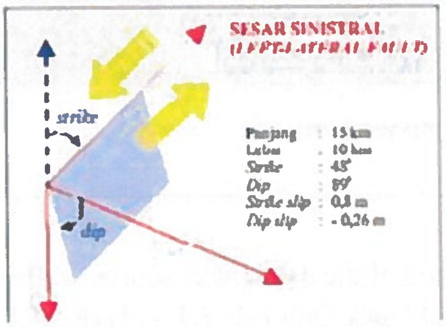
Figure 2-8:The hypothesis dip of the fault of the earthquake source in Bantul by Audio Magnetotelluric (location of Opak fault is in A13-14) (Rovicky)

Walter, Wang et al(2008) analyzed the source of the epicenter from aftershocks data. The result is earthquake hypocenters were not aligned along the Opak River Fault as has been thought by many experts but rather at an unidentified location. As shown in Figure 2-9, the alignment of the recorded aftershocks well correlates with the rupture mechanism as suggested by the Harvard Moment.

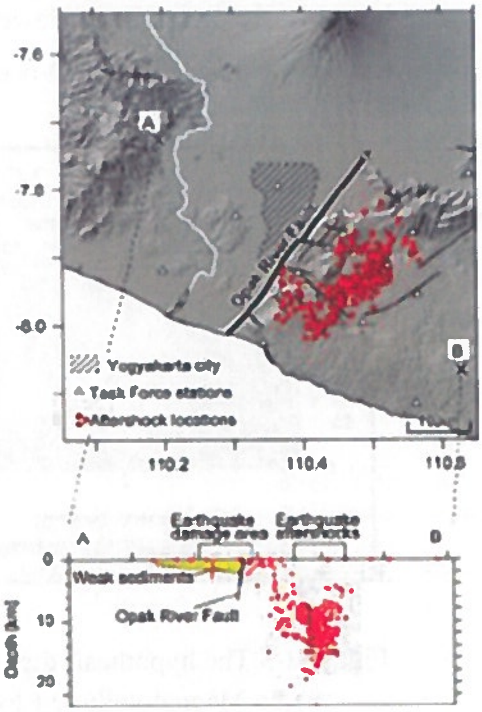
Setidjaji, Barianto et al(2008)also estimated the active fault using USGS as the main shock in the middle of aftershock epicenter and has conclusion of left lateral fault that has not previously mapped. The result of hypothetical fault came fromin two fault scenario which is fault 1 in N65 E and Fault 2 in N 50E (Setidjaji, Barianto et al. 2008). The rupture length along 8 km is obtained from the calculation of empirical relationship between magnitude and length rupture. The scenario of this assumption is parallel with general distribution of aftershocks. (Haifani 2008) calculated from 75 point of destruction by the assumption of deterministic scenario in Subsurface fault lied in 10 km depth and 20,27 fault length.



a. Hypotheses Fault by (Tsuji, Yamamoto et al. 2009)



b. Hypotheses Fault by (Abidin, Andreas et al. 2009)



c. Aftershock data and fault (Walter, Wang et al. 2008)

Figure 2-9:The hypotheses Fault of Earthquake 2006 in Yogyakarta region by different researcher.

The interpretation of 2006 Yogyakarta earthquake source can be divided by two main objects. The one that concluded Opak Fault is the main source but has to reconstruct the Fault from the dip that trending from west to east to be reverse fault and not a normal fault as already being described in geological map. The other researcher like Walter, Abidin, Tsuji, has concluded subsurface fault as the source of the earthquake that happened in 2006. It was left lateral fault near Opak fault. In this research the researcher used both of this assumption to calculate building that were damaged.

2.2.2. **Ground Motion**

The characteristic of ground motion can be defined as spectral response, peak ground acceleration and peak ground velocity. Soil characteristic is an important factor for ground motion and attenuation function to create peak ground acceleration and peak ground velocity. Peak Ground Acceleration (PGA) is the largest value of ground surface during an earthquake. It calculates how hard the ground surface shakes in a given geographic area. The lithology is the dominant factor to calculate the acceleration of ground motion.

Peak Ground Velocity (PGV) expresses the peak of the first integration of the acceleration record. As another parameter to characterize ground motion amplitude; the result of PGV may provide more accurate damage potencies than PGA and also correlated with earthquake intensity.

Permanent ground displacement is associated with the lower frequency of earth motion but difficult to determine accurately. Another parameter of ground motion is a response spectra. It describes the maximum response to a particular input motion of the natural frequency (natural period) and damping (Kramer 1996)

Soil condition has very significant influence to the level of ground motion. The response spectra that happened in the surface is influenced by soil type and thickness of the soil. Seed et al (1976) in (Kramer 1996) has calculated the response spectra from ground motion at site with rock sites, stiff soil sites, deep cohesion less soil and soft to medium stiff clay deposits. The effect of spectral acceleration in soil sites is higher than rock sites (figure 2-10).

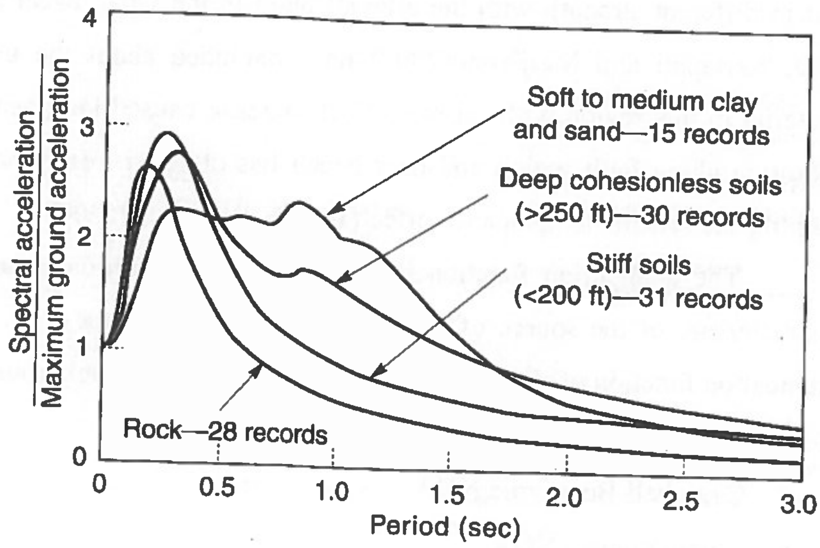


Figure 2-10:Average normalized response spectra (5%)damping for different local site condition(Kramer 1996)

Because the soil condition makes different ground acceleration of the sites, the soils are classified into different sites. Based on SNI 1726-2002, the soils were classified in three types: soft soil, medium soil and hard soil (table 2-3)

Table 2-3:Soil classification based on SNI 1726-2002(Kimpraswil 2002)

Type of Soil	Average shear wave velocity (Vs)	Average Standard Penetration Test (N-SPT)	Average undrained shear strength Su (Kpa)
Hard Soil	$Vs \geq 350$	$N \geq 50$	$Su \geq 100$
Medium Soil	$175 \leq Vs < 350$	$15 \leq N < 50$	$50 \leq Su < 100$
Soft Soil	$Vs < 175$	$N < 15$	$Su < 50$
	Or any soft soil where the total thickness is more than 3 m with PI >20%, wn≥ 40% and Su< 25 Kpa		
Special Soil	Required special examination on every site		

Pramiwijoyo, Karnawati et al. (2008) has determined local soil from Standard Penetration Test (SPT) in Bantul region. The result of N average in 30 m depth at 10 sites varied from 18,60 to 36,85. The type of soil was classified as medium soil. From geological aspect, the uncompacted volcanic deposit of young Merapi is formed by tuff. It has high possibility along period on ground vibration but in different strength with the alluvial plain in the Opak River and in coastal area. Kertapati and Marjiyono(2007) has concluded about the unsolidification material in this region with seismic effect increase caused long period of ground vibration along fault region and near beach has effected from lahar deposit that amplify the seismic to resonance effect(Walter, Wang et al. 2008)

The attenuation function to calculate ground motion is selected by the characteristic of the source of earthquake. (Irsyam, Sengara et al. 2010) used 3 attenuation function of shallow coastal for fault zones and background zones.

- Boore-Atkinson NGA.
- Campbell-Bozorgnia NGA.
- Chiou-Youngs NGA.

The calculation of attenuation function is using shear wave velocity. the correlation is needed to calculate shear wave velocity. N- SPT is the function of soil type, confining pressure and soil density from the borehole in 30 m depth that has repeated blows by hammer in constant diameter. The Qc in cone penetration test is the tip resistance of the soil property which is high in cohesive soil but low in non cohesive soil. (Kramer 1996) has describe the correlation of Vs, N-SPT and CPT in the table 2-4 below.

Table 2-4 :The correlation of Vs with N-SPT and Qc

Reference	Vs (m/s)	R	Soil Type
Ohta, Goto 1978	$Vs=85,3N^{0.341}$	0.72	All (Japan)
Imai, Tonoguchi 1982	$Vs=96.9N^{0.314}$	0.867, 0.868	All (Japan)
Sykore, Stokoe 1983	$Vs = 101N^{0.29}$	0.84	Sand (USA)
Reference	Vs (m/s)	Explanation	Soil Type
Sykora 1983	$Vs = 1.7qc +440$	Vs in fps and qc in kg/cm^2	Non Cohesive
Baldi (1989)	$Vs=277(qc)^{0.13}(\sigma_{v0})^{0.27}$	qc, (σ_{v0}) in MPa, Vs in m/s	

The research of hazard assessment in Yogyakarta earthquake has been done related to ground motion. (Setiawan 2009) analyze seismic microzonation of Bantul region with 2 methods i.e. SAW (Simple additive wave) and AHP (analytical Hieratical Process). The result indicates the highest susceptibility on area along Opak fault. (Rudolph 2008) has created analysis of Java Island for Hazard assessment with HAZUS software. Probability Seismic Hazard Analysis (PSHA) use to create microzonation in the region. (Haifani 2008) analyze the macro seismic of Hazard with the GIS application in Yogyakarta from two indicate source of fault in surrounding Opak Fault.

2.2.3. **Ground Failure**

"Permanent Ground Deformation is a quantification of the ground failure that occurred as a result of liquefaction, landslides and surface fault rupture. Liquefaction is a behavior of soil which the saturated soil losses a substantial amount of strength due to high excess pore water generated by and accumulated during earthquake. The ground displacement of liquefaction is divided into lateral spreading and ground settlement" (FEMA 2009)

The main factor that influenced liquefaction phenomena is type of soil, tense of soil condition, and the magnitude of earthquake. Youd (1973)in(Sudjarwo 2006) explains about high liquefaction susceptibility from uncompacted and unconsolidated sand, wet and saturated or located under water table base level, and the site tremble in a long period to trigger liquefaction. The soil must have condition that clay contents <15 %, Liquid Limits < 35 % and water content > (0.9 x LL).

Sudjarwo (2006) analyzed the soil in geology engineering from the CPT and N-SPT in Bantul District to create the liquefaction potency. The research determined the thickness and the depth of the potentially liquefied soil layers.. The liquefaction susceptibility was conducted using CPT and N-SPT methods, with the peak ground acceleration value of 0.25, earthquake magnitude of 6.2 SR and local water table condition. Figure 2-11 shows the liquefaction that happened in Bantul after 2006 earthquake.

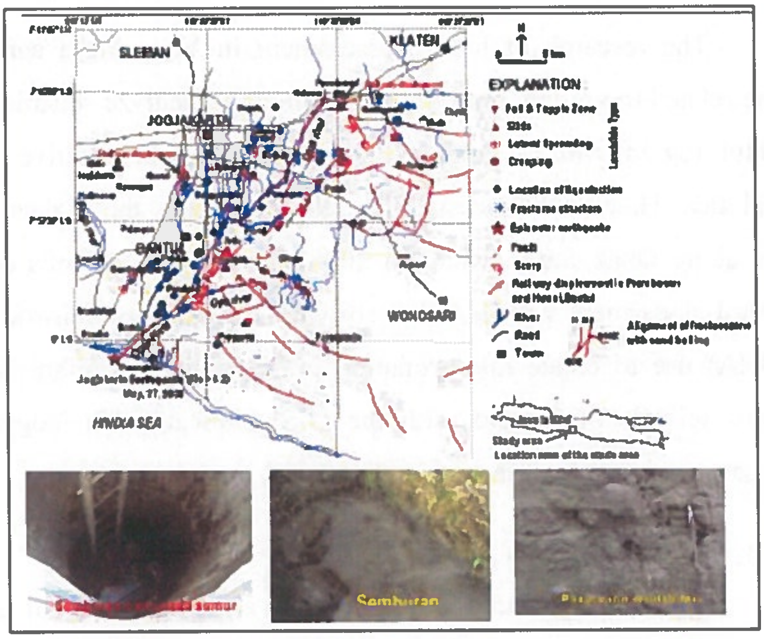


Figure 2-11:The liquefaction that happened in Jogjakarta when Earthquake occurred in 2006 (Soebowo, Tohari et al. 2007)

The loose soil layer consists of silty sand- sand at the depth between 0.2-12.8 m are potentially liquefied during the earthquake. Lateral spreading varies between 0.2 m and 5.2 m and the total settlement induced by the liquefaction is varied between 0.21 cm and 12.98 cm. It is concentrating in middle part of Opak Fault. The liquefaction and settlement zone occupies the upper sediment of Bantul graben near Opak Fault (Soebowo, Tohari et al. 2007).

2.3. Vulnerability

International Strategy for Disaster Reduction (ISDR) in (Leon 2006) is defining that vulnerability as" the set of condition and process resulting from physical, social, economic, and environmental factors, which increase the susceptibility of a community to hazard impact"

Westen (2009) stated vulnerability in four types:

1. Physical vulnerability, the potential impact for physical on environment or infrastructure and population.
2. Economic vulnerability, the potential impact of hazard on economic assets and processes.
3. Social vulnerability, the potential impacts of events groups.
4. Environmental vulnerability, the potential impacts of events on the environment.

The most frequently evaluated in the disaster study are fatalities, injuries, structural damage or collapse to buildings, and non-structural damage to contents of buildings

2.3.1. Building Vulnerability

Building Vulnerability of structure can be defined as probability of physical loss on building when particular shaking occur which depends on aggregate performance of its components and characteristic of hazard and of characteristic of its ground where its stands (Thapaliya 2006)

The natural frequency is a vibration of building where the frequency is the number of times per second that building will vibrate. Damping is the motion of building that has a complex vibration during an earthquake. The vibration can move forward and backward with specified time in specified magnitude.

Seismic vulnerability of building is the amount of damage in building structure by particular level of earthquake intensity. UNDP divided factor that affected building vulnerability into two levels. Primary factor are the subsoil conditions and building construction material. The second factor is building shape, height, size, age, and construction quality.

1. Building structure

   Building structure is divided into three main quality structure: frame structure (all the load on the building are carried out to the frame and transmitted through foundation to beneath of soil), Load bearing structure (the arrangement of masonry units are bonded by mortar and transmit all the load in the structure) and Dual structure (The infill of masonry carry the horizontal load bay compression structure).

2. Building Height

   The building natural period is the inverse of the frequency. The natural frequency in the building is different from short to tall building, the short building will have short natural period or high frequency and the taller building will have low frequency or long site period. From the modes of vibration higher building will have greater displacement, because in tall building the horizontal movement of the floor is large in during an earthquake. The formula of natural frequency of building is given by formula:

$$f = (1/2\pi)\sqrt{k/m} \quad \text{or} \quad f = 10/Nr.$$

Where:

f = fundamental natural frequency in Hz
k = stiffness of the building
m = mass of the building in kg
Nr = Number of Storey.

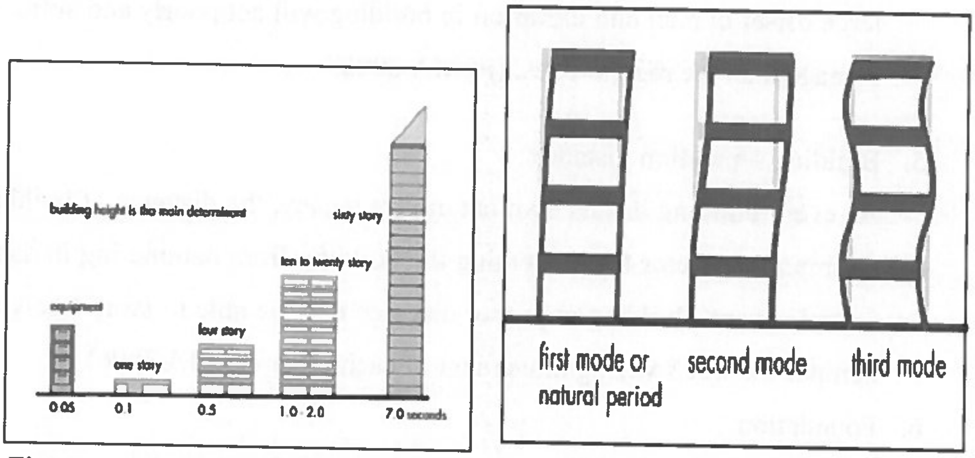


Figure 2-12:Comparative building periods, determined by height and Modes of vibration(FEMA 2006)

3. Building material

Building material and construction technique are the main reason of building damage's. Siddiq (2006) describes the seismic performance of construction material in Indonesia when earthquake occurred (table 2-5).

Table 2-5:Building composite and Structure, as the resistance to earthquake (Siddiq 2006)

No	Material and Building structure system	Suitability Level against Lateral Earthquake Loads				Comment
		Very Good	Good	Less	Bad	
01	Brick /conblock wall pair				X	Brittle. Not ductile
02	Confined brick		X	X		Medium capacity, medium ductility
03	Confined conblock		X	X		
04	Hollow conblock reinforced (RM)		X			
05	Wood frame masonry		X			
06	Bracing wood frame	X	X			High capacity, high ductility, minimum weight
07	Concrete frame structure RC	X				
08	Bracing Steel Frame structure	X				
09	Rigid Steel Frame structure	X				

4. Building Shape

Building shape affects the extended of building's damage. The regularity and symmetry of building shape like rectangular is inherently stronger than L shape or U shape. Irregular shapes will twist when it shakes and increases the damage. Large length building to width ratio or large height to width ratio, large offset in plan and elevation in building will act poorly and suffer greater damage than the regular ones. (FEMA 2006)

5. Building separation distance
   As every building has its own natural frequency, the distance of building play an important factor for preventing the building from hammering in damage of seismic event. Building at proper distance may be able to sway freely and not hamper the free swaying movement of each other (FEMA 2006)
6. Foundation
   The inadequate foundation design can create failure to building even in strong structural when face to earthquake. Tilting, cracking or failure of superstructures may results from soil liquefaction. Types of foundation, from very shallow foundation and mixed types can lead the damage to differential settlement. For the weak soil the appropriate investigation has to carry out to establish bearing capacity in nature of soil.

2.3.2. Building Stocks

Analysis of structure type of building is a factor to convert building model types from NEHRP to Indonesian model. The bamboo structure and zinc roof are not the type of building structure in America. To adopt HAZUS modification of Indonesian structure is needed. The similarity of structure parameter plays an important role in this part.

(Jaiswal and Wald 2008) has divined global building type around the world. The building stock in Indonesia can be divided in rural and urban area. In rural area the building is dominated by traditional one-story, unreinforced clay brick/block masonry in cement or lime mortar. In the urban area, most of the houses are low to mid-rise reinforced concrete frame buildings infilled with masonry walls. The typical housing can be seen in the table 2-6 below

The residents house in Indonesia especially in Java are dominantly from mud brick. These typical houses usually are single-story buildings. The main load bearing structure in these buildings consists of brick masonry walls which are built in cement mortar and timber roof structures. The building is categorized as non engineered structure.

Table 2-6 :Housing stock distribution based compiled for Indonesia (Jaiswal and Wald 2008)

Sr. No.	Residential housing type obtained from census data	PAGER Structure Type	Fraction of housing stock in percentage
1.	Unreinforced clay brick masonry with timber roof	UFB3	30%
2.	Stone masonry walls with timber roof	RS1	30%
3.	Mid rise reinforced concrete frame with infilled masonry walls	C3M	20%
4.	Timber frame with mud walls	W2	10%
5.	Informal	INF	10%

The confined masonry is a construction that offers an alternative to both unreinforced masonry and RC frame construction. It consists of masonry walls (made either of clay brick or concrete block units) and horizontal and vertical RC confining members built on all four sides of a masonry wall panel. It has similarity to reinforced masonry that the vertical and horizontal reinforcement bars are provided to enhance the strength of masonry walls. Masonry units are usually hollow and are made of concrete or clay. The exception of the masonry unit is that they tend to be far smaller in cross-section.(Brzev 2007)

Figure 2-13: Confined masonry construction in Indonesia

In Philippine, Miura, Midokawa et al (2008) classify building class in urban area at Manila. The buildings were classified as concrete hollow brick, reinforced concrete, and concrete frame. The concrete hollow brick (CHB) correlated to URM in HAZUS. The capacity curve is made by Delphi method with the judgment of the expert. The fragility curves in The Metro Manila can be seen in the figure 2-8 below:

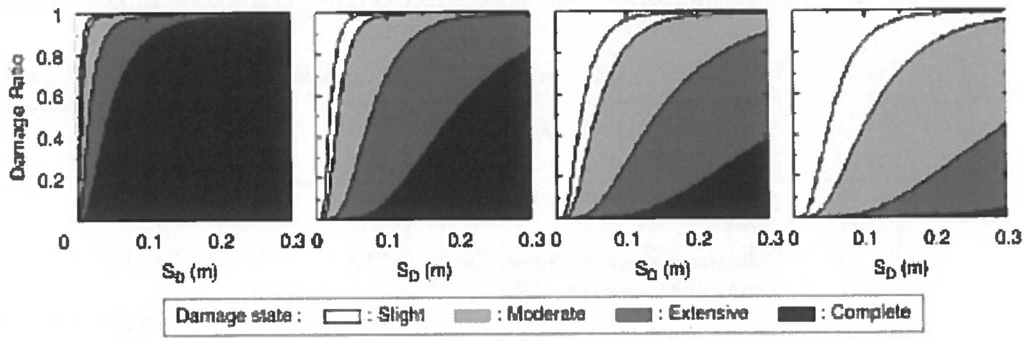


Figure 2-14: Fragility curves in Manila, CHB, C1L, C1M, and C1H ((Miura, Midorikawa et al. 2008)

The standard for building in Indonesia is designed from National Standard of Building (SNI 1276.2002). Yogyakarta region has building standard from maximum damage in zone 3 of return period 500 years (max. PGA 0,15). It means that building construction in Bantul region is supposed to be saved. However the impact of the earthquake in Yogyakarta gives different result. Preliminary report of the damage structure building in Bantul came from the lack of engineering supervision.

The study of structure type in building strength and earthquake resistance relationship's has been done in Bantul regency. Murakami, Pramitasari et al (2008) concluded brick houses with/without reinforcement are much more vulnerable than wooden structures to earthquakes. The damaged of brick buildings was mostly because of failure in structural from insufficient quality and amount of material used for reinforcement. Most of the damage in wooden structures with brick walls was the collapse of the brick parts, while the majority of wholly wooden structures received minimum harm because their structural characteristics allowed them to absorb seismic energy. The figure 2.15 shows the damaged which correlates with the earthquake in Bantul region

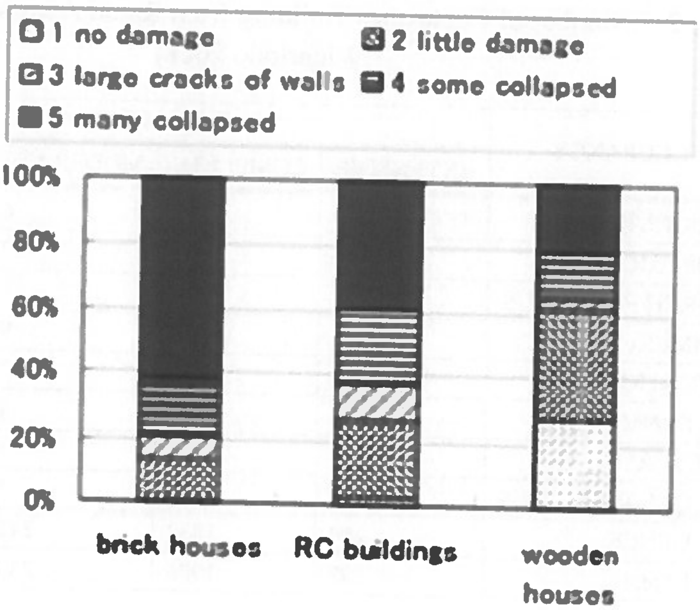


Figure 2-15: Correlation of Building damaged in Bantul Regency(Murakami, Pramitasari et al. 2008)

Before earthquake the typical building of Yogyakarta region is generally consist of one(one and half) brick thick masonry without reinforcement, as in (Sarwidi and Winarno 2006), it consist of mud brick and brick depends on the mixture of material. The change of modernity made the typical houses of half brick thick masonry building with reinforcement, but it is not well anchored in the wall.

Kerle and Widiartono(2008)calculated 3.013 building which classified into extensive 297 buildings, complete 1906 buildings, moderate 280 buildings, and low damage 530 buildings in Palbapang village. (Table 2-7) show the number of damage building in Palbapang village. This damage assessment is calculated using rapid assessment. The survey was not done in all Palbapang villages because in Serut sub village only 7 building were counted.

The rapid assessment of Palbapang village were counted to the various occupancy and building type the percentage of this rapid assessment one by (Kerle and Widartono 2008) mostly in residential building which reached 93 % of the area and the building type mostly in Mud brick (79 %) of the survey(figure 2-16).

Table 2-7:Number of Occupancy Building from Rapid Assessment by (Kerle and Widartono 2008)

OCCUPANCY	DAMAGE				Grand Total
	EXTENSIVE	COMPLETE	MODERATE	LOW	
AGRICULTURE	1	14	6	28	49
CEMETARY	1	21	12	11	45
CHURCH/RELIGIOUS		1	1		2
COMMERCIAL		9	9	28	46
EDUCATION	3	4	2	7	16
GOVERNMENT		8	4	8	20
INDUSTRY		6	1	8	15
MOSQUE/RELIGIOUS	3	11	3	12	29
RESIDENCE	289	1832	242	428	2791
Grand Total	297	1906	280	530	3013

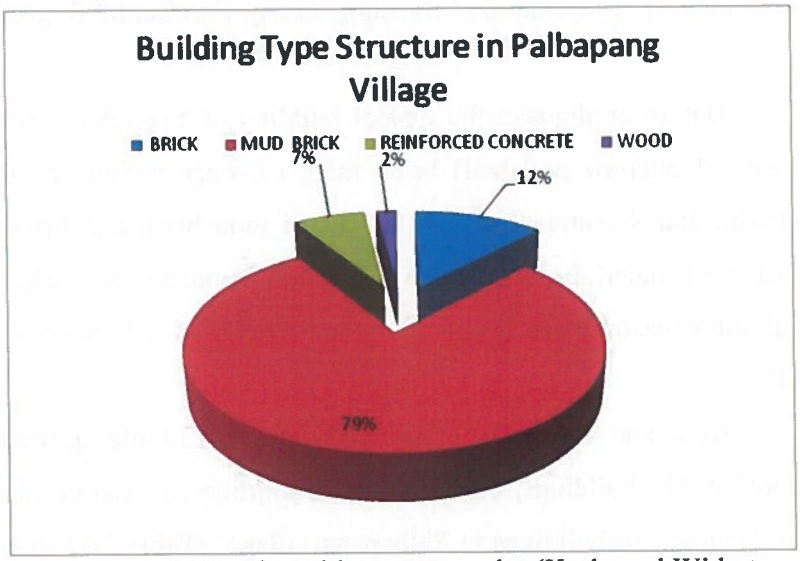


Figure 2-16:The pie chart of Rapid assessment by (Kerle and Widartono 2008).

After earthquake half brick thick masonry buildings with reinforcement were built in most of the study area. The building reconstruction can be divided by two groups. The building that rebuilt by supervision of consultant and the others was with no supervision of the consultant.

2.4. HAZUS MH

The uses of GIS in disaster management is becoming a standard operating procedure because the software can assess, compile, and display large amounts of data in a short period of time. The basic earthquake loss estimation framework consists of:

1. Evaluating seismic hazard for the given area;
2. Collecting relevant and targeted data (e.g., in emergency response it is imperative to collect data pertaining to building and population characteristics; however, for recovery efforts the interest may shift to economical characteristics);
3. Compiling and preparing data for input into the software tool performing loss estimation calculations;
4. Analyzing the calculated losses for a specific or multiple scenarios; and
5. Interpreting and incorporating projected losses into disaster response and mitigation plans.

In 1997, as the response of the need in effective national and community planning in United States, Federal Emergency Management Agency (FEMA) developed a standardized model for estimating losses caused by earthquakes namely HAZUS. HAZUS-MH, Hazards United States Multi-Hazard, is a comprehensive software tool developed by FEMA of the United States through the NIBS, to determine multi-hazard loss estimations in the United States on a regional basis.

In earthquake loss estimations, once the inventories are updated and an earthquake scenario is specified, HAZUS-MH performs a series of operations to compute site-specific loss estimations. Typically, these operations utilize equations embedded within the program and extract relevant information from corresponding databases to calculate losses. For example, physical damage for buildings for a specified ground motion is defined by capacity curves, which determine peak building response, and by fragility curves, which describe the probability of reaching or exceeding various damage states for a given building response. The loss estimation outputs include maps of seismic hazards, structural and non-structural damage probabilities to building and lifeline inventories, post-earthquake fire ignitions, inundated areas, debris generation, social losses, and both direct and indirect economic losses.

HAZUS Provide Three level analysis to allow users to choose either default settings in a level 1 analysis or to improve the level of detail of loss estimations in level 2 or 3 analyses. In level 1 analysis, results are based on default data from HAZUS for describing the hazard (regional earthquake hazard models), assessing soil amplification (generic amplifications for broad soil classes), and assessing vulnerability (default building inventory). In level 2 analyses the local data will refine to the analysis include: the collection of a detailed building inventory, the development of site-specific earth science hazards maps, the compilation of data to model the economy, and the calculation of region specific ground-motion parameters and site amplifications. The Third level involves the built in loss estimation with the local data used for the specific problems in an advanced users.

2.4.1. **Potential Earth Science Hazard**

In HAZUS Input of earthquake epicenter, location and magnitude are combined with the soil map, liquefaction probability and landslide probability to create the hazard map. The earthquake hazard can be divided into two subjects i.e. Ground motion and ground failure.

a. **Ground Motion**

To create ground motion the input of demand based on input requirement:

- Scenario Basis: to determine ground shaking of the hazard by choosing three options (deterministic calculation, probabilistic map user supplied map).
- Attenuation function: The attenuation function based on the region in United States (western and central united states)
- Soil map: the soil map must identify the scheme with the site class from 1997 NEHRP provision.

In deterministic calculation, location and magnitude can be determined from arbitrary event. However in this scenario, the fault is assumed as equal length on each side of epicenter. If the location of epicenter is in the end of the line, the relocation of the source has to be done to conclude of deterministic scenario in this type.

Ground motion is attenuated with distance from the source using attenuation relation. The used in HAZUS defines from ground shaking for rock condition based on earthquake magnitude with spectral demand at 0.3 and 1.0 seconds. The distance between surface rupture to site as an integral part of attenuation relationship characterize the decrease in ground shaking intensity The result depends on which attenuation function that be used to calculate it.

The methodology of HAZUS standardize response spectrum from PGA, periods of spectral acceleration in 0.3 second and 1 second. The region of spectral acceleration from zero seconds to T_{AV} and the region from period T_{AV} to T_{VD} create spectral displacement as can see in the figure 2-18 below. The equation provided in HAZUS to convert spectral acceleration to spectral displacement

$$T = 0.32\sqrt{\frac{S_D}{S_A}} \quad \text{or} \quad S_D = 9.8.\ S_A.\ T^2$$

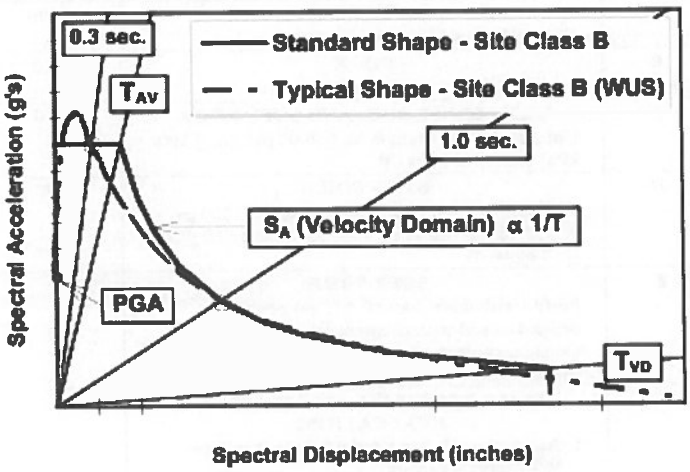


Figure 2-17: Standardization Response Spectral Shape

Source parameter must determine before calculating attenuation function. The figure below shows the source of distance from dip fault and strike fault to the location.

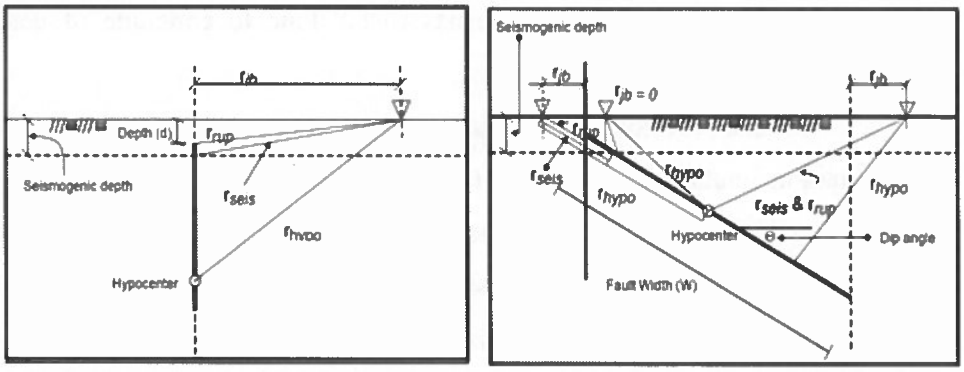


Figure 2-18:Source-to-Site Distances in vertical Faults and dipping faults

NEHRP has classified the site class in 6 classes from hard rock to soft soil and soil that require evaluation of soils with different velocity and amplification factor. (FEMA 2009). The site class description from NEHRP can be seen in the table 2-8 below

Table 2-8:Site Class Description From NEHRP (FEMA 2009)

Site Class	Site Class Description	Shear Wave Velocity (m/sec) Minimum	Shear Wave Velocity (m/sec) 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)		

b. Ground Failure

There are three type of ground failure; liquefaction, landslide and surface fault rupture. The liquefaction susceptibility has occurred in Palbapang village. HAZUS is using qualitative method from Youd and Perkins (1978) (Table 2-9). It is using lithology ages and types to estimate liquefaction potency. The geological map of Yogyakarta and geological engineering map of Bantul have similar form to identify the lithology type and age. The age of lithology in Bantul is in the end of Pleistocene era. The lithology type is young volcanic deposit (the grain size varies from silt to sand in Bantul sub district).

Table 2-9 :The liquefaction susceptibility by sedimentary deposit from Youd and Perkins in (FEMA 2009)

Type of Deposit	General Distribution of Cohesion less Sediments in Deposits	Likelihood that Cohesion less Sediments when Saturated would be Susceptible to Liquefaction (by Age of Deposit)			
		< 500 yr Modern	Holocene < 11 ka	Pleistocene 11 ka - 2 Ma	Pre-Pleistocene > 2 Ma
(a) Continental Deposits					
River channel	Locally variable	Very high	High	Low	Very low
Flood plain	Locally variable	High	Moderate	Low	Very low
Alluvial fan and plain	Widespread	Moderate	Low	Low	Very low
Marine terrace and plains	Widespread	Low	Very	Low	Very low
Delta and fan-delta	Widespread	High	Moderate	Low	Very low
Lacustrine and playa	Variable	High	Moderate	Low	Very low
Colluvium	Variable	High	Moderate	Low	Very low
Talus	Widespread	Low	Low	Very Low	Very low
Dunes	Widespread	High	Moderate	Low	Very low
Loess	Variable	High	High	High	Unknown
Glacial till	Variable	Low	Low	Very low	Very low
Tuff	Rare	Low	Low	Very low	Very low
Tephra	Widespread	High	High	?	?
Residual soil	Rare	Low	Low	Very low	Very low
Sebka	Locally variable	High	Moderate	Low	Very low
(b) Coastal Zone					

Delta	Widespread	Very high	High	Low	Very low
Estuarine Beach	Locally variable	High	Moderate	Low	Very low
High wave energy	Widespread	Moderate	Low	Very low	Very low
Low wave energy	Widespread	High	Moderate	Low	Very low
Lagoonal	Locally variable	High	Moderate	Low	Very low
Fore shore	Locally variable	High	Moderate	Low	Very low
(c) Artificial					
Uncompacted fill	Variable	Very high	-	-	-
Compacted fill	Variable	Low	-	-	-

After defined liquefaction susceptibility, the portion of geological map is generated as the considering factor to assess the probability of liquefaction. In HAZUS, the portion of the geologic map may not be susceptible to liquefaction. Therefore it is considered as the probability of liquefaction from unit mapping. The proportions of map unit to liquefaction susceptibility and the conditional probability follow the table 2-10 below:

Table 2-10 :The proportion of map in liquefaction susceptibility

Mapped Relative Susceptibility	Proportion of Map Unit
Very High	0.25
High	0.20
Moderate	0.10
Low	0.05
Very Low	0.02
None	0.00

The liquefaction probability is created by the equation of :

$$P[Liquefaction_{sc}] = \frac{P[\text{liquefaction}_{sc}/PGA = a]}{K_M.K_w}.P_{ml}$$

Where :

$P[\text{liquefaction}_{sc}/PGA = a]$ is the conditional liquefaction probability for a given susceptibility category at a specified level of peak ground acceleration

K_M is the moment magnitude (**M**) correction factor

$K_m = 0.0027M^3 - 0.0267M^2 - 0.2055M + 2.9188$

K_w is the ground water correction factor

$K_w = 0.022d_w + 0.93$

P_{ml} is proportion of map unit susceptible to liquefaction

In HAZUS, the correlation of the magnitude is reflected with correction factor from magnitude 7.5 and ground water level at 5 feet. It is subscript from the influence factor of ground shaking duration and ground water. The value of liquefaction probability were defined from PGA with statistical method from Liao, et al (1988) in (FEMA 2009) . The relationship of empirical procedures from PGA and Susceptibility category can be seen in the table 2-11.

Table 2-11 :Relationship probability for Liquefaction Categories

Susceptibility	$P[liquefaction_{sc}/PGA = a]$
Very High	$0 \leq 9.09a - 0.82 \leq 1.0$
High	$0 \leq 7.67a - 0.92 \leq 1.0$
Moderate	$0 \leq 6.67a - 1.0 \leq 1.0$
Low	$0 \leq 5.57 - 1.18 \leq 1.0$
Very Low	$0 \leq 4.16a - 1.02 \leq 1.0$
None	0.0

From liquefaction susceptibility the expected permanent ground displacement due to lateral spreading and ground settlement can be determined. The relation of liquefaction and ground displacement uses equation:

$$E[PGD_{SC}] = K_A.E[PGD|(PGA/PL_{SC})=a]$$

Where :

$E[PGD|(PGA/PL_{SC})=a]$ is the expected PGD for susceptibility in specified level of normalize ground shaking(PGA/PGA(t))

PGA(t)) is the threshold of ground acceleration to induce liquefaction.

K_A is the displacement correction factor because the equation is based on Magnitude M = 7.5. The equation for correction factor is:

$$K_A = 0.0086M^3 - 0.0914M^2 + 0.4698M - 0.9835$$

The displacement in lateral spreading is the combination of liquefaction with ground motion which normalized through the threshold of PGA to zero probability of liquefaction. The assumption of ground settlement is the relationship of susceptibility in liquefaction and settlement that could occur in the area. Usually the deposit with high susceptibility has high potency to liquefaction in lateral spreading and in ground settlement

Table 2-12: Spreading displacement and settlement relationship due to liquefaction

Liquefaction	PGA[t]	Settlement (m)
Very High	0.09g	0.3048
High	0.12g	0.1524
Moderate	0.15g	0.0508
Low	0.21g	0.0254
Very Low	0.26g	0
None	N/A	0

2.4.2. **Rapid Visual Screening**

To identify the building, the form of RVS (Rapid Visual Screening) is used to gathered data. The basic of the form consist of three region of seismicity as describe in the table below.

Table 2-13 :Regions of Seismicity with Corresponding Spectral Acceleration Response

Region of Seismicity	*Spectral Acceleration Response, SA (short period,or 0.2 sec)*	*Spectral Acceleration Response, SA (long period or 1.0 sec)*
Low	less than 0.167 *g* (in horizontal direction)	less than 0.067 *g* (in horizontal direction)
Moderate	greater than or equal to 0.167 *g* but less than 0.500 g (in horizontal direction)	greater than or equal to 0.067 *g* but less than 0.200 g (in horizontal direction)
High	greater than or equal to 0.500 *g* (in horizontal direction)	greater than or equal to 0.200 *g* (in horizontal direction)

Soil type has major influence in ground motion that creates structural damage on building. In visual screening the condition of soil hardly identified, so the geological map, engineering geology map had to be collected before doing RVS.

In RVS the scoring of the form in side walk is based on type of building in the area, the plan irregularity, vertical irregularity, how the building follow the structure in building codes (bench mark) the height of building.

There are 15 types of building from RVS which also use in HAZUS with the addition of 1 type of building (Mobile House)(FEMA 2009). HAZUS divines RVS building based on the height of building from low rise building to high rise building which makes the classification of building type has 36 classes as seen in Appendix 9.

2.4.3. **Damage Matrix Curves**

HAZUS determines damage in probability of slight, moderate, extensive and complete damage to general building inventory, and then convert these probabilities into number of damaged buildings. In HAZUS, building information derives from groups of 36 model building types (Appendix 9) and 33 occupancy classes (Appendix 8). Degree of damage is computed for each group combination of model building type and occupancy class.

The general building stocks were designed as high code, moderate code, low code and pre-code. The seismic level of building damage follow the function in Universal Building Codes (UBC) 1976, and NEHRP provision 1985. The Building will have designed as the codes if the building follows the rule of building design codes in every seismic zones area. The seismic codes are the maximum ground acceleration in the seismic zones.

The typical of building structure in HAZUS is divided into 5 class, wood type, concrete, steel, masonry and manufacture house. These typical buildings then divided by storey of the building i.e. low, medium and high. The damaged state of vulnerability of the building can be seen in the table 2-14

Table 2-14:Sample of The damage matrix and fragility of building (FEMA 2009)

Damage State		Description
	**Slight**	Small plaster cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneers. Small cracks are assumed to be visible with a maximum width of less than 1/8 inch (cracks wider than 1/8 inch are referred to as "large" cracks).
	**Moderate**	Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
	**Extensive**	Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations.
	**Complete**	Structure may have large permanent lateral displacement or be in imminent danger of collapse due to cripple wall failure or failure of the lateral load resisting system; some structures may slip and fall off the foundation; large foundation cracks. Three percent of the total area of buildings with Complete damage is expected to be collapsed, on average.

HAZUS uses earthquake demand and structural capacity in the form of spectral acceleration and spectral displacement. The ground motion is transformed to account structural damping and displacement of the building in the capacity curves by design capacity, yield capacity, and ultimate capacity. The spectral displacement represents lateral displacement and Spectral acceleration represents the lateral force for seismic. (Figure 2-20)

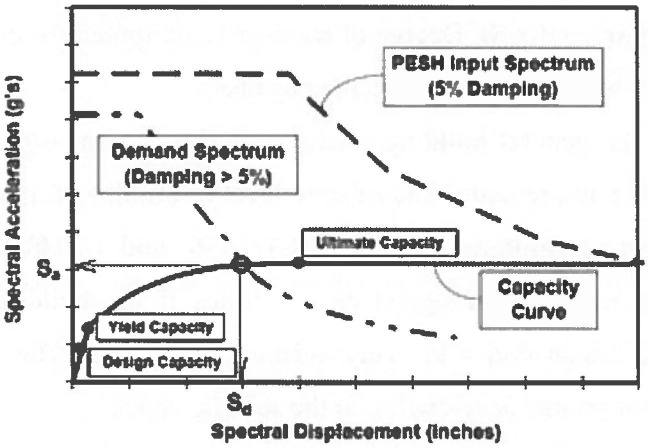


Figure 2-19: The sample of capacity curves and demand spectrum

FEMA describes fragility curves as "the estimation of the cumulative probabilities of being exceeding in each damage state for the given level of ground shaking and or ground failure". The fragility curves depend on model of building types, height of building, seismic design level of building and the response spectrum from PGA for ground motion and PGD for ground failure where the sites of buildings located(figure 2-21). In HAZUS, the calculation is created by the group of building and not in the individual building.

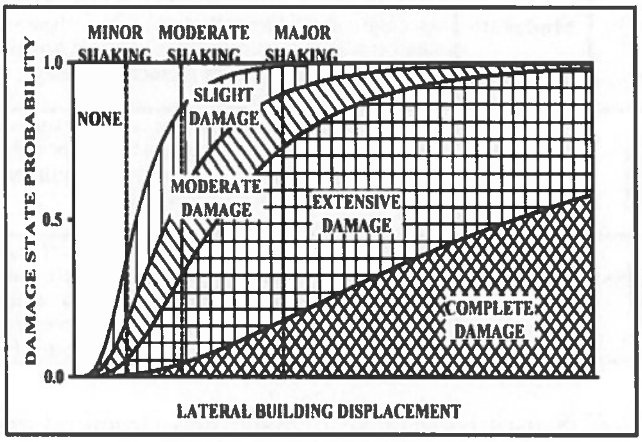


Figure 2-20:The fragility Curves of The Building.

3. STUDY AREA

3.1. General Information about Bantul District

3.1.1. Demography

Bantul District is one of 5 Districts/Cities of Daerah Istimewa Yogyakarta (DIY) province. 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 area of Bantul District is 50.685 Hectares. Bantul District consists of 17 Sub District, those are Srandakan, Sanden, Kretek, Pundong, Bambanglipuro, Pandak, Bantul, Jetis, Imogiri, Dlingo, Pleret, Piyungan, Banguntapan, Sewon, Kasihan, Pajangan and Sedayu District.

Bantul district has geographically position between 07 0 44' 04" - 08 0 00' 27" South Latitude and 110 0 12' 34" - 110 0 31' 08" East Longitude. The width of Bantul District area is 508.85 km2 (15,90% DIY province's width). Bantul has flat topography in the middle to south and hills in the west and eastern part. The location of Bantul district can be seen in figure 3-1.

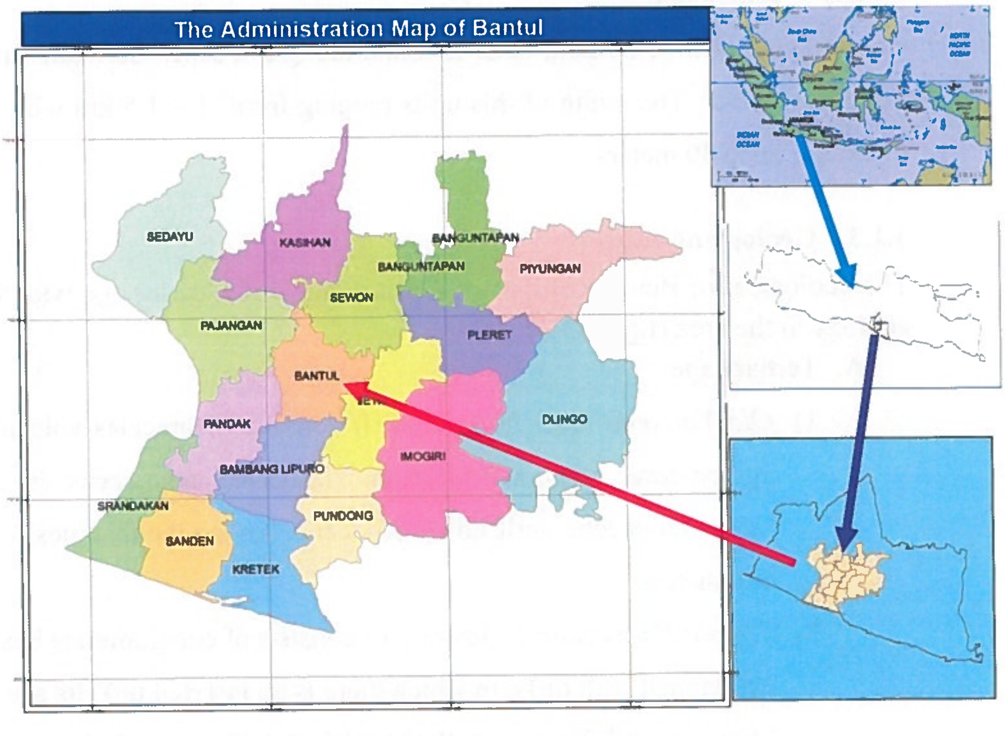


Figure 3-1: Location of Bantul district

3.1.2. Geomorphology of Bantul

Generally, the geomorphology of the Bantul district represents land form resulted from the volcanic activity. It can be divided into 4 geomorphology units (figure 3-2)as follows (Wilopo, 1999,)in (Brontowiyono 2008)

• *Fluvio Volcanic Foot Slope of Merapi*: It is covered by alluvial and fluvial sediment resulted from Young volcanic of Merapi Formation, this area has the slope of about 1% with a parallel drainage pattern. More to the South, the river valley becomes wider and meanders.

• *Denuded Hills*: it is covered by the lithology dominated by *Kebo-Butak-Semilir-Nglanggran Formation*. this formation were consists of sandstone, conglomerate, and limestone. The elevation is around 25 - 972 meters above sea level with the slope inclination up to 90%. The Drainage pattern is dendritic.

• *Alluvial Plain Unit*: This unit is covered by alluvial plain. The deposit in alluvial plain came from Young Merapi and the formation in Denuded Hills. It has elevation 0 – 25 meter above sea level. Drainage pattern is meander; slope inclination is less than 1%. The land use system in this area is farmland and groups of settlement.

• *Sand Dune Unit:* This sand dune is found along the beach between Opak River and Progo River .The width of this units ranging from 1 – 1.5 km with sediment thickness up to 30 meters.

3.1.3. Geology of Bantul

The geological of Bantul consists of Tertiary age and Quarter age with structural geology in the area (figure 3-3):

A. Tertiary age

1) *Old Volcanic Rock Formation*: It consists of breccias-volcanic rocks, agglomerate, tuffs, and insertion of lava-volcanic rocks, its age is in Upper Oligocene until Lower Miocene, having the thickness of around 600 meters.

2) *Sentolo Formation:* Its lower part consists of conglomerate basement, overlapped with tuffs, in which there is an inserted tuff. Its age is Early Miocene until Pliocene with the thickness of around 950 m.

3) *Sambipitu Formation:* This formation consists of sandstone and muddy-stone tuffs, and sometimes it is found as inserted breccias. The fragment that forms either breccias or sandstone is generally in the form of fragment of pumice; its age is Lower Miocene.
4) *Kebo-Butak-Semilir-Nglanggran Formation:* this formation is consist of breccias compiled by volcanic materials. Among the mass of the breccias, inserted lava whose major part has experienced the process of breccias is found. Its age is Middle Miocene.

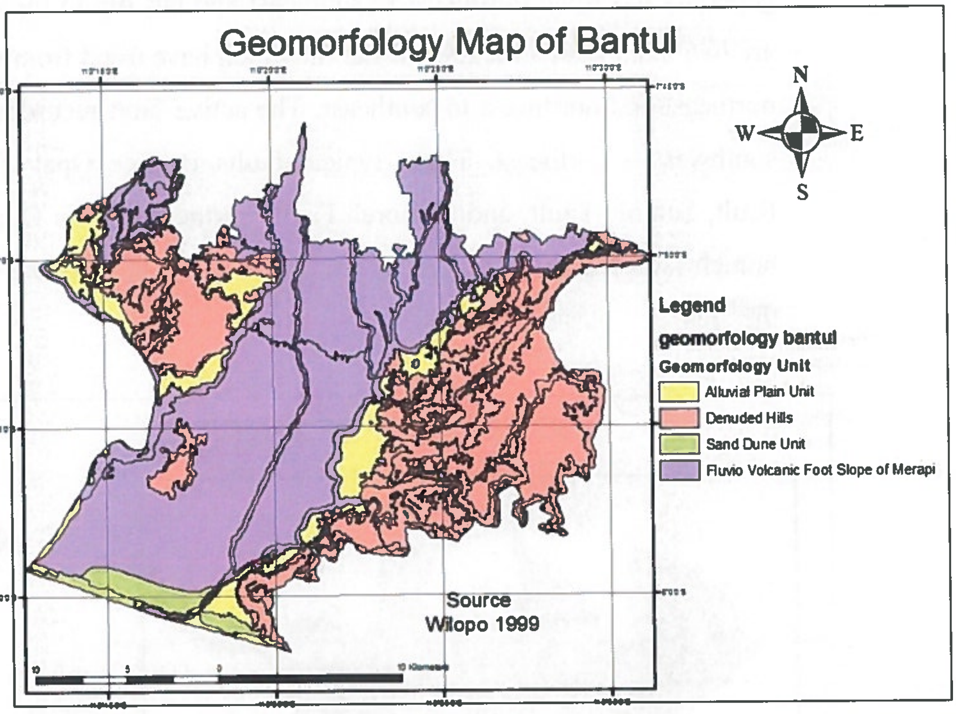


Figure 3-2:The geomorphology of Bantul

B. Quarternary age

The landform from this Quaternary age is in flat area with the slope inclination between 0 -2 %.

1) *Young Merapi Volcanic Formation*: It is included in the upper Pleistocene. It consists of materials resulted from the reworked of Old Merapi sediment in the form of tuff sediment, sand, and breccias, It is weakly consolidated.

2) *Sand Dunes:* This unit is from the sediment of fine to coarse sand, which is spreading out along the beach.
3) *Alluvial*: this unit is an alluvial plain from Tertiary deposits and also from lahars of Merapi Volcano.

C. Geological structure

Structural geology in Bantul area consists of joint structures, fold and fault. The joint structure can be found in the rocks that have been faulted and folded, and also can be found in the karsts area. The fold structure generally has trend northwest to southeast and has dip to the north. There are two main fault structures in Bantul which have trend from southwest to northeast and northwest to southeast. The active fault recorded have trend southwest – northeast. These typical faults include Opak Fault, Progo Fault, Sentolo Fault, and Manoreh Fault. Furthermore the Opak Fault has branch fault which controlled by tectonic movement to create landform in the area.

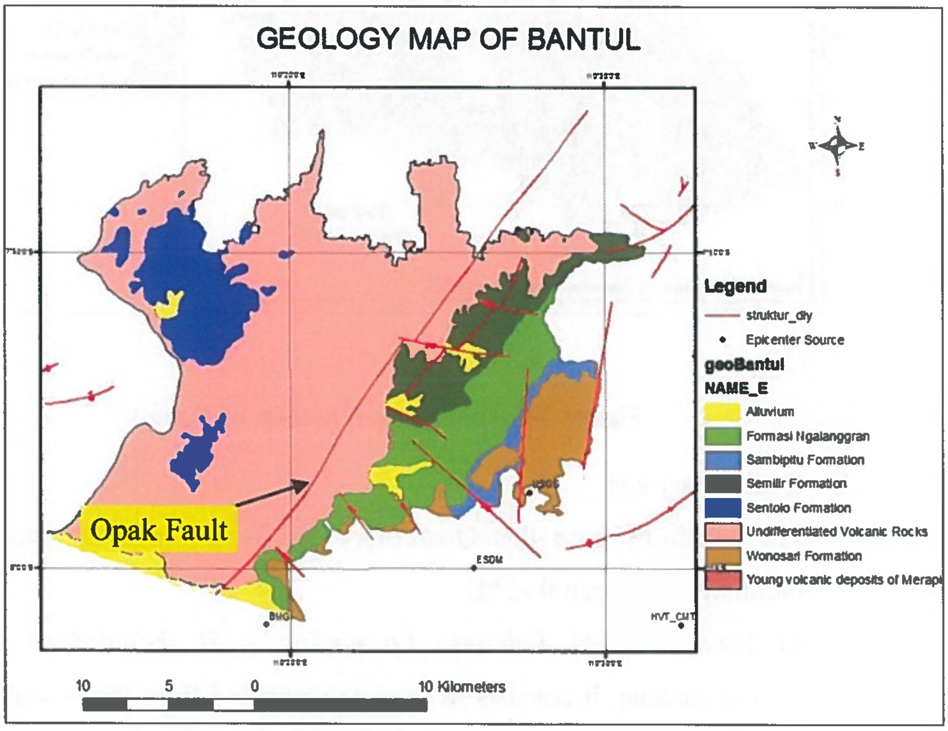


Figure 3-3:Geology Map of Bantul

3.1.4. Geology Engineering of Bantul

The geology engineering is consist of lithology group which categorized by the similarity factor of formation, lithology, grain size, and soil. The Geology Agency created the geology engineering map from laboratory analyze, hand auger and core penetration. The unit of geology engineering can be divide as (figure 3-4) :

- Clay – Silty Clay (Ac-mc). It formed from alluvial and young volcanic deposit. It has group symbol CL/CH-MH, It located in the flat area at the south of Bantul
- Silt of Young volcanic deposit. It formed from young volcanic deposit but in flat area has mixed with alluvial , qc = 20 -64 $kg/cm^{3.}$ Group symbol ML-MH. It located in the middle to south east of Bantul.
- Sand – Silty Sand of Young Merapi volcanic deposit. It formed from young volcanic deposit but in flat area has mixed with alluvial, qc = 30 - 130 $kg/cm^{3.}$ Group symbol SM-SW .It located in the west to middle of Bantul region.
- Limestone of Sentolo Formation. It formed from tertiary deposit. It located in the western part of Bantul. It is a solitary hill.
- Breccia of Nglanggran Formation. It formed from tertiary deposit. It is located in the eastern part of Bantul. The hill is extending from north to south.
- Tufaceous and Sandstone Tufaceous of Semilir formation. It formed from tertiary deposit. It located in the south east of Bantul region.

3.1.5. Hydrology of Bantul

The hydrology of Bantul consists of surface water and groundwater. The surface water in Bantul consists of many river catchment areas (DAS), i.e. The Progo River in the west, Opak River in the middle and Oyo River in the east. Those rivers are supplied by streams such as Bedog (Progo) Gajahwong and Code (Opak) and Mujung and Kaliurang in Oya. The Opak and Oya United in the Indian Ocean. The average rainfall is between 1500 - 3500 mm/year with the wet months from November –April and the dry months from June – September. The Palbapang village has average rainfall between 1500 – 2500 mm/year as shows in figure 3-5. Water resources Management office of Bantul has calculated water table in Bantul district. The depth of water table varied from 0.43 m in January as the highest value and 11.4 m in October as lowest value in October as shows in the table 3-1. The fluctuation has negative trend. The recharge has started in December and the discharge has started in June. The assumption of fluctuation in Palbapang village took the data from Bantul sub district. It has highest value -0.84 m in January and lowest value in October at -1,48 m.

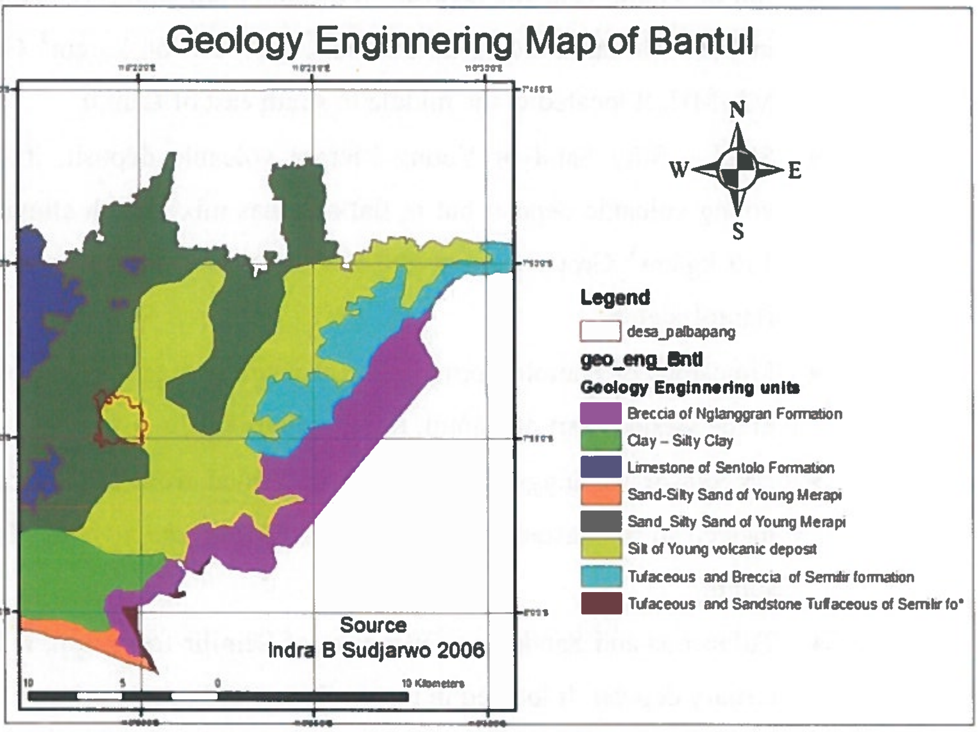


Figure 3-4:The geological engineering Map of Bantul

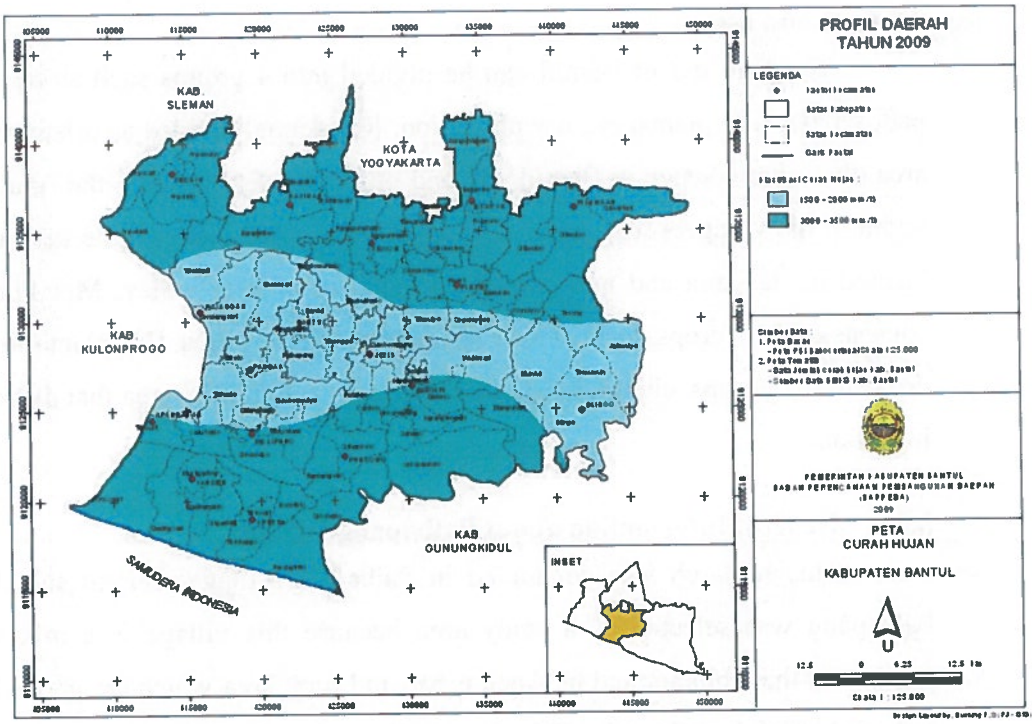
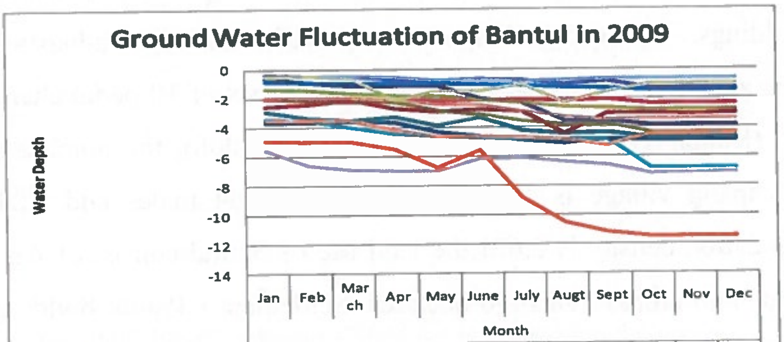


Figure 3-5: Rainfall Map Bantul (Bappeda Bantul)

Table 3-1: Ground water fluctuation of Bantul in 2009 (Source SDA Office of Bantul)



	Jan	Feb	March	Apr	May	June	July	Augt	Sept	Oct	Nov	Dec
Kasihan Sub district	-3.66	-3.64	-3.59	-3.68	-4.29	-4.59	-4.89	-5.09	-4.79	-4.88	-4.89	-4.89
Timbulharjo, Sewon	-2.55	-2.37	-2.1	-2.7	-2.9	-2.75	-2.9	-4.49	-3.1	-3.1	-3.11	-3.1
Jambitan, Banguntapan	-1.96	-2.17	-2.26	-2.26	-2.86	-3.16	-3.56	-3.86	-3.76	-4.36	-4.37	-4.36
Sedayu	-0.65	-0.95	-1.14	-1.19	-1.18	-2.02	-2.35	-3.55	-3.55	-3.85	-3.86	-3.85
Srimulyo, Piyungan	-2.88	-3.35	-3.45	-3.25	-3.85	-3.35	-4.25	-4.45	-4.35	-4.75	-4.75	-4.75
Manggunan, Dlinggo	-4.9	-4.96	-4.98	-5.51	-6.74	-5.57	-8.77	-10.4	-11.1	-11.4	-11.4	-11.4
Bantul	-0.84	-0.89	-0.97	-0.99	-0.98	-1.08	-1.12	-1.27	-1.31	-1.47	-1.48	-1.47
Pandak	-2.02	-2.04	-2.07	-2.1	-2.15	-2.12	-2.07	-2.15	-2.12	-2.37	-2.38	-2.37
Poncosari, Srandakan	-1.38	-1.48	-1.64	-1.8	-1.88	-2.13	-2.28	-2.59	-2.68	-2.81	-2.8	-2.79
Gadingharjo, Sanden	-0.41	-0.48	-0.48	-0.8	-0.75	-0.7	-0.8	-1.1	-0.85	-1.35	-1.37	-1.37
Parangtritis, Kretek	-3.45	-3.53	-4.05	-4.5	-4.65	-4.75	-4.85	-4.85	-4.85	-6.85	-6.85	-6.85
Imogiri	-3.54	-3.52	-3.51	-4.19	-4.59	-4.59	-4.69	-4.82	-5.29	-4.49	-4.46	-4.47
Jetis	-0.52	-0.48	-0.46	-0.55	-0.75	-0.8	-0.85	-0.78	-0.7	-0.7	-0.7	-0.7
Pleret	-1.96	-1.96	-1.96	-2.12	-2.36	-2.46	-2.86	-3.26	-3.46	-3.41	-3.42	-3.41
Bambanglipuro	-0.5	-0.53	-0.63	-2.06	-1.5	-1.5	-1.1	-2.3	-1.6	-1.1	-1.1	-1.11
Pajangan	-5.55	-6.56	-6.86	-6.92	-6.95	-6.1	-6.05	-6.35	-6.55	-7.15	-7.05	-7.07

3.1.6. Land use

The land use of Bantul can be divided into 4 groups such as residential, paddy field, mix plantation, dry plantation. Residential divided as urban and rural area, the urban located in Bantul city and other sub districts city, the rural spread width in the villagers with garden. Paddy field divided into two the irrigated that located in flat area and non irrigated located in hills or valley. Mix Plantation consists of fruit, crops, located near residential and hilly area. Dry plantation is the dry plant like crops, clump, located near villages and in hilly area that difficult for irrigation.

3.2. General Information about Palbapang Village

This research was conducted in Palbapang village -Bantul sub district. Palbapang was selected as a study area because this village is a mix unit of residential that collaborated between urban and rural area which are goods for the test of HAZUS in Indonesia. This area also has extensive damage of earthquake in 2006, ones of the sub village (Serut) had the most damaged building in Bantul sub district. In this sub village only 7 building survive with heavy damaged (HRC 2007), The damaged building are mix from the government building to residential buildings, Palbapang village was selected randomly. Palbapang villages has an area about 552,38 hectares. Palbapang consists of 10 pedukuhan (sub village) 81 RT (Rukun Tetangga). Based on (Statistik 2008), the number of population in Palbapang village is 14.912 consists of 7.064 males and 7,848 females. The population density is 2.621.the land use of Bantul consist of Agriculture (paddy fields and crops) 358.1456 hectares, Settlement (Public building and residence) 136.4190 and 26.6755 hectares, cemetery 5.067 hectares, roads 28.700 hectares, and others is 4.272 hectares.

Monograph data in Palbapang village has counted number of building in 2009 such as religious building 55, Education 22, Industry 42 (Small 12, House 30), Commercial 249, and Residence 3.143 building. The total buildings counted were 3511. The buildings counted not include cemetery and agriculture. The location of Palbapang village shows in the figure 3-6 below.

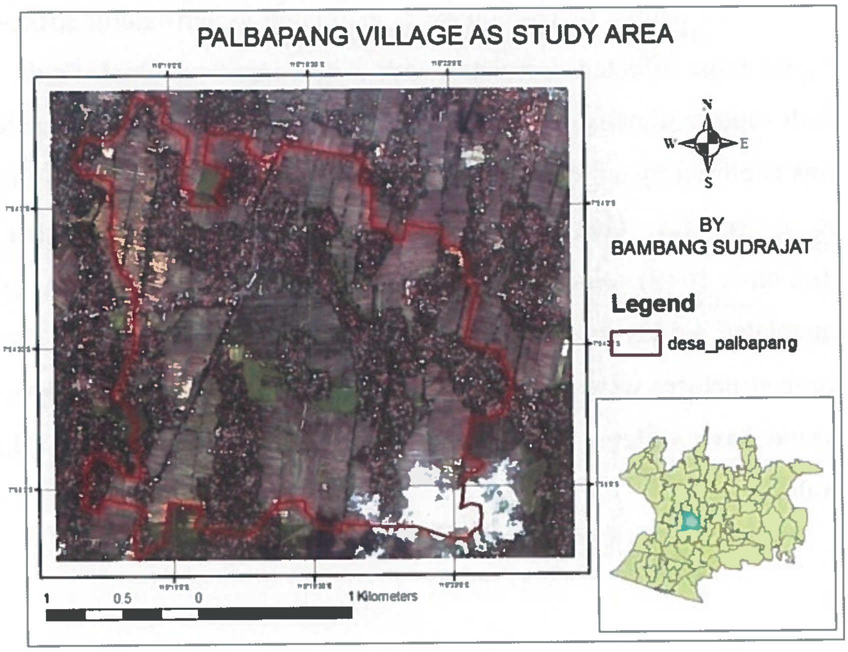


Figure 3-6: Site location of Palbapang village as study area from quickbird imagery(22 April 2010).

3.3. Earthquake in Bantul Regency on 27 May 2006

On 27th may 2006, an earthquake struck in Bantul district at 05:54 hrs in the morning with a magnitude of 6.3 on the Richter scale. It causes extreme and widespread destruction. Villages in Bantul and its surrounding areas were most affected. The official figures remain at 5,749 people killed, over 38,000 injured and more than 127,000 houses completely destroyed, with over 450,000 additional houses damaged by the earthquake. It is estimated that 1,173,742 people were made homeless(Elnashai, Kim et al. 2006).The epicenter reported in different location from different institution as describe on the table 3-2below:

Table 3-2:Source Parameter from different Institution ((Elnashai, Kim et al. 2006))

Institution	Time	Depth (km)	Magnitude			Epicenter	
			Mb	Ms	Mw	Latitude (S)	Longitude (E)
BMG, Indonesia	5:54:01	11.87	5.9			8.03	110.32
ESDM, Indonesia	5:54:01	17			6.2	8.00	110.43
USGS, USA	5:53:58	10			6.3	7.96	110.46
Harvard CMT, USA	5:54:05	21.7	6.0	6.3	6.4	8.03	110.54
ERI, Japan	5:53:59	10			6.4	8.00	110.30
NIED, Japan	5:53:58	10			6.3	7.89	110.41
EMSC, Europe	5:53:58	10			6.4	8.04	110.39
GEOFON, Germany	5:54:02	N/A	5.8			8.04	110.43

The source of earthquake is estimated as left-lateral strike-slip fault. The region most affected correlates with a movement of Opak Fault. The estimated fault rupture dimensions are 20 km long by 10 km wide. The earthquake shaking was captured by a number of seismographs. It was leading to a highly unreliable set of records. The spectra shown in this report indicate that low ductility structures (μ=2) were subjected in the region with max PGA of 0.6-0.7. It is calculated 4-5 times as much as the code coefficient in Bantul. Therefore, even if these structures were designed to resist seismic forces according to the code, they would have suffered unexpectedly high levels of damage(Elnashai, Kim et al. 2006).

4. RESEARCH METHODOLOGIES

This research is mainly divided into three stages. The first is pre fieldwork. In this stage, the identification of building stocks and hazard were generated. The second is fieldwork process. It about collecting primary data and secondary data with the use of stratified purposive sampling in building inventory and purposive incidental sampling in calculating water table, and the last is post fieldwork. In this stage, the analysis of HAZUS methodology is generated to conduct building damage assessment as shown in the conceptual framework below.

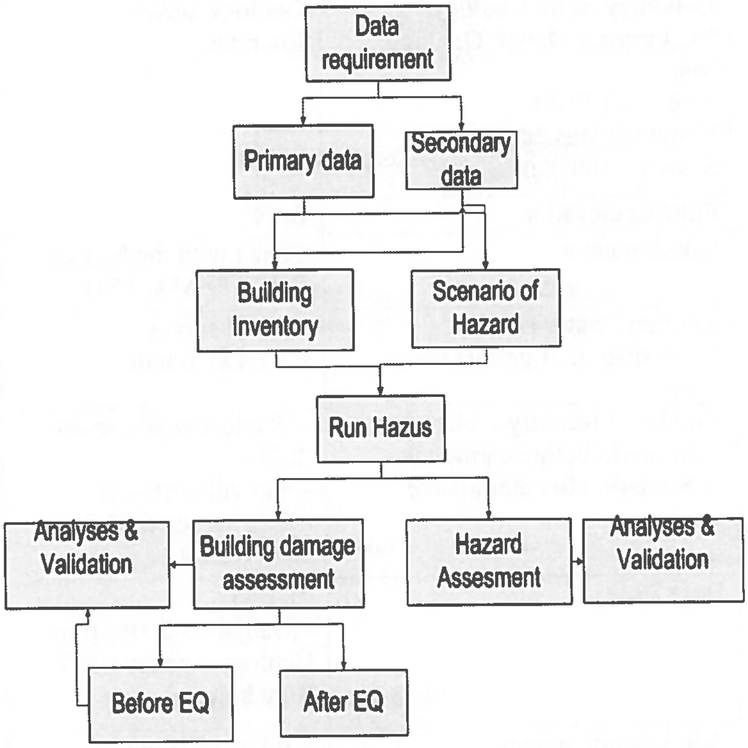


Figure 4-1: Conceptual Research Framework

4.1. Pre-Field Work

The researcher collected literatures review including journals, reports, books, and previous studies that related to information about data needs and methods. The information would be used during field work and data analysis stage. Searches through specialist websites related to the earthquake also resulted in additional information sources.

Table 4-1: Data Availability

No	Data	Sources	Research Activity
1	Quickbird Imagery a. Scenario before earthquake - date acquisition 1 June 2006 - 3 band (blue, green and red) - Resolution 1m. b. Scenario after earthquake - date acquisition 22 April 2010 - 3 band (blue, green and red) - Resolution 0.6 m.	a. Bappeda Bantul. b.Digital Globe	Creating Building footprint
2	Lithology from Geology Engineering Map & Geology Map Scale 1 : 100.000 Geomorfology Map Scale 1 : 100.000	Geology agency Literature,	Creating liquefaction map and ground motion.
3	Point of elevation	BPN	Creating Topography
4	Questionnaire	Create with the base of RVS (FEMA, 154)	Field Survey of Building
5	a.Ground water Level b. fluctuation of ground water table.	a. Field survey b. DSDA Bantul	Creating groundwater map
7	Building Inventory a. Scenario before earthquake b. Scenario after earthquake	- (Kerle and Widartono 2008) - Sub village Chief - field survey (after earthquake)	Creating database for building damage assessment in HAZUS
8	Bore Hole	- UGM - (Sudjarwo 2006) from Geology Agency (CPT Bore hole)	Creating liquefaction map and ground motion map
9	Administrative map - Bantul (1: 38.000) - Palbapang Village (1 : 15.000)	- Bappeda Bantul - Palbapang village	Creating cencus track Creating states and country

The researcher also collected data from the institutional office such as; Water resources management office for data of fluctuation of ground water and bore hole data of Bantul district; BPN office for data of building footprint before earthquake, the administration map of Palbapang regency as the ward unit; Bappeda for data of Images on earthquakes, demography data of Bantul, Administration map of Bantul; Palbapang village office for data monographic, and administration map of Palbapang village.

4.2. Field Data Collection/Fieldwork

The fieldwork was conducted in August until October 2010 to collect a primary data from the villagers about the type of building, occupancy class, number of storey, total floor area, built of the building, and also measure the depth of water table. The researcher does geo-reference to validate positional accuracy in quickbird image.

Field observations are conducted in a number of sites in the sub villages. Interviews with local communities focused on building types, building occupancy, building ages, number of stories, building area (total floor area), the depth of ground water and falling hazard that could happen in the building. These interviews are primarily intended to test the model of the building when face with the earthquake with HAZUS software. The tools conducted in the field are GPS to locate the building, Tape measure to measure the depth of ground water.

4.2.1. Georeference and Digitation of Imagery

The georeferences using the tool of GPS conducted in 8 point with the error 0.009 to 0,04 meter (table 4-2). The reference located at the point on location that can be seen from the quickbird image (figure 4-2), the location spread around the Palbapang village and surrounding area.

Table 4-2 : The reference point of field area

	FID	Shape *	Name	Y	X	Hgt_ell_	Descriptio	HRMS	SolutionTy	Code
	0	Point	pb1	-7.906075	110.339257	61.788	<none>	0.00881	fix	<none>
	1	Point	pb2	-7.919025	110.329822	56.802	<none>	0.01175	fix	<none>
	2	Point	pb3	-7.912982	110.317262	60.244	<none>	0.02119	fix	<none>
	3	Point	pb4	-7.905308	110.320794	63.974	<none>	0.0112	fix	<none>
	4	Point	pb5	-7.905622	110.315005	64.903	<none>	0.01117	fix	<none>
	5	Point	pb6	-7.900881	110.32184	64.621	<none>	0.01734	fix	<none>
	6	Point	st_1305096	-7.90085	110.32182	64.818	<none>	0.02399	fix	<none>
	7	Point	pb8	-7.898324	110.333161	65.335	<none>	0.02351	fix	<none>
	8	Point	pb9	-7.918146	110.314927	58.102	<none>	0.03992	fix	<none>

The Digitations from quickbird Imagery has to be done to build building footprint. The half of digitations was already done by BPN. The building from BPN is correlated with the image of Bantul city in scenario before earthquake. The researcher digitizes the Image in the need to calculate building area. The digitizing of the building footprint also does in Building after Earthquake, the digitizing done in every building. In Palbapang village, the numbers of building from field survey were correlated to the building footprint from the digitations. The sample of building footprint after earthquake overlay with quickbird image can see in the figure 4-3 below

Figure 4-2: The georeference of quickbird imagery, and the measure of position in the field.

Figure 4-3: Sample of building footprint digitations in scenario before earthquake at Karasan sub village

Figure 4-4: Sample of digitations building footprint after earthquake in Bolon subvillage

4.2.2. Sampling Method

The sampling method is using to Inhabitants in Palbapang regency and also water table measurement. 499 Buildings were selected by using Stratified Purposive Sampling. Stratified Purposive Sampling is the method of technical sampling with using certain consideration. The parameter used in the field is based on the house that rebuilt by JRF, Pokmas and self supporting. In this approach, the number of observation was selected in the representative RT (Rukun Tetangga). RT is the smallest unit of neighborhood governance. The sampling is taking 20 -30 houses. Interviews were done by the researcher accompanied with other researcher (figure 4-5). The samplings of water table measurement were taken by using incidental purposive sampling. Incidental purposive sampling is the method of technical sampling with using incidental and certain consideration. The water table is selected by easiest access to the road. 52 sampling has taken in each of sub village and also related near to respondent in the village.

Figure 4-5: Field Survey in Palbapang village

4.3. Post-Field Work Activities

Collected data is analyzed and processed using HAZUS. Figure 4-4 shows the framework in HAZUS, The result of this process, including earthquake hazard map, vulnerability building, and risk map including damage building.

4.3.1. Determine Hazard Map

The assumption of Deterministic scenario of hazard is based by the earthquake that happened in Jogjakarta Province in 27 May 2006, This scenario of earthquake create the "what if" for a particular assumption.The assumption is taking for the vulnerability of building in Bantul region. To determine damage matrix in palbapang with various building before and after earthquake, and how the reconstruction of the building based to earthquake based building.

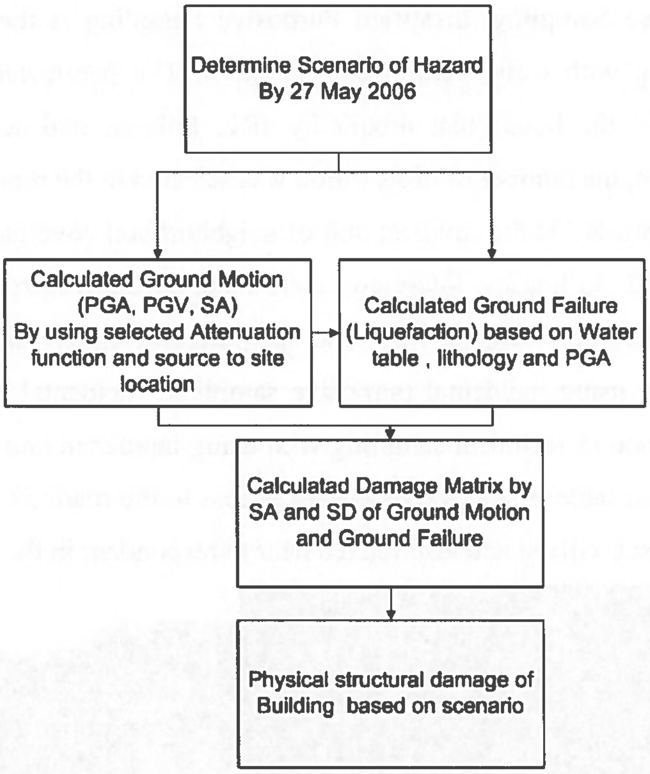


Figure 4-6: Frame work of building damage assessment using HAZUS

4.3.1.1. Determine Ground Motion Map

The researcher determines the ground motion based on PGA, PGV and Spectral Acceleration as follow:

- Determine shear wave velocity (Vs) using data from Borehole of N-CPT as the data of Vs and correlate into soil type site. The correlation of CPT is using the calculation from Sykora in table 2-4.
- Determine shear wave velocity (Vs) from geomorphology map with the base of the elevation and the deposit calculated by the distance of tertiary age of lithology (Matsuoka, Wakamatsu et al. 2006) to see how the relationship between geomorphology and the site soil class in the area and to see the correlation with other calculation by researcher. The calculation

of Vs is based on principle that the higher the elevation, the steeper of the slope angle and the nearest distance of bed rock, Vs value become higher.

The formula of Vs is :

$$\log AVS30 = a + b \log Ev + c \log Sp + d \log Dm \pm \sigma$$

Where:

a, *b*, *c*, and *d* represent regression coefficients, and σ is a standard deviation (Appendix 2).
Ev= Elevation in (m)
Sp = Tangent of slope * 1000
Dm = the distance (km) from hill or mountain of pre tertiary or tertiary.

In this calculation the nearest hill is from west side of Palbapang village which is the land form from Sentolo formation.

- Determine ground motion map

  The researcher calculates ground motion by using combination of WUS attenuation function for two scenarios (BMG source and USGS source). The scenario of hazard is created by using arbitrary event in HAZUS. It computes the fault rupture length and assumes fault rupture to be in equal length on each side of the epicenter. In avoiding miss calculation, the modification is created. The used of this attenuation function is Extensional for Strike slip Fault and Normal Fault and Non extensional for Reverse Fault (table 4-3)

Table 4-3: Attenuation function of WUS Shallow Crustal event Extensional and Non Extensional(FEMA 2009)

Name	Participation Attenuation Functions	Weight
WUS Shallow Crustal Event - Extensional	Abrahamson and Silva (1997): Hanging Wall	0.20
	Sadigh,Chang, Egan, Makdisi, and Young (1997)	0.20
	Boore, Joyner and Fumal (1997)	0.20
	Spudich et al. (1999)	0.20
	Campbell & Bozorgnia (2003)	0.20
WUS Shallow Crustal Event – Non-Extensional	Abrahamson and Silva (1997): Hanging Wall	0.25
	Sadigh,Chang, Egan, Makdisi, and Young (1997)	0.25
	Boore, Joyner and Fumal (1997)	0.25
	Campbell & Bozorgnia (2003)	0.25

- Determine elastic response spectra in 5 % damping. The researcher using the spectral acceleration of 0.3 second and 1 second to calculated the elastic response spectrum with 5 % damping.

4.3.1.2. Determine Liquefaction Map

The researcher determines the Liquefaction susceptibility based on the geological condition and the depth of water table. The step to determine Liquefaction susceptibility as follow:

Juang and Elton in (Piya 2004) has develop the weighting factor for liquefaction potency (table 4-4)

Table 4-4: Weighting factor of liquefaction susceptibility

Factor	Weighting	Liquefaction Susceptibility				
		Very High 5	High 4	Medium 3	Low 2	Very Low 1
Depth to Water table	Very Important	< 1.5 m	1.5 – 3 m	3 – 6 m	6 – 10 m	>10 m
Grain Size	Very Important	0.075– 1 mm	1-3 mm	>3 mm	<0.075mm	
Depth of Burial	Very Important	1.5 -3 m	3-6 m	6 -10 m	<1.5 m	>10 m
Capping layer	Very Important			Good Caping	Fair Capping	No Capping
Age of Deposit	Important	<500 year	Late Holocene	Holocene	Pleistocene	Pre-Pleistocene
Liquefiable layer thick	Important	>2.5 m	1.2-2.5 m	0.6 – 1.2 m	<0.6 m	

In this research, the factor of liquefaction susceptibility is calculated with scale from Low to Very High. The weighted factor is taken from the very important value to important value

Table 4-5: Percentage of Weighting value in liquefaction susceptibility.

Factor	Weighting Value
Depth to Water table	30%
Grain Size	30%
Age of lithology	20%
Liquefiable layer thick	20%

The Liquefaction Susceptibility is correlating to HAZUS. The step of the process in HAZUS as follow:

- Correlate the Water table in area to the HAZUS, Water table map. Using the center of Census track, interpolated the Map in each census track.

- Use scenario of May, by using the fluctuation of water table in assuming water table will reach the same base level in the same month. Bantul sub district fluctuation determines as the point of water table.
- Use geological data to create the Probability of Liquefaction from CPT 17 and the correlation of borehole and geology engineering map (Figure 4-7). The site location of R.17 has upper layer thickness 0.6 m in sand unit. The bore hole R-27 has upper layer thickness of sand unit 0.5 m.
- Calculated correction factor of moment magnitude and water table depth on the map for liquefaction potency
- Correlate the value result in HAZUS and method of HAZUS with other liquefaction potency.
- Calculate ground displacement from the liquefaction susceptibility

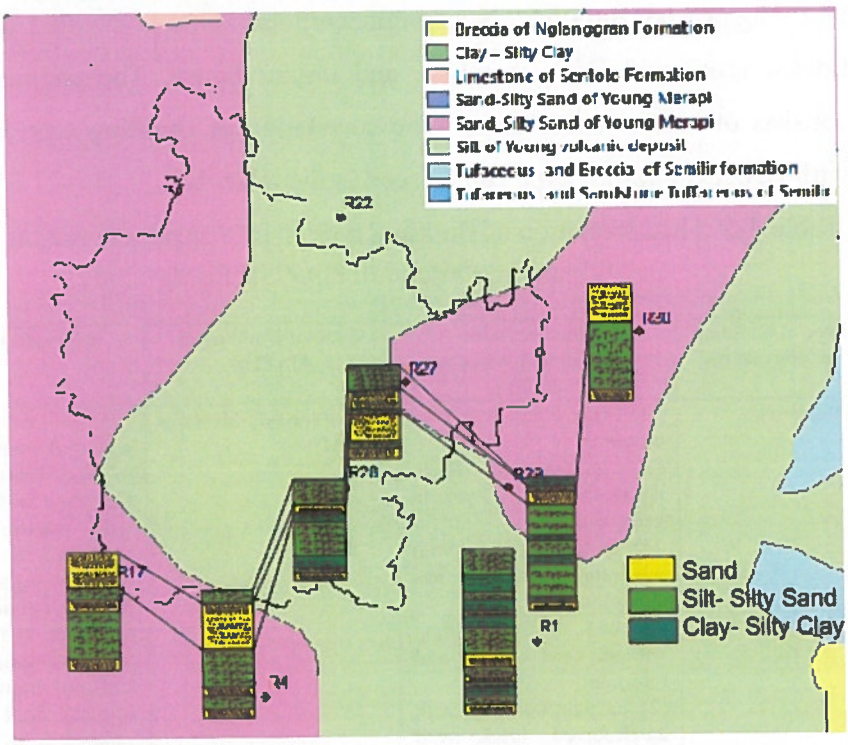


Figure 4-7:Borehole in Palbapang village and surrounding area from CPT (Source :Geology Agency)

4.3.2. Generated Building Stocks

4.3.2.1. Questionnaire based on RVS

The questionnaire is based on Rapid Visual Screening (RVS) from FEMA. Before create the questionnaire, the seismicity of the region is correlated to the region of seismicity that created by FEMA. FEMA is divided the region into three seismic: low seismicity, medium seismicity and high seismicity.

Irsyam,Sengara et.al.(2010) has created the spectral acceleration response, SA (short period, or 0.2 sec) value in 0,6 g. The long period in Bantul region is in 0.2 – 0.25 g. It is concluding Bantul with high seismicity.

Building type on HAZUS has to be converted to the building type in Indonesia. In Yogyakarta region, the buildings consist of non engineered Building and Engineered Building. Non engineered building is divided as mud brick, bricks, reinforced brick, bamboo, and timber house. The engineered building consists of reinforced concrete. The correlation of Building type in Yogyakarta with HAZUS building type can be seen in the table 4-6.

Table 4-6 :The correlation of Building type in in Yogyakarta region (Sarwidi and Winarno 2006)and In HAZUS(FEMA 2009)

Type of Building in Yogyakarta	Characteristic (Sarwidi and Winarno 2006)	Type of Building in HAZUS	Characteristic (HAZUS)
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) 13 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
Wood House 2	reinforce bamboo/wood building in well condition and good quality of material	Wood House (W1)	

In study area, the building occupancy is consist of settlement (residential), government office include disaster mitigation office, shop and market, Warung (Restaurant), Kandang Sapi (barnyard), clinic, bank, school (TPA, SD,SMP, SMA) and Mosque.

Basic Structural Hazard (BSH) score on Rapid Visual Screening has to modify into the type of structural on Bantul Area. Rapid Screening procedure from SHRM project has created modification factor with element of building storey, quality of construction, vertical and plan irregularities, pounding, cladding, soil condition and slope ambience. The modification can be correlated to Indonesia region which structure of building has different material in used. This modification gives different result from FEMA. The modification from (Agrawal and Chourada 2006) in the table 4-7 can be adopted in Bantul condition.

The design code of structural type in Palbapang village is made by assumptions. The assumption for building before earthquake is as Pre code and Low Code building. The assumption is made because in 1987 even the government created the rule of building base of earthquake but all the buildings not base on it. In 2002 the building started to represent in base of earthquake in low code, as can see in the table 4-9. The structural building after 2006 that reconstruct and rebuilt in study area started to base on earthquake base building.

Table 4-7:The Performance Modification Factors(Agrawal and Chourada 2006)

Modifiers	Description	Modification Factor
High Rise	Upto 2 storey	0
	Between 3 - 7 storey	-0.2
	More than 7 storey	-0.5
Quality of Construction	High	0
	Medium	-0.25
	Low	-0.50
Vertical Irregularity	Steps in elevation, inclined walls, discontinuities in load path, building on hills	-0.50
	Without vertical irregularity	0
Soft Storey	Open on all sides of buildings, tall ground floor, buildings on stilts	-0.50
	Without soft storey	0
Plan Irregularity	"L", "U", "E", "T", or other irregular building shape	-0.50
	Without plan irregularity	0
Pounding	Floor levels of adjacent buildings not aligned and less than 100 mm of separation per storey	-0.50
	Without pounding	0
Cladding	Many large heavy stone or concrete panels, glass panels and masonry veneer do not qualify	-0.50
	Without vertical irregularity	0
Soil Condition	Buildings founded on rocks (SR)	0
	Buildings founded on cohesionless soil (SC)	-0.3
	Buildings founded on black cotton soil (BC)	-0.6
Ground Condition & Slope Ambience	Buildings in flat plain land domain	0
	Buildings on hill slopes/tank bunds/reservoir rims with slope > 10° - gentle	-0.10
	-do- - moderate	-0.20
	-do- - steep	-0.30

Design code is following modification score of building based on RVS. The type of URM and wood still follow the Low Code /Pre Code, for RM / C1 and S3 the building the design code is used the modification factor of (Agrawal and Chourada 2006).The value of Building codes generated in the term of condition:

Pre Code = n = 0
Low Code = n < 2
Moderate Code = 2 < n < Basic score
High Code = n > Basic Score

Table 4-8 : Modified Design Codes based on Seismic Factor adopted from UBC seismic Zones to Bantul Region

2002 Indonesia Seismic Zones map	Seismic factor	2010 Indonesia Sesimic Zones Map	Seismic factor	Post 2010	2006-2010	2002-2006	1987 -2002	Before 1987
Zone 6	0.3	Zone 10	0.6	High Code	High Code	Moderate Code	Low Code	Pre Code
		Zone 9	0.5	High Code			W1 = Mod. Code	W1 = Mod. Code
Zone 5	0.25	Zone 8	0.4	High Code	High Code	Moderate Code	Low Code	Pre Code
		Zone 7	0.3	Moderate Code	Moderate Code		W1 = Mod. Code	W1 = Mod. Code
Zone 4	0.2	Zone 6	0.25	Moderate Code	Moderate Code	Moderate Code	Low Code	Pre Code
		Zone 5	0.2	Moderate Code			W1 = Low Code	W1 = Low Code
Zone 3	0.15	Zone 5	0.2	Moderate Code	Moderate Code	Low Code	Pre Code	Pre Code
		Zone 4	0.15	Low Code	Low Code		W1 = Low Code	W1 = Low Code
Zone 2	0.1	Zone 3	0.15	Low Code	Low Code	Pre Code	Pre Code	Pre Code
		Zone 2	0.1	Low Code		W1 = Low Code	W1 = Low Code	W1 = Low Code
Zone 1	0.03	Zone 1	0.05	Pre Code	Pre Code	Pre Code	Pre Code	Pre Code
					W1 = Low Code	W1 = Low Code	W1 = Low Code	W1 = Low Code

Bantul region

4.3.2.2. Homogeneous units area mapping

It is important to know the spatial distribution of buildings in the event of an earthquake. This study is determined by the size of the basic mapping units for capturing the building data. The homogeneous area mapping is dividing region into census track. In HAZUS, the damage of building are estimated in census track units and not in individual building level. The concept of the homogeneous is used to mark those areas, which have the same building material type and building occupancy. In this research, Palbapang Village is dividing into 10 census track. The Census track is based on administrative border (Appendix 1). The structural type of building before earthquake is generated by correlation of building structure from Sarwidi and HAZUS.

The occupancy class in census track is made by the number and percentage of building type with different building occupancy. The correlation of the building is used to calculate homogeneous of the building

Table 4-9: Sample of building types percentage in occupancy class at Kadirojo census track.

Occupancy Class	Building Types													
	RM2L						W1		W2		WOOD		Grand Total	
Building	LC	%	MC	%	Total	%	LC	%	LC	%		%		%
Residential 1	6	12%	44	88%	50	96%	1	50%	1	50%	2	4%	52	100%
Government 2					0	0%	1	100%		0%	1	100%	1	100%
Religious 1		0%	1	100%	1	100%					0	0%	1	100%
Education 1		0%	3	100%	3	100%					0	0%	3	100%
Grand Total	6	11%	48	89%	54	95%	2	67%	1	33%	3	5%	57	100%

4.3.2.3. Damage Matrix and Fragility curves

The calculation of damage probability in model of structural Building type can be shown by the step below:

- Input requirement as in HAZUS methodology Model building Type and seismic design level
- Correlate the elastic response spectra to inelastic response spectra by using the reduction factor
- Calculate spectral displacement corresponding with Spectral acceleration.
- Generate capacity curves with the parameter of yield capacity point and ultimate capacity point with the values of parameter taken from HAZUS and MIURA (Philippine).
- Calculate peak building response (peak spectral displacement, Sd) to overlay the response curve and capacity curve.
- Calculate cumulative probability of damage for building class with the parameter of fragility curves from spectral acceleration and from liquefaction susceptibility.
- Calculate discrete damage probability and generate the matrix for building type

5. RESULT AND DISCUSSION

5.1. Result and Discussion on Hazard Assessment

5.1.1. Ground Motion Assessment

The use of deterministic analysis to calculate ground motion in Palbapang village based on the location source parameter of BMG and USGS. These two sources have different parameters. Epicenter of BMG is correlated into the Opak fault mechanism. In the other hand the USGS epicenter is based on the reactivated subsurface fault.

The determination of shear wave velocity is conducted as the correlation of site class of soil in Palbapang village. The CPT data in R-17/CPT-18 at depth 2,6 meter is 120 kg/cm^2. The equation of Vs from Sykora(1983) is 196,29m/s. The calculation using geomorphology aspect has concluded in Palbapang Village. The result is varying from low value in 187.03 to 198.36 m/s and in high value from 317.63 to 336.93m/s (sees Appendix 2). The median value of this result is 258 m/s. Low value result has significance correlated into the value from CPT, while the result in median value has correlated with the SPT result in Bantul. This result may conclude about the correlation of geomorphology and lithology condition to the soil site class(Matsuoka, Wakamatsu et al. 2006). The value of Vs is correlating to slope inclination and lithology type. This result indicated class of soil in the research area as **Stiff Soil** (shear wave velocity between 180 to 350 m./s).

The parameter of the earthquake source on BMG based scenario and USGS based scenario is described in the table 5-1 below:

Table 5-1: The Parameter of Earthquake Scenario

Parameter	Scenario 1	Scenario 2
Type of fault	Reverse Fault	Strike slip Fault
Strike /Dip	N37E/45^0	N48E/89^0
Length of the fault	40	15
Width of The fault	8	10
Depth of The Fault	11.87 (hypocenter of BMG)	10 (hypocenter of USGS)
Magnitude	5.9 Mb converted to Mw as 6.25	6.3 Mw
Subsurface rupture	20 km	8 km "based on The Equation Log (L) = 0.6 M – 2.9"

The parameter of fault is input in the HAZUS model. The hypothetical fault to generate the scenario can be seen in the figure below. The BMG Fault scenario is based on Opak Fault and the USGS Fault based on strike slip fault east of Opak Fault.

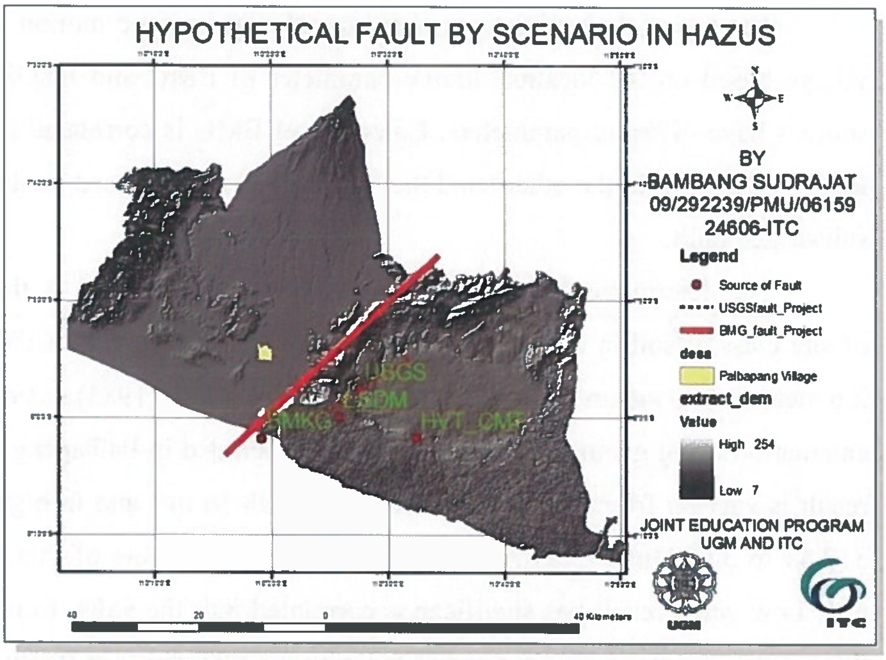
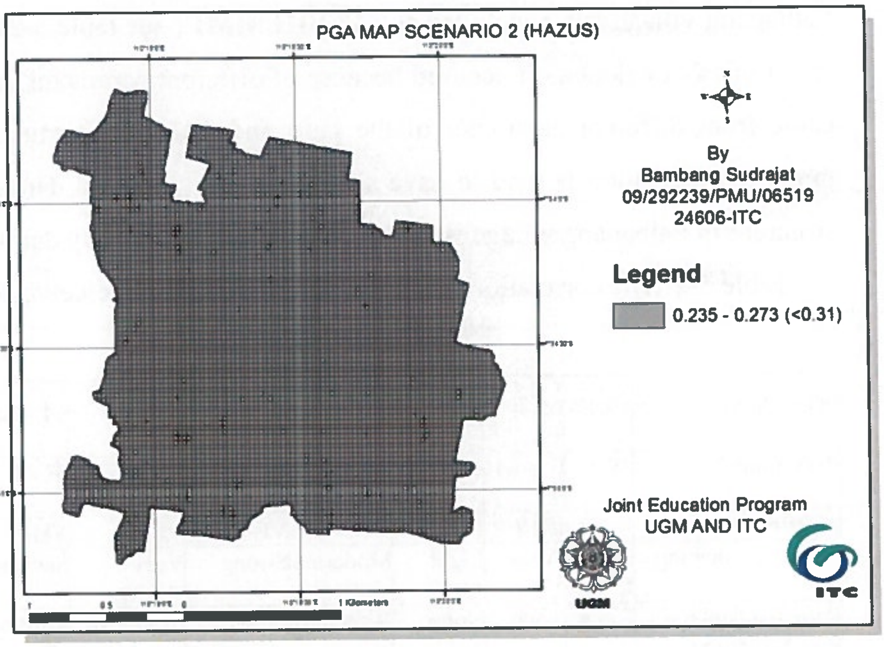


Figure 5-1: The hypothetical fault scenario in Yogyakarta earthquake 2006

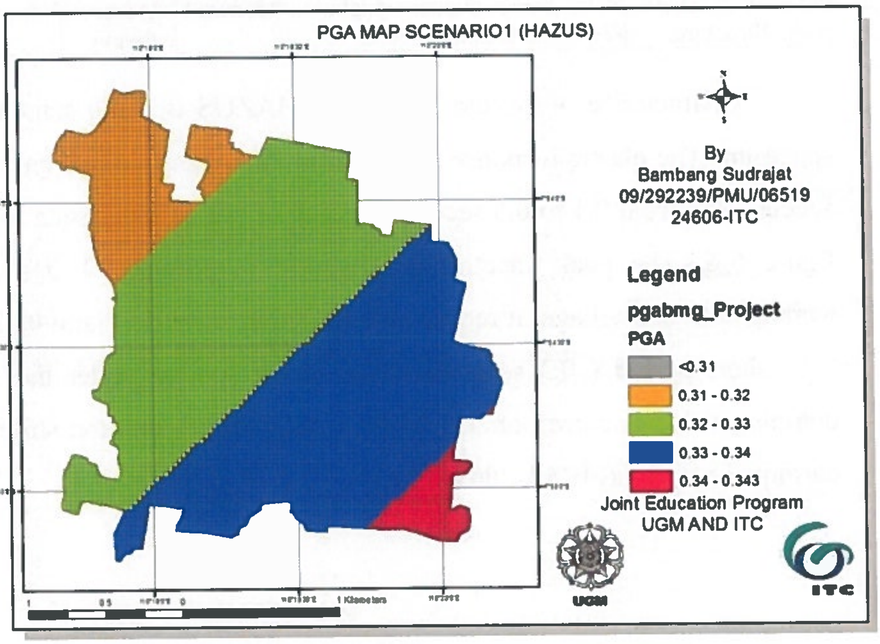
The result of PGA in HAZUS, is varied between 0.310 - 0.344 g. The result occurred because of 40 km long fault makes the ground acceleration near the fault line high. The result of this calculation is compared to (Haifani 2008) which has result 0.381 gal using Boore 1997 and Campbell 1997. It is also compared with (Pramumijoyo, Karnawati et al. 2008) with the result in BMG scenario at 0.20 – 0.30.g and (Elnashai, Kim et al. 2006) which has calculated the scenario of thrust fault in Bantul with determine PGA from Campbell 0.23 to 0.67 and from Ambraseys 0.25 to 0.37 in stiff soil.

The result of calculation on scenario 2 in HAZUS is varying between 0.23 – 0.27 gal. The result occurred because the distance of the fault is far about 20 km of the fault makes the ground acceleration not high. The result of this calculation is compared with (Haifani 2008) which has result 0.157 gal using Boore 1997 and

Campbell 1997. It also compared with (Pramumijoyo, Karnawati et al. 2008) that have scenario of USGS at 0.20 – 0.30.g and (Elnashai, Kim et al. 2006) which has calculated with the scenario of strike-slip fault in Bantul with determine PGA from Campbell 0.165 to 0.44 and from Ambraseys 0.20 to 0.29 in stiff soil.



a



b

Figure 5-2 :The PGA of Palbapang Village on scenario 1 and 2 using HAZUS Tools.

Murakami, Pramitasari et al.(2008) has calculated the intensity of earthquake in Peni Sub village, Palbapang Village. The result is 7.9 MSK which correlated to MMI as VII MMI. The correlation of Hazard Map in scenario 1 and scenario 2 with other researcher has similarity in intensity scales. The Intensity in Palbapang village has concluded at **VII-VIII MMI** (see table 5-2). The different result of PGA calculation occured because of different parameter is used. It might came from different parameter of the fault and different formula. However the range of calculation is tend to have similarity. The potential damage of building structure in Palbapang village is range from moderate to heavy damage.

Table 5-2: The correlation between PGA, PGV ,MMI perceive shaking and potential damage (USGS)

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
PGV (cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
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 Res. Structures	None	None	None	Very light	Light	Moderate	Moderat e/heavy	Heavy	Very heavy
Potential damage Vuln. Structures	None	None	None	Light	Moderate	Moderat e /heavy	Heavy	Very heavy	Very heavy

Characterize of ground shaking in HAZUS is using standardize response spectrum. The elastic response spectrum in Palbapang village has result of peak acceleration from 0.1 to 0.5 seconds in each of scenarios as seen in figure 5.5 and figure 5-6. The peak spectral acceleration in scenario 1 has high value in Karangasem sub village. it recorded at 0.67 g in scenario 1 and 0.52 g in scenario 2 In short period (0.3 seconds). The design spectra under the 5% of critical damping value is corresponding to the responses of common structure under the earthquake design(FEMA 2009).

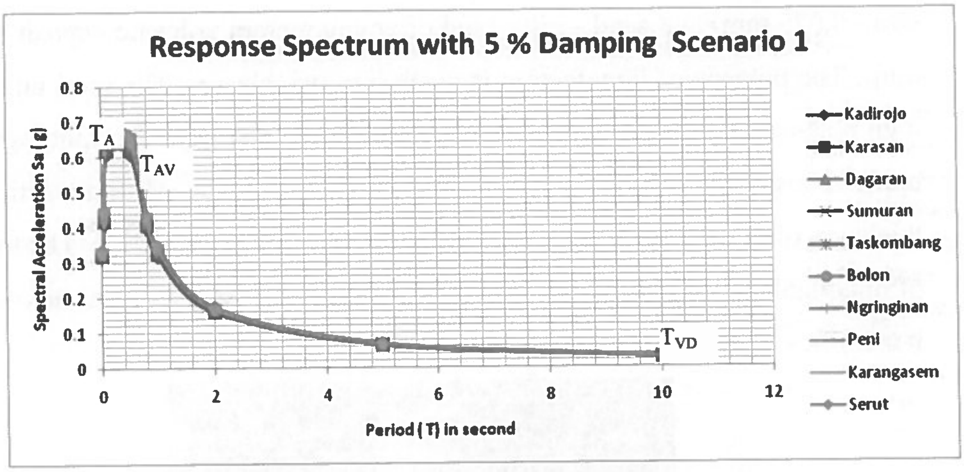


Figure 5-3: Elastic Response Spectrum of Scenario 1 in HAZUS.

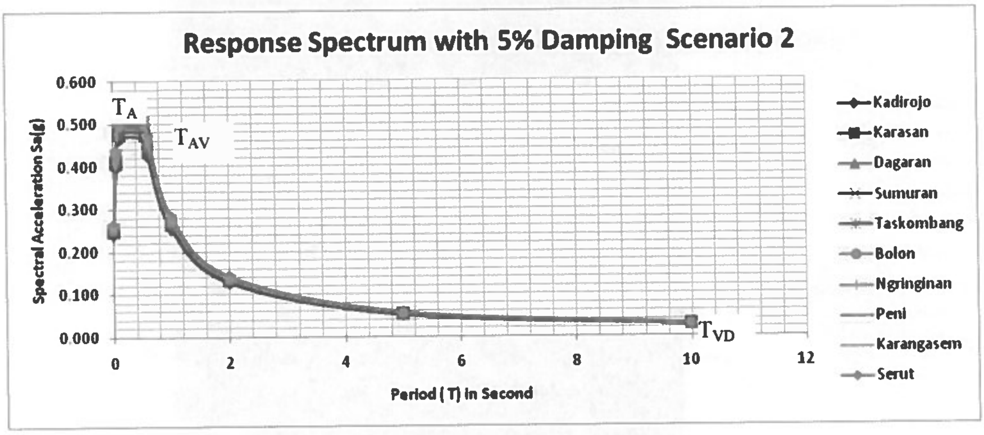


Figure 5-4: Elastic Response Spectrum of Scenario 2 in HAZUS.

5.1.2. Ground Failure Assessment

The sampling of water table measurement has been conducted from August to October (Figure 5-7). The purpose of the measurement is to collect ground water level data. The result of the sampling is correlated with the water table data to draw conclusion on the May scenario. May is used because 2006 earthquake occurred on May. This scenario is used for both scenarios in the Yogyakarta earthquake.

The susceptibility factor is based on Juang and Elton in (Piya 2004).The ground water level in Palbapang village level is varying from 0.59 to 1.18 m. It categorizes as very high potency of liquefaction (<1.5 m). The geology engineering of Palbapang village consists of silt of young volcanic deposit (grain size <0.075 mm) and sand – silty sand of young merapi volcanic deposit (0.075-1 mm). The potency of liquefaction is given into two classes. The sand unit is very high potency and the silt unit is categorized as low potency. The lithology age is upper Pleistocene which is categorized as low potency of liquefaction. The thickness of liquefiable layer is taken from borehole (Appendix 14). The thickness of liquefiable layer in sand unit is between 0.7-1 m and in silt unit is below 0.6 m. It classifies as medium and low potency.

Figure 5-5: The sampling of measuring water table in Karasan sub village.

The factor of ground water level, grain size, age of lithology and liquefiable layer is weighted to create liquefaction susceptibility based on the very important level (30%) and important level (20%). The sum of the liquefaction susceptibility of Palbapang village is ranging from 3 – 4. It classified as **medium to high susceptibility**. High susceptibility can be found in Kadirojo sub village, Dagaran sub village and Ngringinan sub village.

Sudjarwo(2006) also measured Liquefaction susceptibility from CPT. The high susceptibility is calculated in Gedangan(part of Dagaran sub village), Palbapang village.This result has similarity with the liquefaction susceptibility in Dagaran sub village that has **high susceptibility.**

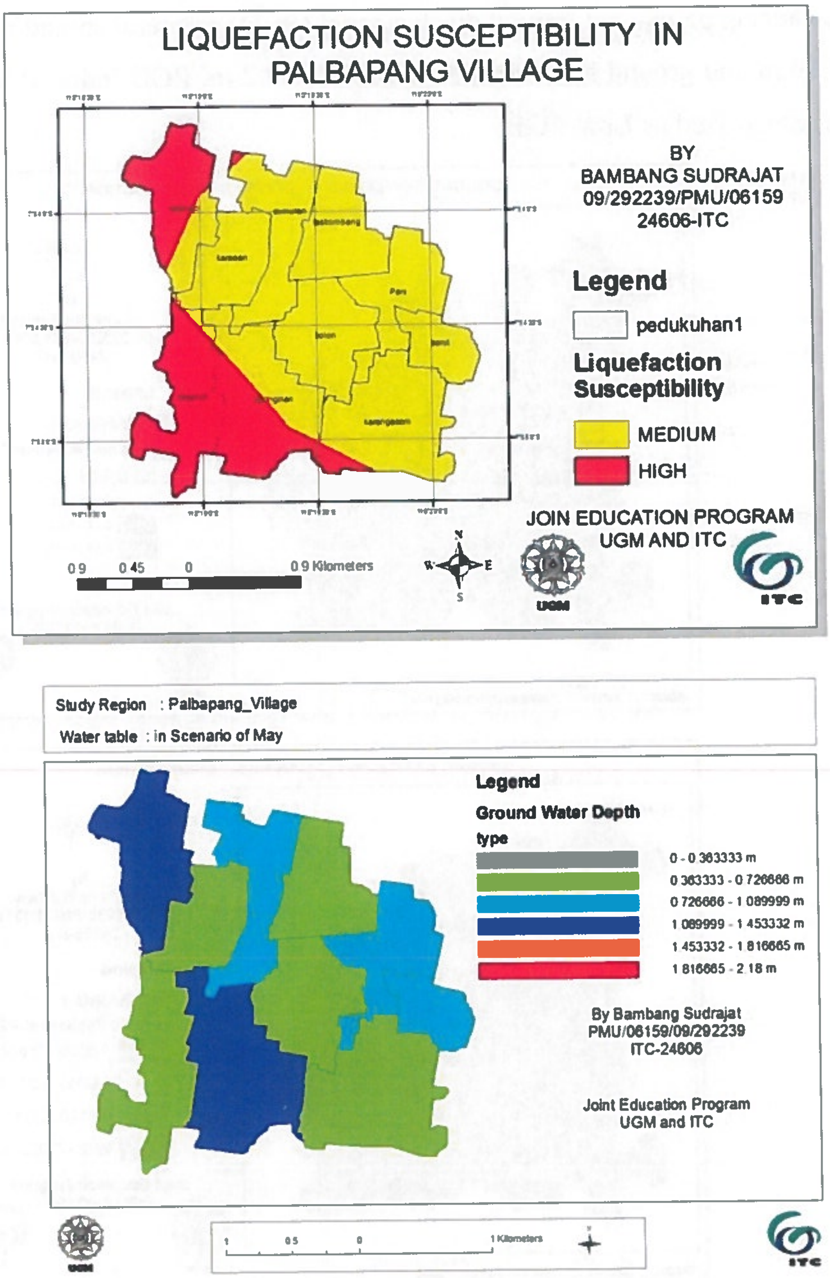
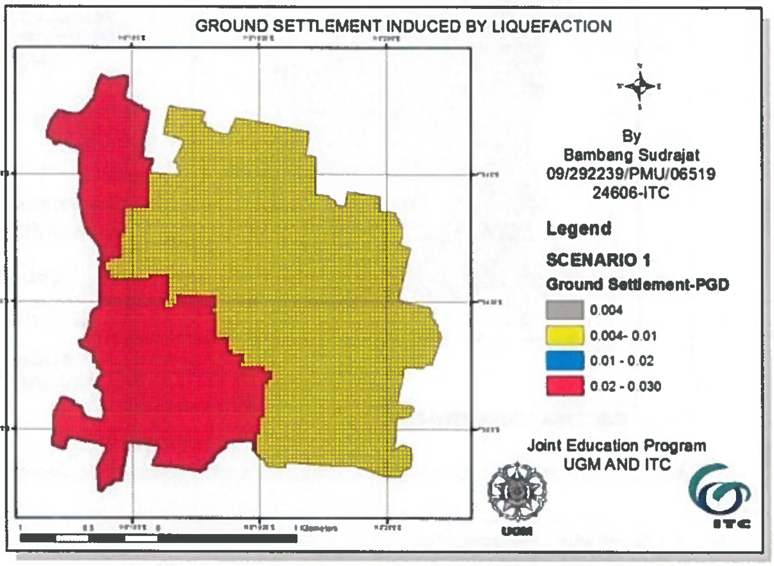


Figure 5-6: Water depth and liquefaction susceptibility of Palbapang village

The Probability of liquefaction is influenced by ground shaking (PGA), ground shake duration, and groundwater depth. The probability of liquefaction from HAZUS in Scenario 1 is varies from 0.1 to 0.2. This liquefaction is causing lateral displacement from 0.18 to 0.31 m and ground settlement from 0.00 to.0.03

m. The result of liquefaction probability in scenario 2 varies from 0.06 to 0.18. It is causing permanent ground displacement (PGD) at lateral spreading from 0.10 to 0.19 m and ground settlement from 0.00 to 0.02 m. PGD induced by liquefaction is categorized as **Low PGD.**



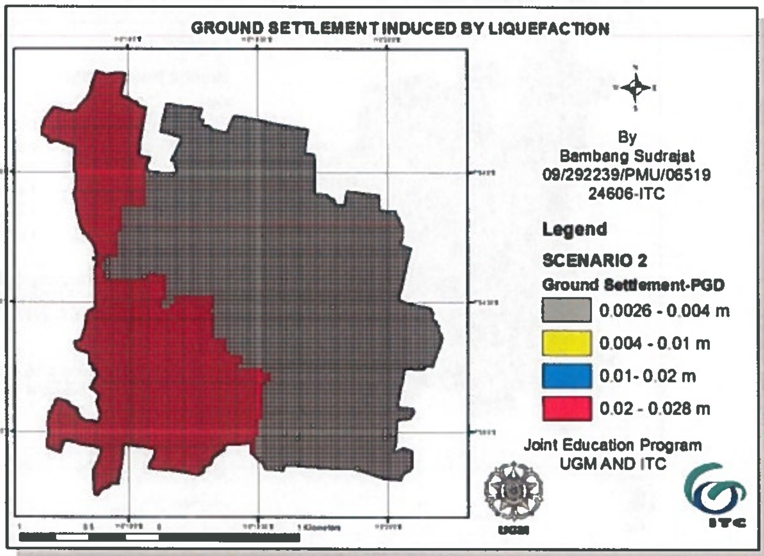


Figure 5-7: Ground settlement in Palbapang village By Scenario 1 and 2

The result of this calculation is compared with the liquefaction that happened in Bantul(Soebowo, Tohari et al. 2007). They have measured liquefaction from CPT and SPT quantitatively. The result is a lateral displacement between 0.5 to 5 m and the ground settlement induced by the liquefaction varies between 0.02 to 0.1 m in Bantul District. Soebowo, Tohari et.al (2007) has divide the PGD from Liquefaction in Bantul from low to very high. PGD categorizes as low if ground settlement below 0.04 m, Medium 0.04 – 0.07 cm, high 0.07-0.1 m and very high above 0.1 m. The high ground displacement is concentrated in Opak Fault area. It can be explained from the distance of epicenter and the soil along Opak Fault. The high PGD is located near to earthquake epicenter. The soil along Opak fault is resulted from young volcanic of Merapi and alluvial fan. The mixture of alluvial and young merapi deposit creates very high potency of liquefaction. The figure 5-9 shows the correlation of liquefaction from researcher and from Subowo which in part of Palbapang village has the result **low PGD**.

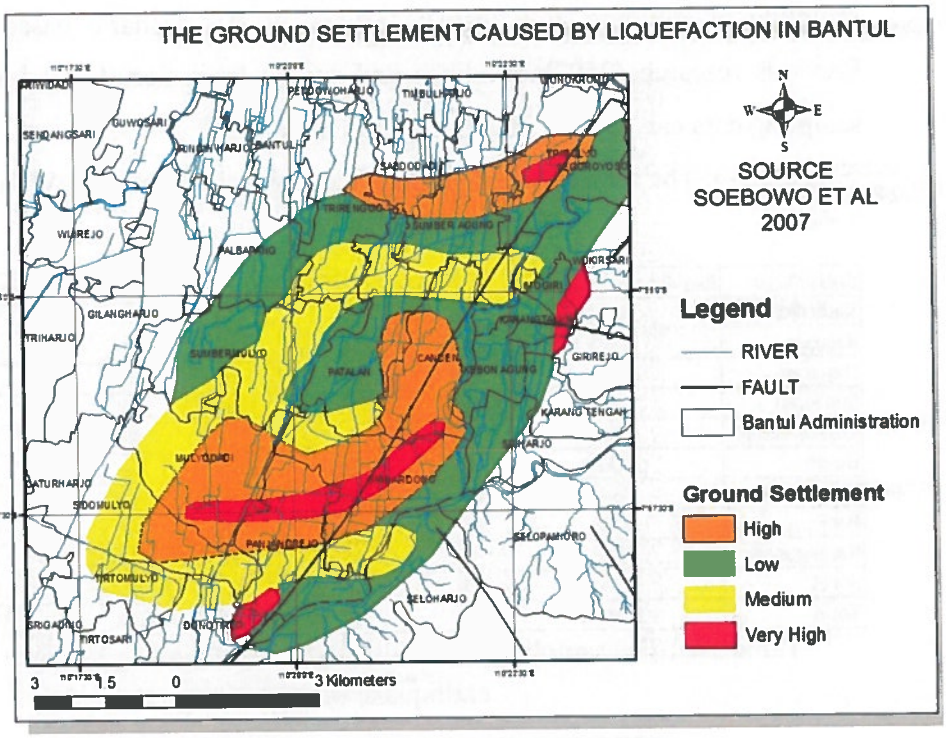


Figure 5-8: The Ground Settlement caused by Liquefaction in Patalan Region Bantul (Soebowo, Tohari et al. 2007)

5.2. Result and Discussion on Building Damage Asessment

5.2.1. Generating Building Stocks

5.2.1.1. Scenario Before Earthquake

The scenario of the building stocks before earthquake is assessed from rapid assessment by (Kerle and Widartono 2008). The building stocks then input in building footprint to calculate building area. The modification of the building is created because some vegetation is covering the building and the points of location are in the empty area. The information in Serut sub village is gathered from the HRC map, sub village chief and survey location. Most of building structures type were mud brick which were collapse or extensive damaged. The sampling of Building in Palbapang village in this scenario based on data by Previous research (2597) buildings and survey from Serut(117) buildings. The sampling data can be seen in table 5-3 and table 5-4.

Table 5-3: The sampling of Building Occupancy in Palbapang Village(before earthquake scenario)

Sub Village	Residential	Commercial	Industrial	Agriculture	Religion	Government	Educational	Total
Kadirojo	327	4	0	1	5	0	3	340
Karasan	218	20	1	0	2	4	1	246
Dagaran	281	2	0	0	6	1	2	292
Sumuran	313	27	0	9	5	8	3	365
Taskombang	252	2	0	2	8	1	1	266
Bolon	302	5	0	11	10	2	1	331
Ngringinan	384	7	2	4	9	1	1	408
Peni	133	0	1	0	1	0	2	137
Karangasem	191	0	0	10	7	0	0	208
Serut	114	0	0	0	8	0	2	124
Total	2515	67	4	37	61	17	16	2717

Table 5-4 : The sampling of Building type in Palbapang Village (before earthquake scenario)

Sub Village	W1	RM2L	URML	Total
Kadirojo	0	49	291	340
Karasan	0	69	177	246
Dagaran	0	7	285	292
Sumuran	16	28	320	365
Taskombang	2	3	261	266
Bolon	14	6	311	331
Ngringinan	3	9	396	408
Peni	0	5	132	137
Karangasem	9	3	196	208
Serut	0	5	119	124
Total	44	184	2488	2717

General occupancy class in Palbapang village is classified as agricultural, commercial, education, industry, religious, government and residence. The percentage of the residential building in Palbapang village is 93 % of total buildings. The building types were dominated by unreinforced masonry (based on brick, mud brick, and reinforced brick).It is 92 % of total buildings. (Figure 5-10). The height of building extend from1 storey to 2 stories.

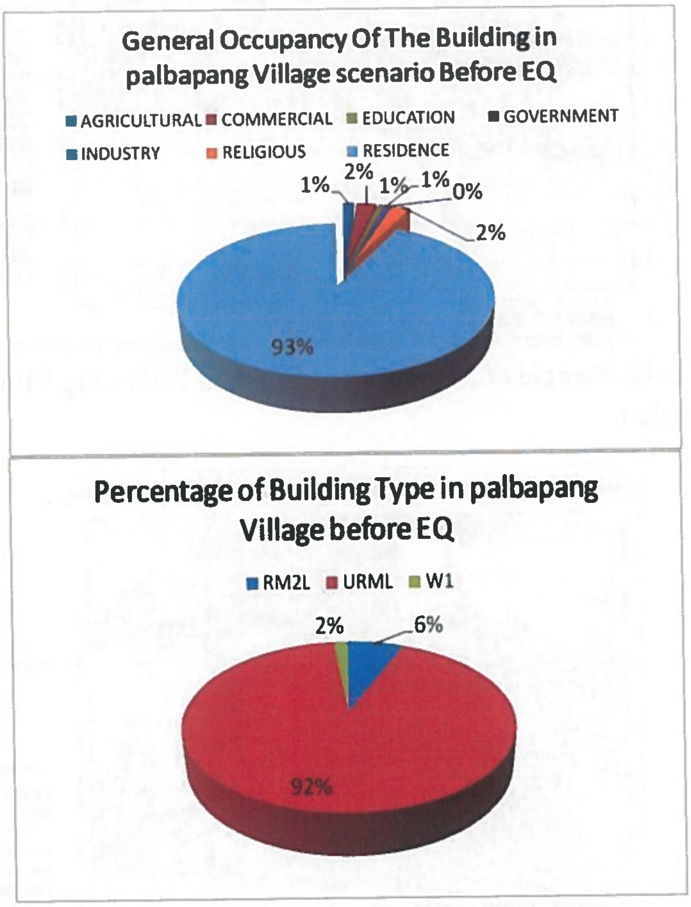


Figure 5-9:The percentage of Building Occupancy and Building structural type in Palbapang village before Earthquake.

The total building areas from sampling are 364.272 m^2. The building areas are generated based on merge of building footprint and the point of rapid survey as shows in figure 5.11 and figure 5-12. The percentage of residential building was 88 % of the total building area. The building types also dominated by unreinforced masonry. It has 90% of the total building area.

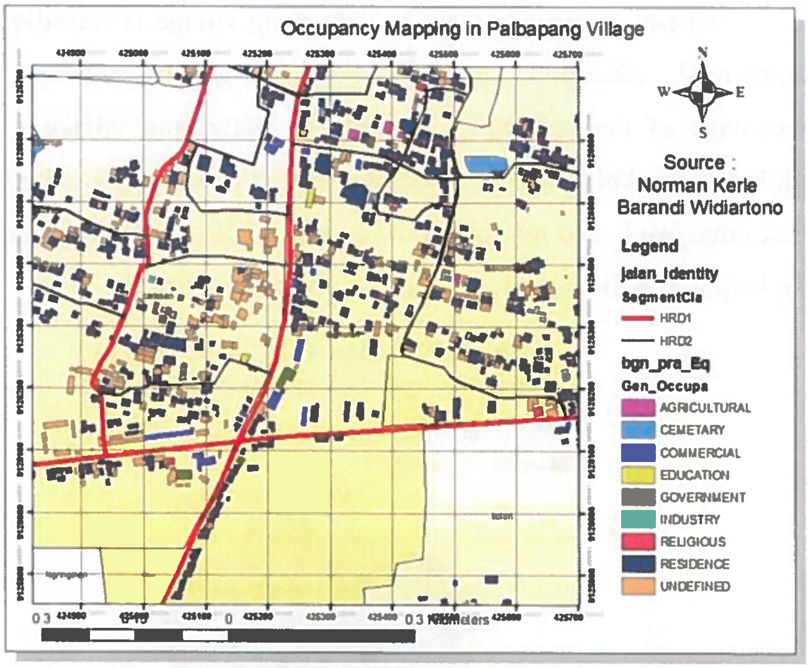


Figure 5-10: Sample of occupancy mapping in Palbapang Village (scenario Before Earthquake).

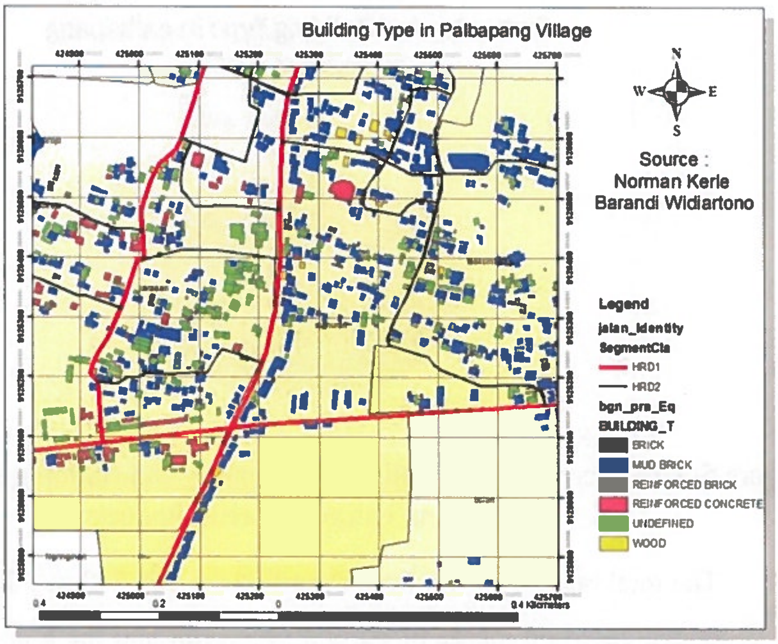


Figure 5-11:Sample of Building structural type in Palbapang Village (scenario Before Earthquake).

5.2.1.2. Scenario After Earthquake

The researcher gathered data of building with the sampling survey. The total of building calculated 499 building with the residential building 91 % of the total sampling (table 5-5) Reinforced Masonry is the dominant building type in Palbapang village. The percentage exceeds 93% of the total building area (table 5-6).

Table 5-5: sampling of Building Occupancy in Palbapang Village (After Earthquake Scenario)

Sub Village	Residential	Commercial	Industrial	Agriculture	Religion	Government	Educational	Total
Kadirojo	52	0	0	0	1	1	3	57
Karasan	45	9	0	1	1	8	0	64
Dagaran	59	0	0	1	1	1	0	62
Sumuran	56	1	0	0	1	4	3	65
Taskombang	35	0	0	0	1	0	1	37
Bolon	39	0	0	0	1	0	0	40
Ngringinan	64	0	0	0	0	0	0	64
Peni	38	0	0	0	0	0	2	40
Karangasem	30	2	0	0	0	0	0	32
Serut	35	1	1	0	0	0	1	38
Total	453	13	1	2	6	14	10	499
Percentage	91%	3%	0%	0%	1%	3%	2%	100%

Table 5-6: The sampling of Structural Building type in Palbapang Village (After Earthquake Scenario)

Sub Village	W1	W2	S3	C1L	RM2L	URML	Total
Kadirojo	1	1	0	0	54	0	57
Karasan	1	1	1	3	57	1	64
Dagaran	1	0	0	1	58	2	62
Sumuran	3	2	0	3	54	3	65
Taskombang	0	0	0	0	37	0	37
Bolon	0	0	0	0	40	0	40
Ngringinan	1	0	0	0	61	1	64
Peni	1	0	0	0	39	0	40
Karangasem	1	1	0	0	30	0	32
Serut	1	1	0	0	36	0	38
Total	10	6	1	7	466	7	499
Percentage	2%	1%	0%	1%	93%	1%	100%

466 buildings were reconstructed in the year 2006 until now, 9 buildings from 2002 – 2006 and 24 buildings were built before 2002. The Height of the building is ranging from 1 to 3 stories. The vertical irregularity and plan irregularities structural building is counted to be 13 and 37 buildings. The fund to reconstruct building is dominated from JRF and POKMAS as seen in the figure 5-13.

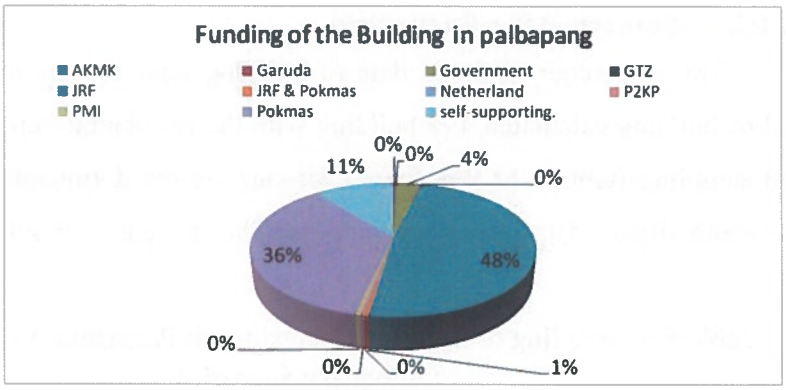
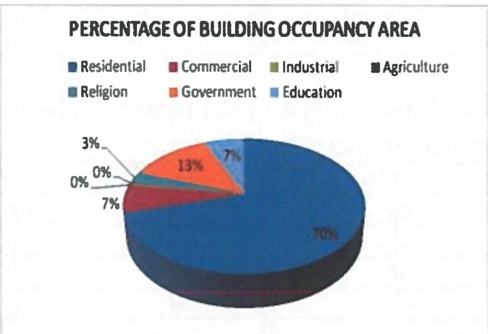


Figure 5-12: Percentage of the funding of building in Palbapang village.

The building areas from sampling are 28.522 m^2 building. The percentage of residential building is 70 % of the total building area. The building structural types are dominated by reinforced masonry. The total area of reinforced masonry is 86% of the total building area. The percentage of building area in general occupancy and building type can be seen in the figure 5-15.



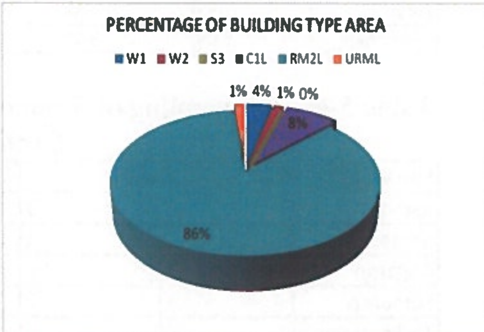


Figure 5-13: Percentage of Building Occupancy area and Building Type area in Palbapang village (scenario after earthquake)

5.2.1.3. Building type in Palbapang Village

The Building structure type in Palbapang village can be categorized as:

1. Masonry Building.

   This typical building structure was divided as Reinforced Masonry and Unreinforced Masonry.

   a. **The Reinforced Masonry (RM2)or Confined Masonry (CM)**

      This typical building before earthquake only distributed in 6% of the total building. People rebuilt the house from URM to RM after 2006 earthquake in Bantul. RM building is dominant in Palbapang village after reconstruction. The distribution has reach 86 % of the total building area. These structural building types were built by the fund of GTZ, JRF and PKPI, POKMAS and self supporting. The typical structural building by GTZ and JRF /PKPI has good quality of material and the technique of the building because the consultants were participated in supervising the construction of building. In the other hand, building construction from POKMAS has moderate quality. The government only gives design criteria of earthquake resistant buildings but the construction is based on the wealthy of the people there. The wealthy people were reconstruct/built their houses with good materials, but the common people were built their houses with lack of good materials.

The construction of the building vary from 1980 – 2009 which 442 buildings from the survey were constructed/ total rehabilitation after 2006, 8 building from 2002-2006 and only 16 building were constructed before 2002. The design code of the building is based on building age, quality of the construction, plan irregularity and vertical irregularity. The height of the building varies from 1- 3 stories but dominant in 1 storey.

a. Built by POKMAS b. Built By JRF

c. Self Supporting Building

Figure 5-14: Sample of Reinforced Masonry Building structure in Palbapang Village

b. **The Unreinforced Masonry (URM) or Unreinforced Clay Brick(URCB)**

These typical building were dominant before earthquake. They distributed 92% of the total sampling building. After earthquake, URM buildings is decreasing until 1 % of the total building area. These typical structures were generated from the survival building and from the community that rebuilt again with the same structure type. The design codes of this typical structure are generated based on Pre-Code or Low Code base building. They consist of one storey building.

Figure 5-15: Sample of Unreinforced Masonry building in Palbapang village

2. **Wood House**

This typical of building is generated based on Wood 1(W1) and Wood 2(W2), the wood 1 has light material and used for the house building, the frames of this typical building were closed only about 2 meter – 2-5 meter. This typical building is built from bamboo and timber. The funding to build the house are generate from Garuda, POKMAS, PMI, Government and self supporting. W2 also has light material but used for Industry and commercial building. Bamboo is the dominant of structure. The distance within frame of these structures were more than 3 meter. Wood house were distributed only 4 % of the survey in Palbapang village. The design code of this structural type is "Low Code"

Figure 5-16: the typical of Wood Building in Palbapang Village

3. **Steel Building (S3)**

   This typical of building is based on light steel building. In Bantul, only few buildings are built for residential used. This typical building has good quality of construction. Based on the design code in Bantul, it has correlate to Medium Code.

Figure 5-17: The light steel frame building In Karasan Sub village

4. **Concrete Building (C1)**

   This typical of building is based on concrete frame building. It is used as government, hospital/clinics, bank and some in barnyard. The distribution of this building in Palbapang village is 2 % which is concentrated in Karasan, Sumuran and Dagaran sub village. The height of this building varies from 2 to 3 stories which is dominated in 2 stories.

Figure 5-18: the Concrete frame building In Sumuran Sub village

5.2.2. Fragility Curves and Damage Matrix of Building

5.2.2.1. Scenario Before Earthquake

HAZUS calculated the building damage based on the probability of damage in term of particular model of building types. The damage matrix was estimated based on ground motion or ground failure parameter in event of seismic that happened in the area.

In HAZUS, every typical building has different damping. URM as the sample has 10% of damping. To calculate the damage matrix, ground motion has to change from elastic response to inelastic response. The modification of spectral response is represented by reduction factor. The reduction ratio is given by the formula:

$$R_A = \frac{2.12}{3.21 - 0.68.\ln(B_{eff})}$$

$$R_F = \frac{1.65}{2.31 - 0.41.\ln(B_{eff})}$$

B_{eff} is the effective damping. The value comes from the sum of elastic damping and hysteretic damping. Hysteretic damping obtained from the degradation factor which is correlating to magnitude. In HAZUS, degradation factor in hysteretic damping is kappa (κ). The inelastic of ground motion in Palbapang village from HAZUS with the scenario 1 has resulted in figure 5-21 and 5-22.

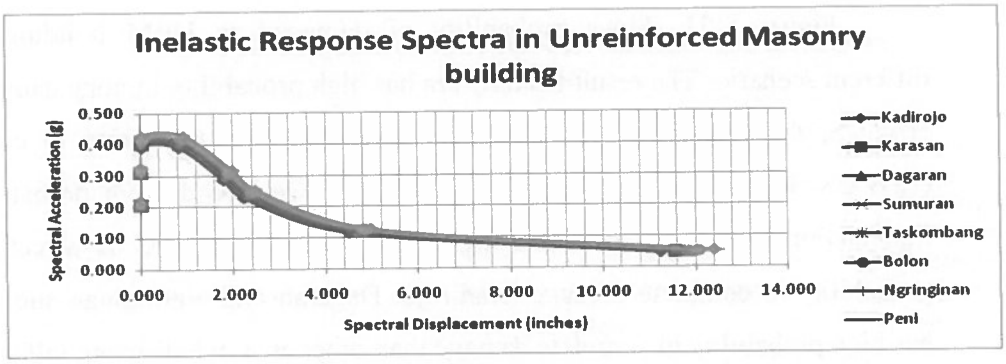


Figure 5-19: Inelastic response spectra for Unreinforced Masonry building

In Philippine, Miura,Midorikawa et.al (2008) created damage matrix based on Judgments expert. The researcher correlates the building from CHB and C1L in Miura to URML and RM2L in HAZUS. (Method of calculation can be seen in the appendix 11).

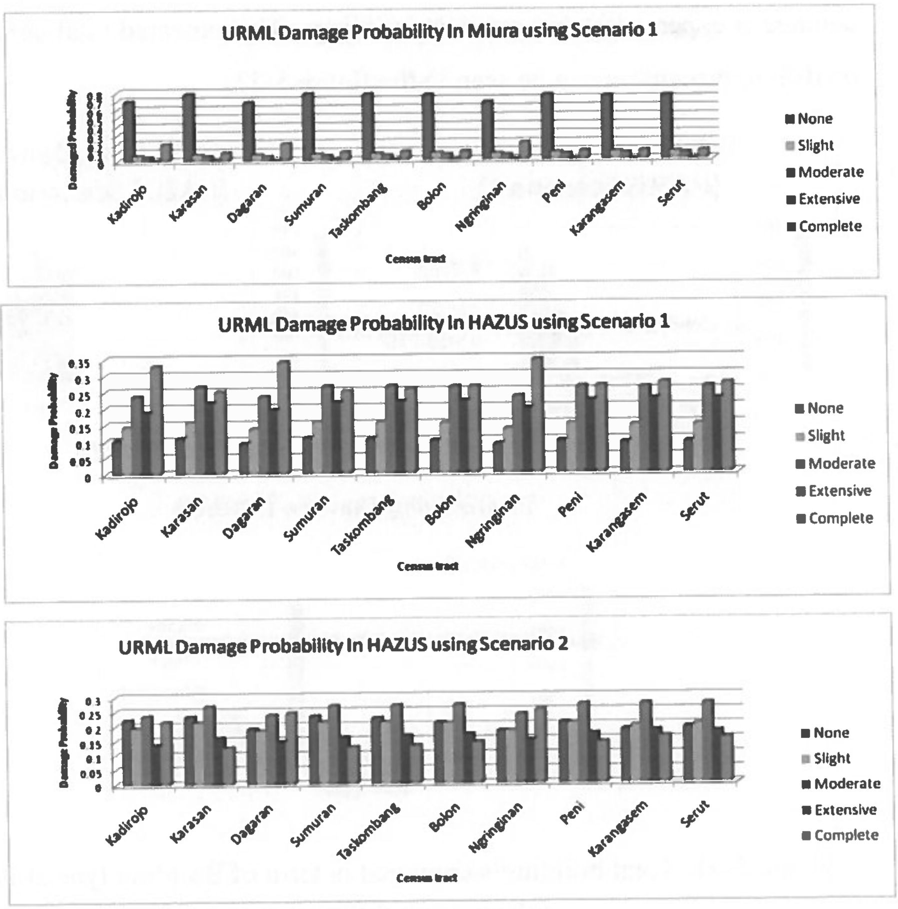


Figure 5-20: Probability of damage in URM building from Miura in scenario 1 and from HAZUS in Scenario 1 and 2.

Figure 5-21 shows probability of damaged in URM buildings from different scenario. The result from Miura has high probability in none damage. In HAZUS, the probability of damage is extending from moderate to complete (HAZUS Scenario 2 and 1). This result is correlated with high probability of liquefaction in this village. The high liquefaction probability is affecting the probability in complete damage. Kadirojo, Dagaran and Ngringinan sub village has high probability in complete damage than other area in Palbapang village.

The calculation in RM and wood building has high probability of damage in none damage. The URM building extend to be the most vulnerable building's structure but wood structure can be categorized as the strongest building in Palbapang village. The expected damage from HAZUS Scenario 1 is at least 744 buildings will have complete damage. In HAZUS scenario 2 and Miura, complete damage is expected in 455 and 374 buildings. The expected total damage building by different scenario can be seen in the figure 5-22.

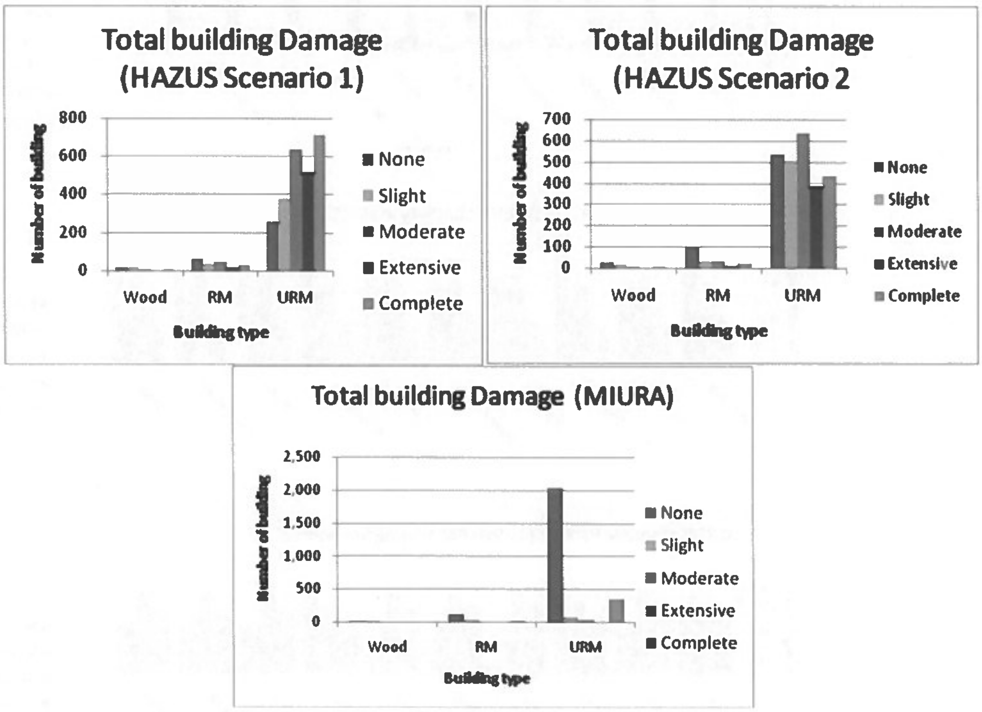


Figure 5-21: Total building's damaged in term of Building type at Palbapang village from different scenario

The high damage probability in Palbapang village is in residential building the residential building is predominant in Palbapang village which has 93% of total building. 704 residential buildings are completely destroyed from the estimation of HAZUS Scenario 1. In Scenario 2, 455 buildings are completely destroyed. The agriculture and commercial building tend to be the strongest building in Palbapang village which has high probability in none damage. Figure 5-23 provide the total building damage in term of occupancy class from different scenario.

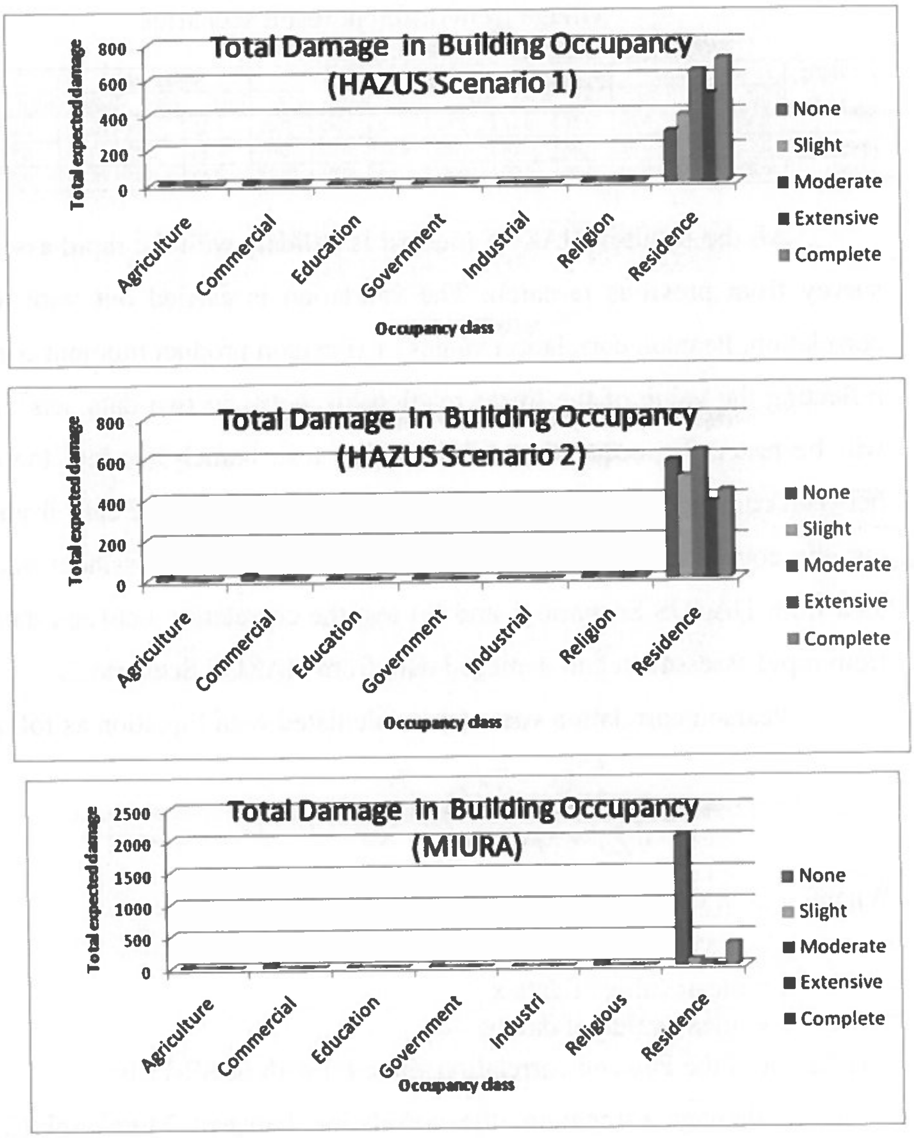


Figure 5-22: Total buildings' damage in term of Building occupancy in Palbapang Village from different scenario.

The Risk of damage building is divided by High damage, medium damage and Low damage. The High damage is added from extensive and complete damaged. Medium is from slight and moderate damaged and light damage is taken from none damage. This result is compared with rapid assessment in Palbapang villages. Kerle and Widiartono(2006) and Murakami, Pramitasari. et.al(2008)have estimated the building's damage in Palbapang village. The correlation of different building structure can be seen in the table below.

Table 5-7: Correlation of expected building damage probability in Palbapang village from different result scenarios.

Building Type	MURAKAMI			KERLE			MIURA			HAZUS Scen.1			HAZUS Scen.2		
	High	Med	Low	High	Med	Low	High	Med	Low	High	Med	Low	High	Med	Low
W	0.38	0.38	0.24	0.31	0.12	0.58	0.12	0.47	0.41	0.12	0.47	0.41	0.08	0.37	0.55
RM	0.73	0.25	0.02	0.07	0.10	0.82	0.13	0.22	0.65	0.23	0.42	0.34	0.14	0.33	0.52
URML	0.83	0.17	0.00	0.79	0.09	0.12	0.14	0.05	0.81	0.49	0.41	0.10	0.33	0.46	0.21

All the result in HAZUS method is validate with the rapid assessment and survey from previous research. The validation is carried out with the pearson correlation. Pearson correlation values / r (Pearson product moment correlation) is reflecting the value of the linear relationship between two data sets. In this case will be tested 3 pieces Pearson correlation test, namely (a) test the correlation between damaged data from rapid assessment and damaged data from Miura (b) test the correlation between damaged data from rapid assessment and damaged data from HAZUS Scenario 1 and (c) test the correlation between damaged data from rapid assessment and damaged data from HAZUS Scenario 2.

Pearson correlation value (r) is calculated with Equation as follows:

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

Where $x_i =$ x value number i

$y_i =$ y value number i

$\bar{x} =$ mean value of data x

$\bar{y} =$ mean value of data y

The Result of the Pearson correlation value (r) with SPSS-17 is:

a) In damage estimation, the correlation between Murakami (2008) with Miura in URM, RM and Wood has strong negative relationship with correlation value (r) = -0.57, -0,83 and -0.35.The standard error is more than 10%. The correlation between Kerle (2006) and Miura has strong positive relationship in RM building (0.993) but negative in other building type. In occupancy class, the commercial building and industry building has strong relationship in damage estimates. The correlation value (r) = 0.99 and 0.80. Other buildings have weak correlation in between.

b) Estimation on building assessment by Murakami and HAZUS Scenario 1 has strong positive relationship in URM building (0.80). However the RM and wood type has negative relationship (-0.74 and -0.35). The correlation between Kerle (2006) and HAZUS Scenario 1 also same in URM building that has strong relationship (0.64) but weak in RM (0.15)and Wood (-0.05). Estimation in occupancy class has conclude that almost all of the building has negative relationship, only religious and residential building have weak to strong positive relationship.

c) Estimation on building assessment by Murakami and HAZUS Scenario 2 in URM, RM and Wood has correlation value (r) = 0.16,-0.98 and -0.79. It means, there is a weak relationship between damage estimates on URM, and negative relationships in RM and wood building. The correlation between Kerle (2006) and HAZUS Scenario 2 in URM, RM and Wood has value (r)= -0.07, 0.88 and 0.48. It means, RM building has strong positive values but weak relationship in Wood and negative relationship in URM building type. Estimation in Occupancy class is concluded that all of the building has negative relationship.

5.2.2.2. Scenario After Earthquake.

The researcher calculate the damage of building base on HAZUS scenario 1, because building's damaged in Scenario 1 has created damage in worst scenario than Scenario 2. The capacity curves and fragility curves are taken from HAZUS. HAZUS scenario 1 has exceeded the strong relationship in URM with previous research. The capacity curve is based on design code from sample scoring.

HAZUS estimates 239 buildings will be at least moderately damaged. This is almost 48.00 % of the total number of buildings sample in the region. There are an estimated 59 buildings that will be completely damaged. Table 5.19 Shows RM building has high probability in none damage. In term of calculating risk the damage matrix is modified into light, moderate and extensive damage. This result tends to have moderate damage except of URM building which tends to have extensive damage.

Table 5-8 :Expected building damage (HAZUS Scenario 1)by building type

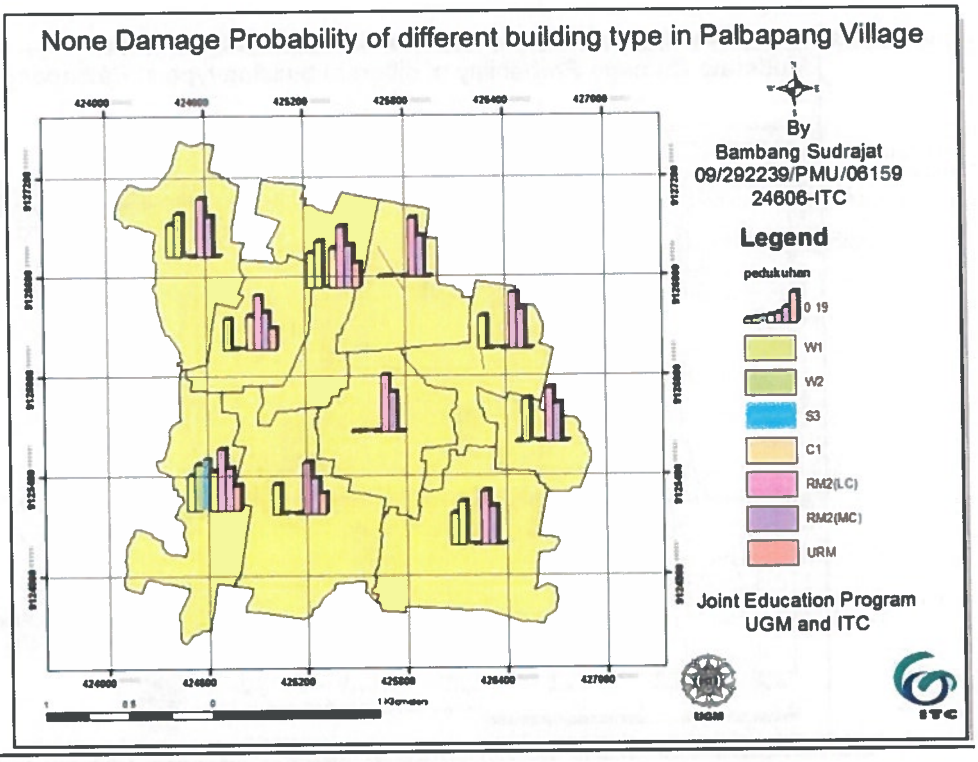
Building Type	None	%	Slight	%	Moderate	%	Extensive	%	Complete	%	Total
Wood	5	32%	6	33%	4	22%	1	3%	2	11%	17
Steel	0	22%	0	20%	0	31%	0	15%	0	12%	1
Concrete	2	27%	1	19%	2	32%	1	10%	1	12%	7
RM	160	34%	94	20%	114	24%	44	10%	54	12%	467
URM	1	14%	1	20%	2	29%	1	18%	1	20%	7
Total	168		102		123		47		59		499

HAZUS estimates building damages in term of occupancy class. Residential building tends to have damage probability in moderate damaged which is almost 33% of the total building in occupancy class. This result occurred because religious building has built before earthquake which stand when it face to the earthquake. Table 5-10 provides the total expected building damage in Palbapang village.

Table 5-9: Expected building damage by building occupancy

Occupancy Class	None	%	Slight	%	Moderate	%	Extensive	%	Complete	%	Total
Agriculture	0	24%	0	24%	1	29%	0	7%	0	15%	2
Commercial	4	33%	3	21%	3	27%	1	10%	1	9%	13
Education	4	36%	2	23%	2	23%	1	7%	1	11%	10
Government	5	33%	3	23%	3	25%	1	9%	1	10%	14
Industrial	0	24%	0	34%	0	29%	0	4%	0	9%	1
Religion	2	36%	1	21%	1	24%	0	8%	1	11%	6
Residential	153	34%	92	20%	111	25%	43	10%	54	12%	453
Total	168		102		123		47		59		499

The map in figure 5-24 and 5-25 shows the probability of damage in Palbapang village.



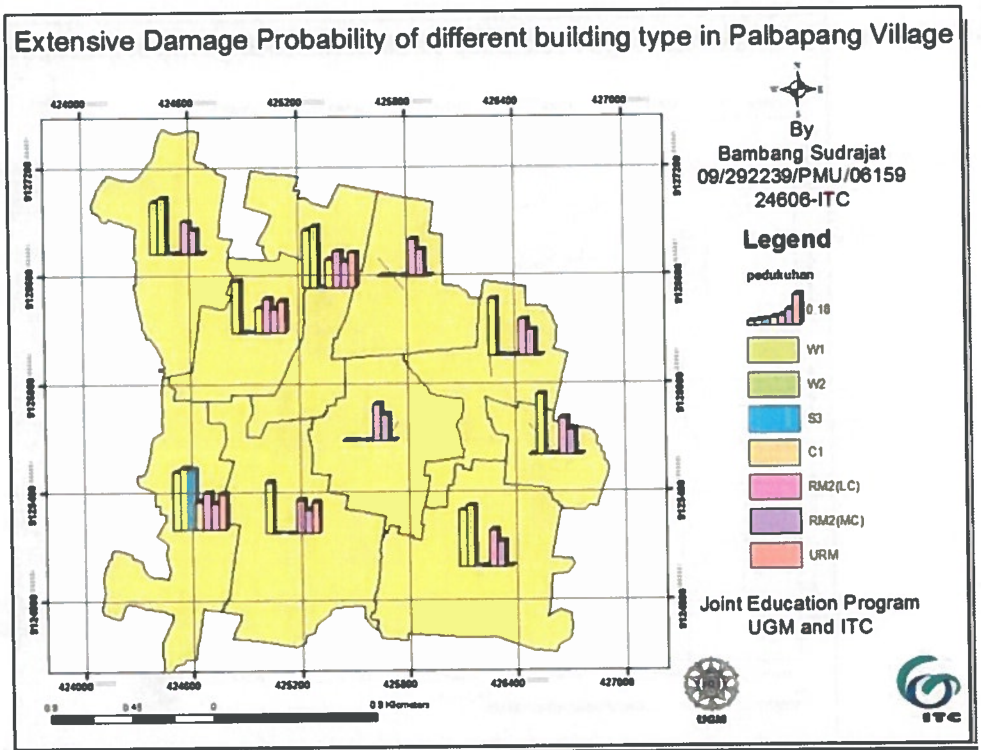
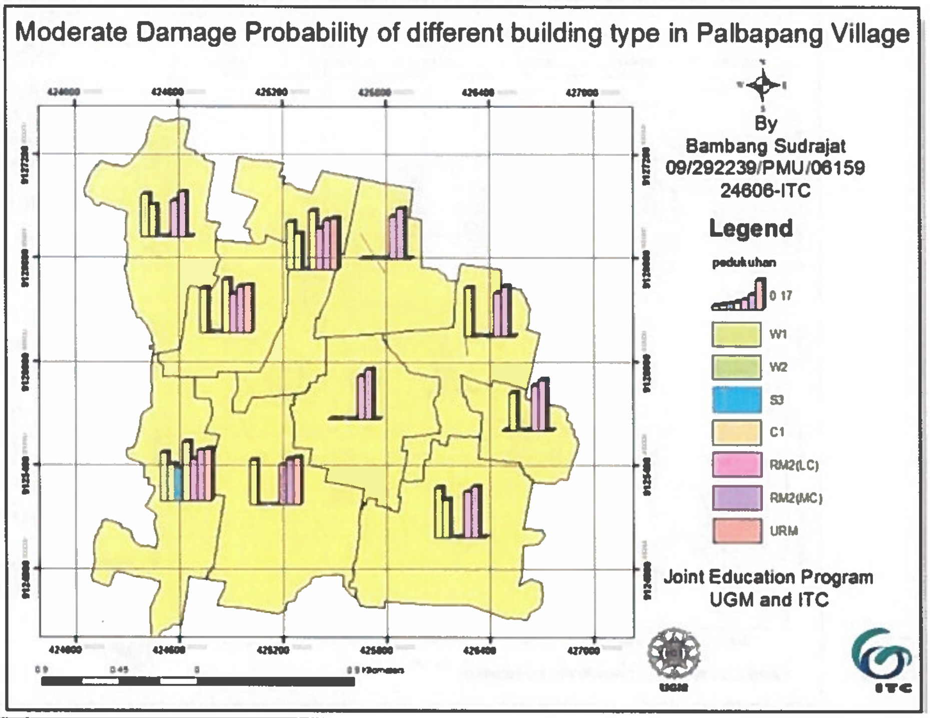


Figure 5-23: The distribution of Probability of none and slight damage in Palbapang village.



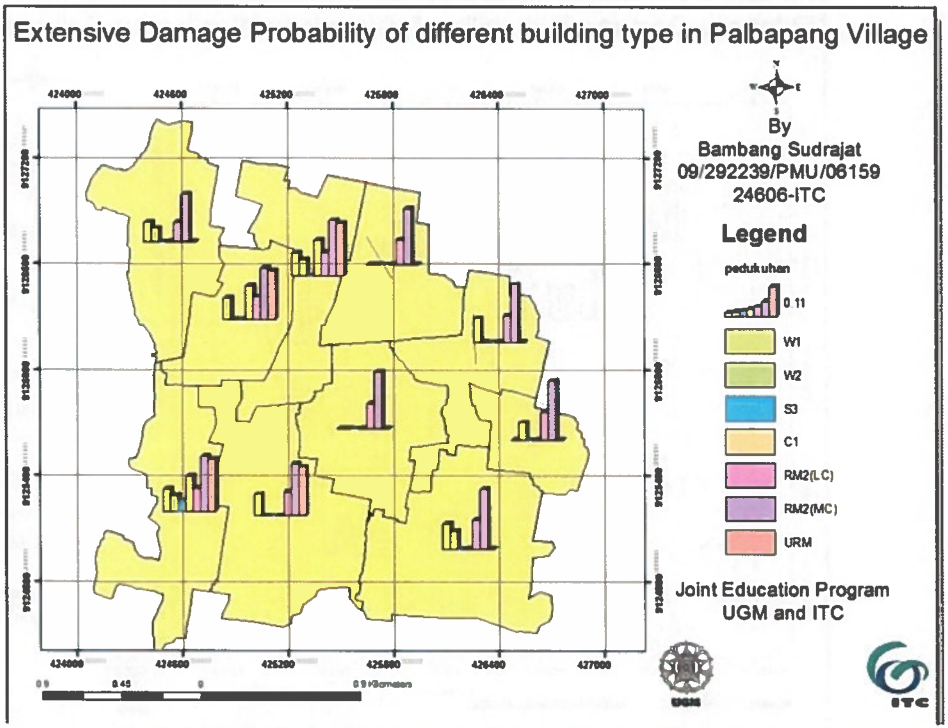


Figure 5-24: The distribution of Probability of moderate and extensive damage in Palbapang village

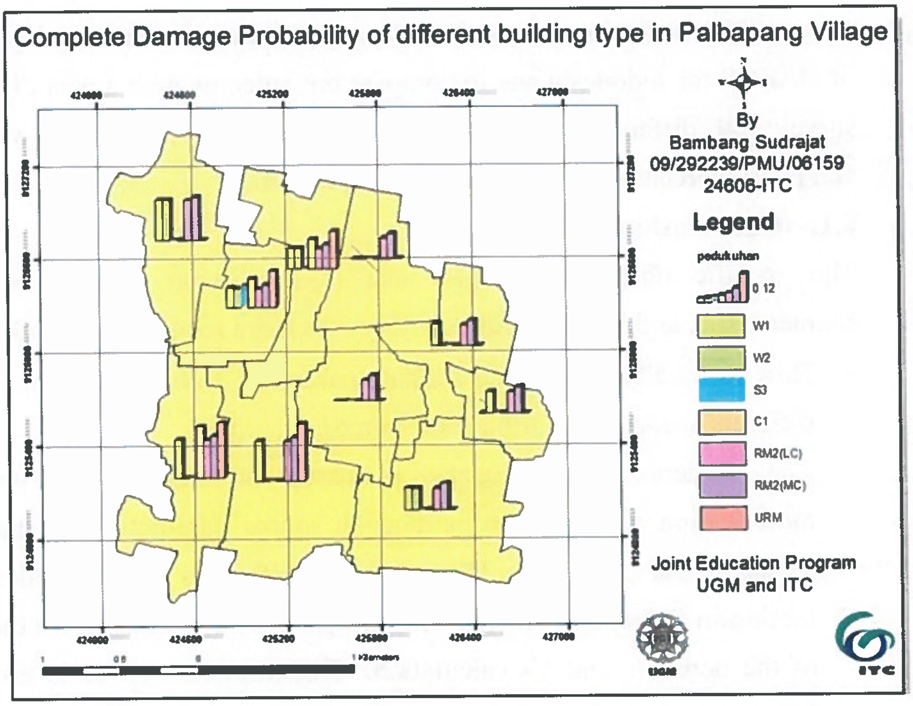


Figure 5-259: The distribution of Probability of complete damage in Palbapang village

6. CONCLUSION AND RECOMMENDATION

The conclusion is based on the objective about adapting input parameters of HAZUS for Indonesia and to compare the outcome with a post disaster damage survey with different scenario of hazard. The specific objectives will be review and the researcher will try to answer the question.

6.1. Conclusion

The specific objectives in part one is identifying parameters for Hazard characteristic, and building vulnerability which are required in HAZUS method

- How to modify the ground shaking parameter to be applied in HAZUS with different scenario of earthquake source?

  The scenario of earthquake is based on deterministic method. The modification is created in earthquake source parameter, soil parameter and ground water parameter. The hypothetical fault is made to calculate ground motion in Palbapang village. The soil parameter is taken from the correlation of the borehole and Vs calculation. Determination of Vs is taken from the lithology, slope inclination and the distance from base rock. The result correlates to soil classification based on HAZUS.

  Liquefaction calculation is based on qualitative calculation which is weighted of scoring on ground water table, deposit type, deposit age, and the thickness of deposit based on important level.. Ground water from the survey correlated to May scenario which base of what month earthquake happened in study area. In applying HAZUS, the ground motion parameter and ground failure parameter is input in Hazard base map. The input parameter consists of soil site, ground water and liquefaction susceptibility. The input of soil site has been correlated to the site class in HAZUS. The liquefaction susceptibility is divided by the high susceptibility and medium susceptibility.

- How to fit the building inventory data of Bantul sub district to be applied in HAZUS?

  Building inventory in HAZUS is classified into building occupancy and building structure type. The occupancy class is information about occupancy in study area such as residential, government, educational, religion, agricultural and industry.

Building structural type in Palbapang village were generated in five model structure i.e. RM, steel, concrete, URM and wood. The building type is correlated from the building in Palbapang to the HAZUS building structure. The predominant buildings in Palbapang village consist of RM and URM. The type of confined masonry which has concrete framing in structural element is correlated to RM building.URM building is correlating to unreinforced brick, or mud brick. Wood building consists of Bamboo and Timber frame. The building codes is adapted from universal building codes to Indonesian condition. The structural of design building is based on the rules of Indonesian building codes (SNI 1726-2002) and hazard zonation map in 2002 and 2010. The building height in study area can be categorized as low buildings which are 1 – 3 stories.

The specific objective in part two is estimating ground motion and ground failure using HAZUS and validates the result with previous research

- How high the correlation between the Hazard Map resulted from HAZUS application with the hazard map resulted from previous research?

  The pga in Palbapang village from different scenario is ranging from 0.17-0.34g. which is correlated to previous research in Bantul district. The heavy damage building in area occurred because lots of building has vulnerable structure in Palbapang village. The difference result from the computation occurs because of different attenuation relationship and different parameter of earthquake source in computing hazard. Even so the ground acceleration is almost similar in range of earthquake intensity. Liquefaction susceptibility can be categorized as High susceptibility. The estimation of HAZUS in ground failure is categorizing permanent ground displacement (PGD) in Low level. This result is compare to other research which has calculated from quantitative approach in part of Palbapang as high susceptibility of liquefaction and the ground settlement causing by liquefaction as Low PGD. The distance of epicenter and type of lithology is affecting probability of liquefaction. This result gives the conclusion about high correlation of ground motion and ground failure in study area based on HAZUS calculation with previous research.

The specific objective in part three is estimating damage building in HAZUS for Palbapang village and validates the output of damage building of HAZUS with damage database on Palbapang village.

- How high the correlation of damage Building estimation from HAZUS application with the building damaged resulted from previous research?
  The correlation in building type has varied from negative relationship to positive relationship. The very strong correlation occurred in URM building based of HAZUS Scenario 1 with previous research. The result of Miura has identified that the building vulnerability is more resistance to earthquake than HAZUS. HAZUS scenario 2 has more distance to epicenter than HAZUS Scenario 1. It generates damage in moderate. Intensity in VII MMI tends to have moderate damage in resistant building and moderate to heavy damage in vulnerable building. The URM building is the weakest structure building in Palbapang village. It has high probability in extensive damage than others. The correlation of building damage has not significant value with standard error more than 10 %, because of the categorize used to create the correlation.
- What is the difference of building damage before and after the earthquake in Jogjakarta with diverse scenario?
  HAZUS scenario 1 is used in hazard assessment for each type of building, the difference from the result after earthquake and before earthquake is declined of extensive/heavy damage. In scenario before earthquake the percentage of URM building was about 92 % in study area and changed into RM building with 93% of study area. the damage probability almost similar from scenario before earthquake and after earthquake even the design level has change from Pre-code/low code to Low code and moderate code in study area. This result occurs because of little sample that researcher took in every sub village which is different than previous research. The probability of liquefaction is also contributed in damage probability.
- How best can HAZUS building base method to use in Indonesia region?
  The use of HAZUS base building in generally can be used in Indonesia region but it had to modify in term of capacity and fragility curves. The standard of building type has similar basis. SNI 2002 as the standard of building in Indonesia is taken from UBC 1997 which also been used by HAZUS.

However the correlation of traditional building which based on wood and bamboo is difficult to create comparison in HAZUS. The typical and quality of material is also different between Indonesia and US. The typical of confined masonry is none in US. The comparison from RM building which is precast intra masonry is different than confined masonry in Indonesia. The unreinforced masonry in US typical is rather strong than Indonesian buildings. This results estimation indicates the vulnerability has different values.

The specific objective in the last part is analyzing the applicability of HAZUS in Palbapang village.

- What is the limitation of HAZUS application in Bantul?

  The HAZUS method requires engineering analysis of potential ground motion and ground failure in structural components. This method had to perform by expert in different field. HAZUS tends to simplify building in census track. The estimation in the field sometimes is different when it correlates to the building owner. It is hard to identify the building's damaged in individual building when the building structural parameter has to be judge by an expert.

- What modification is required in term of parameter to apply HAZUS Model in Indonesia?

  In HAZUS generating building stocks are divided into three main points to input i.e. Building type, Building codes and building height. The modification in parameter is done by correlating similarity building structure in Indonesia especially in Bantul o HAZUS i.e. Confined Masonry as RM2, and unreinforced Brick as URM. The building codes are adapted from Seismic factor in UBC to Indonesian condition with the rules that has provided in Indonesia condition (Table 4-8). However, there is a need to create the modification in term of building inventory and damage matrix parameter. In Indonesia, building occupancy of residential and commercial can be merged as one unit which is no parameter in HAZUS. In HAZUS, the modification must be created using predominant occupancy in residential or in commercial. The building structures in Indonesia traditionally were based on bamboo building which has different quality on structure. The improper quality of bamboo structure is not match for wood structure with in HAZUS.

6.2. Recommendation

The measurement of shear wave velocity can be better if its use Vs measurement. Because the local site effect must have detailed result. The used of geomorphology based on Vs measurement can be used in wider area and in rapid assessment because it has simplification in efficient time.

The HAZUS methodology can be adopted in Indonesia. HAZUS can be generated in mitigation of risk assessment and also to estimate the victim after disaster as rapid assessment because of the efficient time in used. However the building vulnerability must correlate into Indonesian condition. The effort to estimate building vulnerability based on building in Indonesia is needed. The fragility curves and capacity curves must be created by involving building structural expertise. The risk estimation in HAZUS required lot of data. The comprehensive data base can be taken from government (Tax office, BPS and BPN) and also private consultant. The coordination in gathering data base can be effective to perform earthquake risk reduction if every owner data base can cooperate in extending data. Thus, the effort of expert in different field and complete data base can manage the risk assessment, based on HAZUS Method in Indonesia.

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APPENDIX

APPENDIX 1.

Creating Study Area in HAZUS

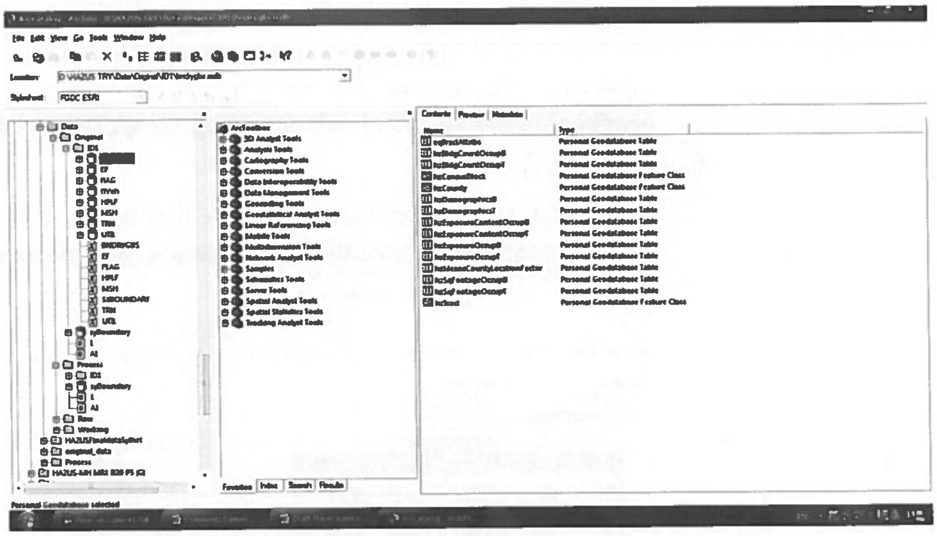
To georeference the study area that can be used in HAZUS. The study area has to convert to United States. The region that will be change from US is in Idaho country to Bantul sub district. the step of the process with the procedure from (ADPC 2009):

1. Development of Study region

   Create database from original data and modified data. Import data structure from the original data and create data structure in each geodatabase. The result is structured database without data inside.

2. Set working environment

   Copy the following geodatabase from the original ID1 (Idaho) folder into the process and original folders. Copy the syboundary.mdb, A1.txt. and 1.txt geodatabase from HAZUS folder. In arc catalog delete the existing feature classes and tables in each geodatabase in the process folders to have basic platform of geodatabase without tables and feature inside.



3. Preparing geodatabase of study region

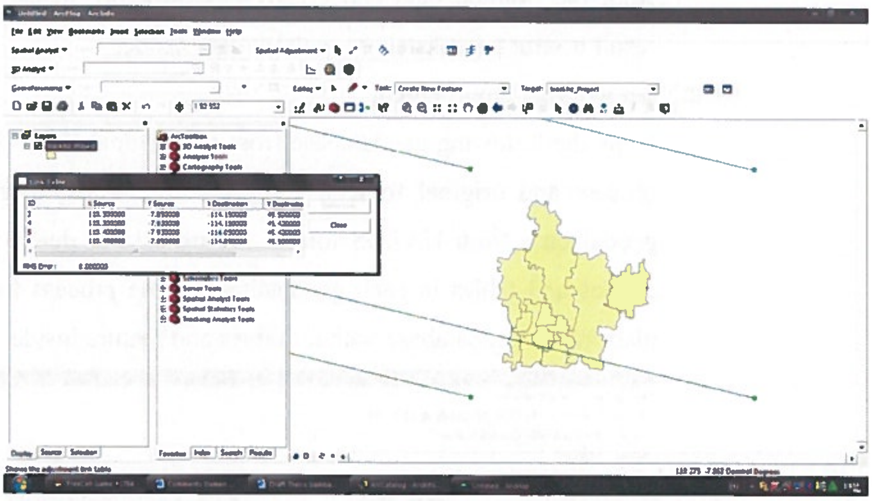
   Create feature and tables in Bantul_process according to original _HAZUS folder using xml schema. In database MSH.mdb must be loaded in it data. As the result the basic structured will be recreated with blank data inside.

4. Loading data into database

Data loading in database is from working folder into process folder. Strict data system must be maintained.

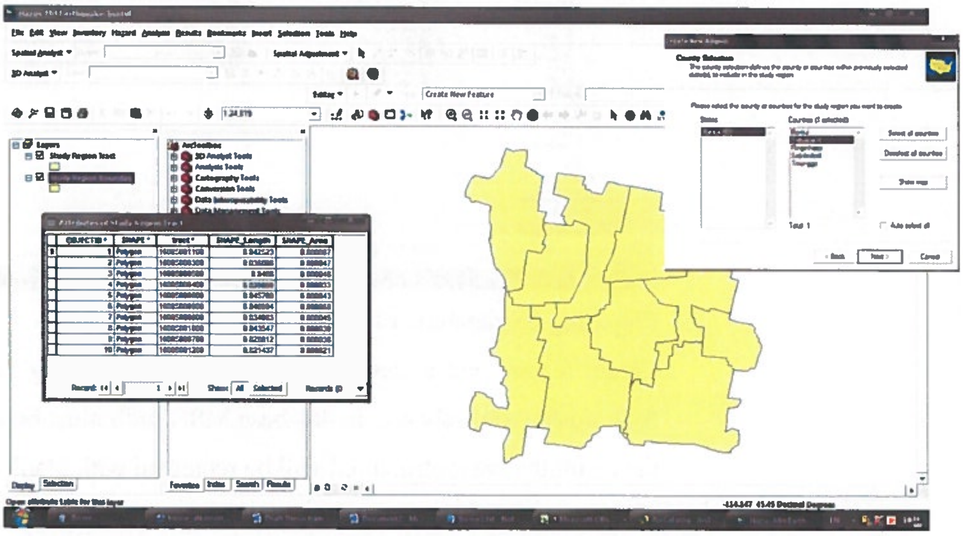
5. Study region boundary data

   The study region in HAZUS are divided into three type. Country as Bantul subdistrict The country will divided into 5 states (the villages in Bantul) and census track will took Pedukuhan (sub village) Idaho has code 16, states 16001, and Census track 16001010502. The states code must follow the code in the original code. Use spatial adjustment to change the location from Bantul to US location.



6. Study region creation

   Data path must be edited in the registry editor before starting HAZUS.



APPENDIX 2

The correlation of standard regresion and geomorphology unit ((Matsuoka, Wakamatsu et al. 2006)

ID	Geomorphologic unit	Regression coefficient				s.d
		a	b	c	d	σ
1	Mountain (pre - Tertiary)	2.900	0	0	0	0.139
2	Mountain (Tertiary)	2.807	0	0	0	0.117
3	Mountain footslope	2.602	0	0	0	0.092
4	Hill	2.349	0	0.152(0.219)	0	0.175
5	Volcano	2.708	0	0	0	0.162
6	Volcanic footslope	2.315	0	0.094(0.382)	0	0.100
7	Volcanic Hill	2.608	0	0	0	0.059
8	Rocky strath terrace	2.546	0	0	0	0.094
9	Gravelly terrace	2.493	0.072(0.270)	0.027(0.101)	-0.164(-0.336)	0.122
10	Terrace covered with volcanic ash soil	2.206	0.093(0.269)	0.065(0.223)	0	0.115
11	Valley bottom low land	2.266	0.144(0.447)	0.016(0.040	-0.113(-0.265)	0.158
12	Alluvial fan	2.350	0.085(0.419)	0.015(0.059)	0	0.116
13	Natural leeve	2.204	0.100(0.368)	0	0	0.124
14	Back marsh	2.190	0.038(0.178)	0	-0.041(-0.152)	0.116
15	Abandoned river channel	2.264	0	0	0	0.091
16	Delta and coastal lowland	2.317	0	0	-0.103(-0.043)	0.107
17	Marine sand and gravel bars	2.415	0	0	0	0.114
18	Sand dune	2.289	0	0	0	0.123
19	Reclaimed land	2.373	0	0	-0.124(-0.468)	0.123
20	Filled Land	2.404	0	0	-0.139(-0.418)	0.120

APPENDIX 3

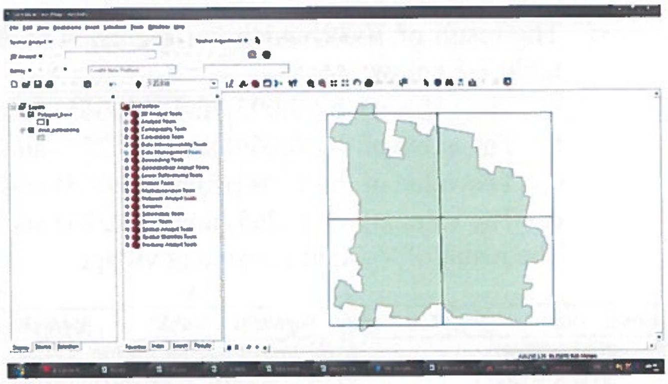
Calculation of Vs30 using equation from Sykora (1983)

No	X	Y	Qc	Vs30 (fps)	Vs30(mps)
S-02	429449	9123961	140	678	206.6544
S-03	426350	9123378	120	644	196.2912
S-04	423986	9118854	110	627	191.1096
S-06	426501	9117849	190	763	232.5624
S-07	432911	9120939	38	504.6	153.8021
S-08	430951	9123667	160	712	217.0176
S-09	430725	9125232	170	729	222.1992
S-10	423139	9121772	150	695	211.836
S-11	424590	9121882	140	678	206.6544
S-12	426759	9120707	120	644	196.2912
S-07B	425843	9118842	155	703.5	214.4268
S-14	429471	9120632	115	635.5	193.7004
S-16	434758	9133075	150	695	211.836
S-17	434360	9129567	100	610	185.928
S-18	424559	9124761	120	644	196.2912
S-19	432800	9131465	110	627	191.1096
S-20	434758	9133075	100	610	185.928
S-21	430142	9133334	124	650.8	198.3638
S-22	425864	9132865	96	603.2	183.8554
S-23	434758	9133075	136	671.2	204.5818
S-24	418948	9121308	134	667.8	203.5454
S-25	418542	9118724	150	695	211.836
S-26	420865	9117664	110	627	191.1096
S-27	422936	9115230	106	620.2	189.037
S-28	428875	9127258	110	627	191.1096
S-30	429315	9125940	130	661	201.4728
S-31	430887	9127857	130	661	201.4728
S-32	430943	9131988	130	661	201.4728

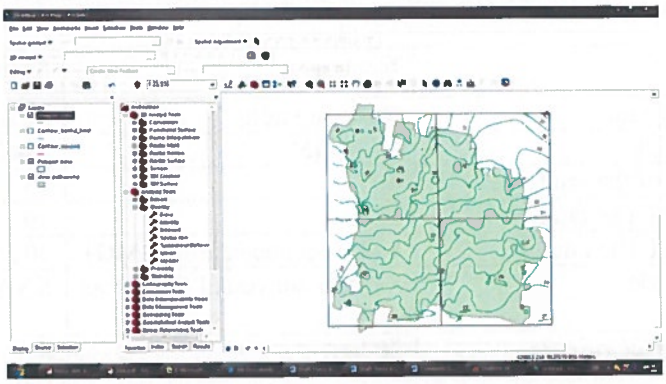
APPENDIX 4

Calculating Vs30 based on Geomorphology and sediment deposit.

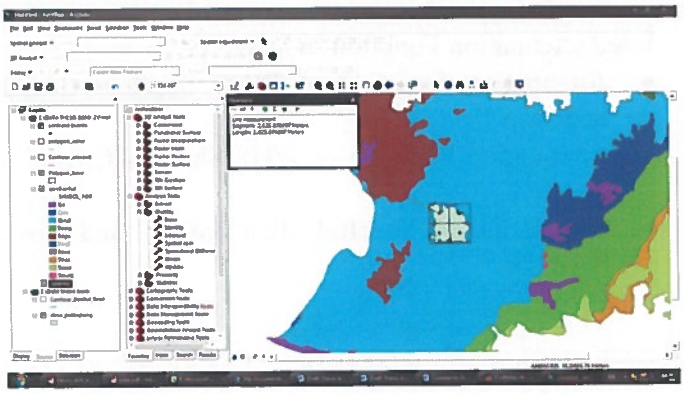
- Create the polygon base in square kilometer in Palbapang village.



- Defined the topography map based on base level from BPN and Bakosurtanal.
- By using natural neighborhood interpolation. Interpolate the data of base level from BPN and Bakosurtanal.
- Create the contour map of Palbapang Village.



- Calculated the distance of Denuded hill of Sentolo Formation



- Used terrace cover with volcanic ash soil as the lithology in Palbapang from geological map of Palbapang that has Formation of Young volcanic of Merapi volcano (see APPENDIX 2).
- The result of Vs30 which has regresion coefficient of b and c in table 7-2 below:
  a. The value of b (0.093) and c (0.065) and the σ is minus
  b. The value of b (0.269) and c (0.223) and the σ is minus
  c. The value of b (0.093) and c (0.065) and the σ is plus
  d. The value of b (0.269) and c (0.223) and the σ is plus
- The result of Vs30 in Palbapang village.

				a		b		c		d	
Contour	elevasi	tan	length from Tertiary	log AVs30	AVs30	log AVs30	AVs30	log AVs30	AVs30	log AVs30	AV
9	38.49	0.005432	2.546	2.286207156	193.2890074	2.297533	198.396	2.516207	328.2518	2.527533	3
8	31.8	0.004355	2.244	2.272259476	187.1800143	2.273908	187.8919	2.502259	317.8773	2.503908	3
7	35.74	0.005158	3.84	2.281757055	191.3185389	2.291671	195.7363	2.511757	324.9055	2.521671	
7	29.32	0.004834	3.528	2.271927665	187.037059	2.283072	191.8988	2.501928	317.6345	2.513072	3

APPENDIX 5

Creating Ground Motion Map based on Scenario of BMG and USGS.

- Used the parameter of Fault from BMG with the typical fault :

	Scenario 1	Scenario 2
Type of fault	Reverse Fault	Strike slip Fault
Strike /Dip	N37E/45^0	N48E/89^0
Length of the fault	40	15
Width of The fault	8	10
Depth of The Fault	11.87 (hypocenter of BMG)	10 (hypocenter of USGS)
Magnitude	5.9 Mb converted to Mw as 6.25	6.3 Mw
Sub surface rupture	20 km	8 km "based on The Equation Log (L) = 0.6 M – 2.9"

Used attenuation Function In HAZUS

- Attenuation Function of WUS Shallow Crustal Non Extensive for Scenario 1
- Attenuation Function of WUS Shallow Crustal Extensive for Scenario 2
- The result of Spectral Acceleration and Spectral Displacement in HAZUS .

Census Tract	Scenario 1				Scenario 2			
	Sa		Sd		Sa		Sd	
	At 0.3 sec (g)	At 1.0 sec (g)	At 0.3 sec (in.)	At 1.0 sec (in.)	At 0.3 sec (g)	At 1.0 sec (g)	At 0.3 sec (in.)	At 1.0 sec (in.)
16005000300	0.607	0.316	0.536	3.099	0.464	0.255	0.409	2.504
16005000400	0.623	0.325	0.549	3.186	0.477	0.263	0.421	2.578
16005000500	0.636	0.333	0.561	3.259	0.491	0.271	0.433	2.656
16005000600	0.624	0.326	0.551	3.194	0.477	0.263	0.421	2.577
16005000700	0.633	0.331	0.558	3.243	0.484	0.267	0.426	2.612
16005000800	0.646	0.339	0.57	3.317	0.498	0.275	0.439	2.691
16005000900	0.646	0.339	0.57	3.319	0.5	0.276	0.441	2.704
16005001000	0.65	0.341	0.573	3.339	0.498	0.275	0.44	2.694
16005001100	0.667	0.351	0.588	3.444	0.518	0.286	0.457	2.803
16005001200	0.663	0.349	0.584	3.419	0.511	0.282	0.45	2.762

- Sample of Calculation T_A, T_{AV} and T_{VD} in Kadirojo sub village.

T_{AV} = Sa 1.0/Sa 0.3

T_{AV} = 0.316/0.607 = 0.52 second

T_A = 0.2. T_{AV}

T_A = 0.2*0.52 = 0.11 second

$T_{VD} = 1/f_e = 10^{(M-5)/2}$

F_e is the assumption of frecuency with has relationship with moment magnitude.

$T_{VD} = 10^{(6.3-5)/2}$ = 8.89 seconds.

- Calculate the Spectral acceleration in standardize spectrum.

Sa(T) =Sa 0.3·(0.4+0.6·T /T_A)	if $0 < T < T_A$
Sa(T) = Sa 0.3	if $T_A < T < T_{AV}$
Sa(T) =Sa 1.0/T	if $T_{AV} < T < T_{VD}$
Sa(T) =Sa 1.0·T_{VD} /T2	if $T_{VD} < T < 10$ s

- Result of estimation elastic spectral response on HAZUS (scenario 1)

Tract	Sub Village	TA	TAV	TVD		Period in Seconds								
					Spectral acceleration	0	0.05	0.1	0.52	0.8	1	2	5	10
16005000300	Kadirojo	0.1	0.5	8.89		0.316	0.534294	0.607	0.607	0.395	0.316	0.158	0.0632	0.028097
16005000400	Karasan	0.1	0.5	8.89		0.322	0.547761	0.623	0.623	0.40625	0.325	0.1625	0.065	0.028897
16005000500	Dagaran	0.1	0.5	8.89		0.327	0.558076	0.636	0.636	0.41625	0.333	0.1665	0.0666	0.029608
16005000600	Sumuran	0.1	0.5	8.89		0.323	0.548201	0.624	0.624	0.4075	0.326	0.163	0.0652	0.028986
16005000700	Taskombang	0.1	0.5	8.89		0.326	0.555835	0.633	0.633	0.41375	0.331	0.1655	0.0662	0.029431
16005000800	Bolon	0.1	0.5	8.89		0.331	0.566155	0.646	0.646	0.42375	0.339	0.1695	0.0678	0.030142
16005000900	Ngringinan	0.1	0.5	8.89		0.331	0.566155	0.646	0.646	0.42375	0.339	0.1695	0.0678	0.030142
16005001000	Peni	0.1	0.5	8.89		0.332	0.569751	0.65	0.65	0.42625	0.341	0.1705	0.0682	0.03032
16005001100	Karangasem	0.1	0.5	8.89		0.338	0.583673	0.667	0.667	0.43875	0.351	0.1755	0.0702	0.031209
16005001200	Serut	0.1	0.5	8.89		0.337	0.580078	0.663	0.663	0.43625	0.349	0.1745	0.0698	0.031031

- Result of estimation elastic spectral response on HAZUS (scenario 2)

Tract	Sub Village	TAV	TA	TVD		Period in Seconds								
					Spectral acceleration	0	0.05	0.11	0.55	0.6	1	2	5	10
16005000300	Kadirojo	0.55	0.11	9.98		0.241	0.396675	0.464	0.464	0.425	0.255	0.1275	0.051	0.02544
16005000400	Karasan	0.55	0.11	9.98		0.248	0.407082	0.477	0.477	0.438333	0.263	0.1315	0.0526	0.026238
16005000500	Dagaran	0.55	0.11	9.98		0.254	0.418799	0.491	0.491	0.451667	0.271	0.1355	0.0542	0.027036
16005000600	Sumuran	0.55	0.11	9.98		0.247	0.407082	0.477	0.477	0.438333	0.263	0.1315	0.0526	0.026238
16005000700	Taskombang	0.55	0.11	9.98		0.251	0.412941	0.484	0.484	0.445	0.267	0.1335	0.0534	0.026637
16005000800	Bolon	0.55	0.11	9.98		0.257	0.424658	0.498	0.498	0.458333	0.275	0.1375	0.055	0.027435
16005000900	Ngringinan	0.55	0.11	9.98		0.258	0.426449	0.5	0.5	0.46	0.276	0.138	0.0552	0.027535
16005001000	Peni	0.55	0.11	9.98		0.257	0.424658	0.498	0.498	0.458333	0.275	0.1375	0.055	0.027435
16005001100	Karangasem	0.55	0.11	9.98		0.266	0.441749	0.518	0.518	0.476667	0.286	0.143	0.0572	0.028532
16005001200	Serut	0.55	0.11	9.98		0.263	0.43589	0.511	0.511	0.47	0.282	0.141	0.0564	0.028133

APPENDIX 6

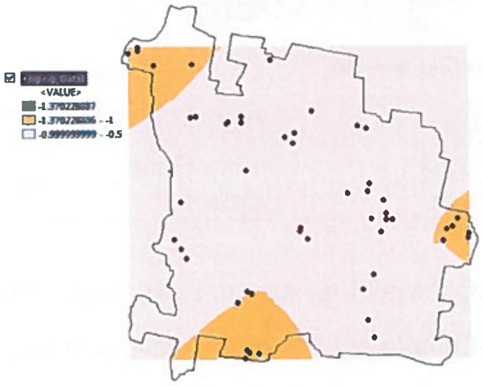
- Water Table Data and assumption in May Scenario

Sumur_Gali	Z	Z1	Z2	delta_Z	X	Y	d_Z2	Month_	dukuh	May
1	-220	70	25	-125	425011	9126468	-1.25	September	karasan	-0.92
2	-157	66	0	-91	424906	9126476	-0.91	September	karasan	-0.58
3	-152	66	0	-86	424896	9126464	-0.86	September	karasan	-0.53
4	-164	60	0	-104	425016	9126514	-1.04	September	karasan	-0.71
5	-138	0	0	-138	426842	9125568	-1.38	August	serut	-1.09
6	-156	64	0	-92	424520	9125452	-0.92	September	dagaran	-0.59
7	-264	73	13	-178	424310	9126933	-1.78	September	kadirojo	-1.45
8	-202	62	0	-140	424621	9126940	-1.4	September	kadirojo	-1.07
9	-255	79	0	-176	424110	9127029	-1.76	September	kadirojo	-1.43
10	-289	113	0	-176	424182	9127051	-1.76	September	kadirojo	-1.43
11	-210	68	0	-142	424969	9125018	-1.42	Oktober	Ngringinan	-0.93
12	-269	75	21	-173	425060	9124605	-1.73	Oktober	Ngringinan	-1.24
13	-196	86	0	-110	426044	9125969	-1.1	September	Peni	-0.77
14	-157	62	0	-95	425045	9126080	-0.95	September	karasan	-0.62
15	-175	85	0	-90	424522	9125830	-0.9	September	dagaran	-0.57
16	-157	62	0	-95	424465	9125524	-0.95	September	dagaran	-0.62
17	-228	57	16	-155	426838	9125535	-1.55	Oktober	serut	-1.06
18	-259	82	23	-154	426710	9125628	-1.54	Oktober	serut	-1.05
19	-232	69	65	-98	426160	9125834	-0.98	August	Peni	-0.69
20	-225	94	18	-113	426225	9125682	-1.13	August	Peni	-0.84
21	-186	62	9	-115	426137	9125584	-1.15	August	Peni	-0.86
22	-219	76	0	-143	426176	9125728	-1.43	Oktober	Peni	-0.94
23	-204	68	0	-136	426178	9125679	-1.36	Oktober	Peni	-0.87
24	-189	68	22	-99	426074	9124724	-0.99	September	karangasem	-0.66
25	-154	41	17	-96	425482	9125619	-0.96	September	bolon	-0.63
26	-187	73	18	-96	425474	9125589	-0.96	September	bolon	-0.63
27	-168	66	7	-95	425542	9125527	-0.95	September	bolon	-0.62
28	-242	62	0	-180	424182	9127077	-1.8	Oktober	kadirojo	-1.31
29	-194	78	0	-116	425954	9126442	-1.16	Oktober	taskombang	-0.67
30	-204	88	0	-116	426026	9126416	-1.16	Oktober	taskombang	-0.67
31	-200	69		-131	425249	9126974	-1.31	Oktober	sumuran	-0.82
33	-213	53	17	-143	425438	9126382	-1.43	Oktober	sumuran	-0.94
34	-220	86		-134	425424	9126302	-1.34	Oktober	sumuran	-0.85
35	-213	73	0	-140	425364	9126346	-1.4	Oktober	sumuran	-0.91
36	-251	78	20	-153	425047	9125106	-1.53	Oktober	Ngringinan	-1.04
37	-229	69	0	-160	425080	9125088	-1.6	Oktober	Ngringinan	-1.11
38	-278	81	42	-155	425029	9124565	-1.55	Oktober	Ngringinan	-1.06
39	-246	62	0	-184	425041	9124629	-1.84	Oktober	Ngringinan	-1.35
40	-246	46	0	-200	425137	9124603	-2	Oktober	Ngringinan	-1.51
41	-249	90	34	-125	424645	9126514	-1.25	Oktober	kadirojo	-0.76
42	-186	50	12	-124	424605	9126512	-1.24	Oktober	kadirojo	-0.75
13	-194	87	0	-107	425868	9125893	-1.07	Oktober	bolon	-0.58
47	-175	58	10	-107	426033	9125904	-1.07	Oktober	bolon	-0.58
48	-198	68	20	-110	426055	9125692	-1.1	Oktober	bolon	-0.61
45	-175	68	10	-97	425987	9125117	-0.97	September	karangasem	-0.64
46	-175	58	20	-97	426022	9124867	-0.97	September	karangasem	-0.64
49	-180	60	20	-100	426071	9125239	-1	Oktober	karangasem	-0.51
51	-226	40	31	-155	426662	9125603	-1.55	Oktober	serut	-1.06
50	-257	78	25	-154	426631	9125510	-1.54	Oktober	serut	-1.05
52	-243	75	15	-153	426753	9125692	-1.53	Oktober	serut	-1.04
44	-158	42	20	-96	425578	9126556	-0.96	September	taskombang	-0.63
43	-171	80	0	-91	424565	9125375	-0.91	September	dagaran	-0.58

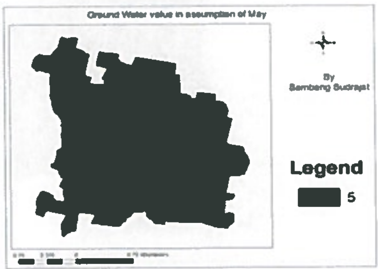
APPENDIX 7

Creating Liquefaction Map based on Scenario of BMG and USGS

- Plotting the ground water table data into the map to make the interpolation with the linear simple kriging to correlate the ground water table map in Palbapang village.

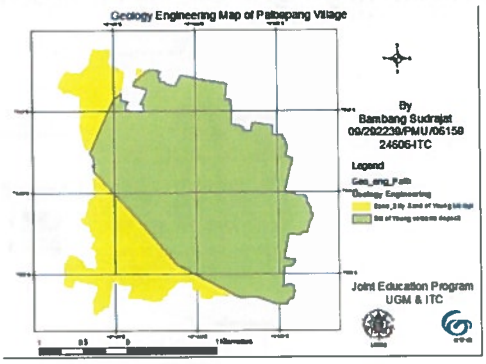


- Classified the Ground water table in Palbapang as "Very high" because of the depth of water table 0-1.5 meter (see APPENDIX 6).

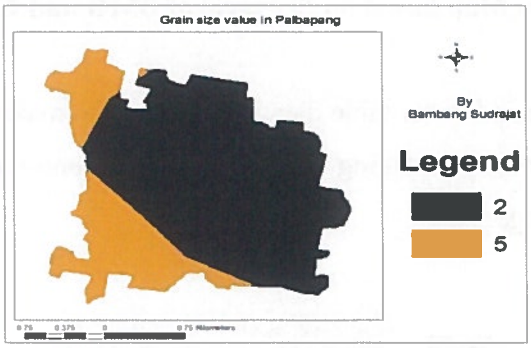


Water Table	Class	Score
< 1.5 m	Very High	5

- Plotting the geology engineering map to classify grain size.



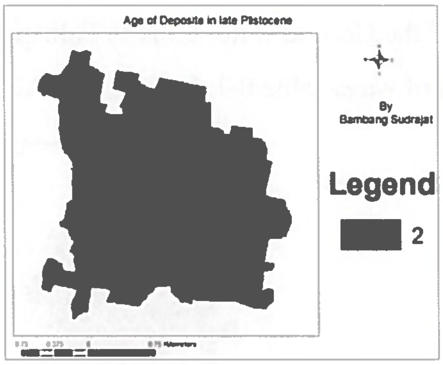
- The classification of Grain size vary between 2 class



Grain size	Class	Score
0.075 – 1 mm	Very High	5
<0.075 mm	Low	2

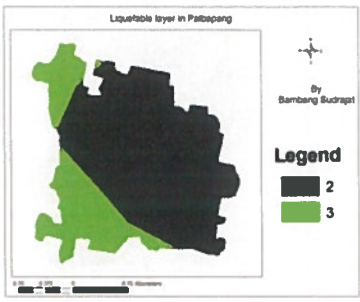
- Plotting the geology map to classify age of lithology.

  Age of lithology from geology map can be correlated as Low



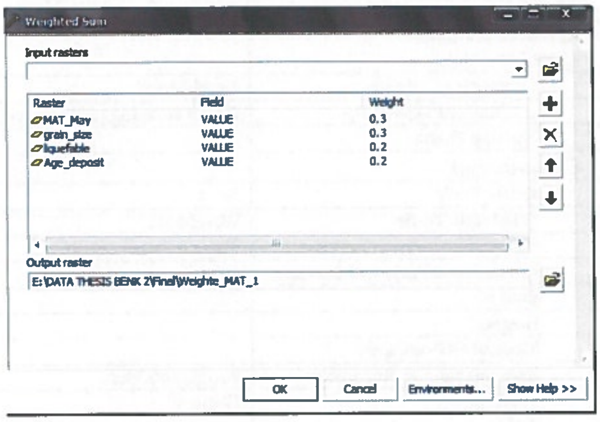
Age of Deposit	Class	Score
Upper Pleistocen	Low	2

- Plotting the thickness of the liquefiable layer from borehole data in geology engineering map to classify the liquefiable layer

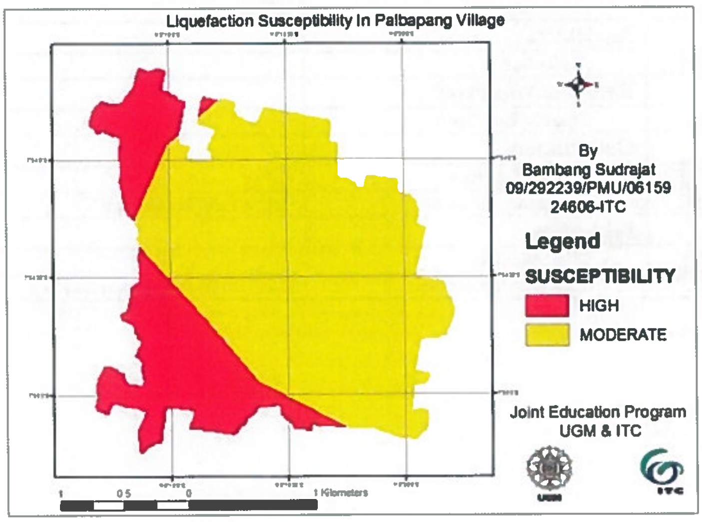


Liquefiable soil layer	Class	Score
0,6 – 1.2	Medium	3
<0.6	Low	2

- And Then Weighted factor in Very High determine into 100 % with Very Important as 30 % and Important as 20 %. The scale is 1 to 5 from very low to very high.



- The Liquefaction Susceptibility in Palbapang area is like in the figure below:



The susceptibility of The Liquefaction then correlated into HAZUS software to generated Liquefaction Probability.

APPENDIX 8

Building Occupancy Classes(FEMA 2009)

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

APPENDIX 9

Building Type Classes(FEMA 2009)

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

APPENDIX 10

A. HAZUS Capacity curves of Building type in Palbapang Village (FEMA 2009)

No	Building Type	Yield		Ultimate		Kappa			Damping
		Sd (inches)	Sa (g' s)	Sd (inches)	Sa (g' s)	Short Dur.	Medium Dur.	Long Dur.	
PRE CODE									
1	URML	0.24	0.2	2.397	0.4	0.4	0.2	0	10
LOW CODE									
2	C1L	0.098	0.062	1.467	0.187	0.6	0.3	0.1	7
3	RM2L	0.16	0.133	1.598	0.267	0.6	0.3	0.1	7
4	W1	0.24	0.2	4.316	0.6	0.7	0.4	0.2	15
5	W2	0.157	0.1	2.349	0.25	0.6	0.3	0.1	10
MODERATE CODE									
6	RM2L	0.32	0.267	3.836	0.533	0.8	0.4	0.2	7
7	S3	0.313	0.2	3.758	0.4	0.6	0.4	0.2	7

B. HAZUS Fragility curves of Building type in Palbapang village(FEMA 2009)

No	Building Type	Slight		Moderate		Extensive		Complete	
		Median	Beta	Median	Beta	Median	Beta	Median	Beta
PRE CODE									
1	URML	0.32	1.2	0.65	1.2	1.62	1.2	3.78	1.2
LOW CODE									
2	C1L	0.9	0.89	1.56	0.9	4.2	0.9	10.8	0.88
3	RM2L	0.72	1.05	1.15	1.07	2.89	1.08	7.88	0.91
4	W1	0.5	0.93	1.25	0.97	3.86	1.03	9.45	0.99
5	W2	0.86	0.97	2.14	0.91	6.62	0.88	16.2	1
LOW CODE									
6	S3	0.54	0.99	0.87	0.99	2.17	1.01	5.91	0.91
7	RM2L	0.72	1.05	1.15	1.07	2.89	1.08	7.88	0.91

C. Fragility curves in Philippine with correlation from meter to inch.

Building type	Sub-type	Capacity curve				Fragility curve				
						Displacement at damage state (inches)				
		DY (inch)	AY (g)	DU (inch)	AU (g)	Slight	Moderate	Extensive	Complete	Bc
CHB	1	0.079	0.39	0.394	0.51	0.197	0.276	0.709	1.772	0.7
	2	0.079	0.41	0.276	0.61	0.197	0.276	0.709	1.772	0.7
	3	**0.079**	**0.42**	**0.276**	**0.61**	**0.197**	**0.276**	**0.709**	**1.772**	0.7
C1L	1	0.315	0.30	2.283	0.42	0.827	1.457	3.937	10.236	0.5
	2	0.197	0.29	0.709	0.44	0.748	1.260	3.465	9.055	0.5
	3	**0.197**	**0.31**	**0.551**	**0.43**	**0.748**	**1.181**	**2.953**	**7.480**	0.5

APPENDIX 11

- Sample of The calculation of Unreinforced Masonry Building (before earthquake) using Miura fragility curves and capacity curves..

Step 1 Determination Structure of Yield Capacity and Ultimate Capacity

Condition	Capacity curves	
	Displacement	Acceleration
begin	0	0
yield	0.079	0.42
ultimite	0.276	0.61

Step 2 Determination effective damping B_{eff}

in Hazus, degradation factor is depending on earthquake duration and energy -absorption capacity of the structure during earthquake

κ factor		Magnitude M
0.4	Short Period	Magnitude M ≤ 5.5
0.2	Moderate Period	Magnitude 5.5 < M<7.5
0	Long Period	Magnitude M ≥ 7.5

Elastic Damping Be 10 %

Hysteretic damping = 63.7(κ)((Say/Sau)-(Sdy/Sdu)

Hysteretic Damping Bh 5.125209076

Effective Damping = Be +Bh

Effective Damping Beff 15.12520908

Reduction Factor

$$R_A = \frac{2.12}{3.21 - 0.68 \ln(B_{eff})}$$

$$R_F = \frac{1.65}{2.31 - 0.41 \ln(B_{eff})}$$

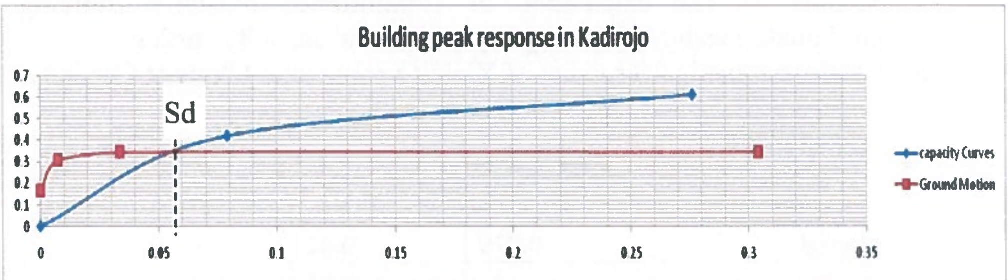
Short Period 0.3 sec Ra 1.55553714

Long Period 1.0 sec Rv 1.379262795

Step 3 Determine inelastic response spectra

T(sec)	f	Sa (g)	Sd (inch)
0	0	0.165538	0.000
0.05	20	0.308378	0.008
0.1	10	0.344897	0.034
0.5	2	0.344897	0.304

Step 4 Correlate the peak building response with capacity curves.



Step 5 Determine ground displacement based on liquefaction in Palbapang Village. From the probability of liquefaction..

probability	Settlement	Spreading
0.1	2	12
0.5	10	60
0.2	0.9	6.077

Step 6 Calculate cumulative Damage Probability

Damage State	Sd	$S_{ds}^{(e)}$	$\beta_{ds}^{(e)}$	$Ln(Sd/S_{ds})$	n(Sd/Sds)/β	Φ(Y)	PGF	Pcomb
Slight	0.06	0.197	0.7	-1.189	-1.698	0.04472	0.200	0.235775162
Moderate	0.06	0.276	0.7	-1.526	-2.180	0.01463	0.200	0.2117006
Extensive	0.06	0.709	0.7	-2.470	-3.528	0.00021	0.200	0.200167565
Complete	0.06	1.772	0.7	-3.386	-4.836	0.00000	0.2	0.200000529

Step 7 Calculate Discrete Damage probability.

Mean damage	Cumulative Damage Probability	Discrete Damage Probability
Complete	0.20000	0.20000
Extensive	0.20017	0.00017
Moderate	0.21170	0.01153
Slight	0.23578	0.02407
No damage	1.00000	0.76422

In Kadirojo The probability of damage

None	Slight	Moderate	Extensive	Complete
0.764	0.024	0.011	0.000	0.2

In other sub village the probability of damage are :

Sub Village	None	Slight	Moderate	Extensive	Complete
Kadirojo	0.76422	0.02407	0.01153	0.00017	0.20000
Karasan	0.86262	0.02717	0.01302	0.00019	0.09700
Dagaran	0.75472	0.02973	0.01528	0.00026	0.20000
Sumuran	0.85632	0.03095	0.01548	0.00024	0.09700
Taskombang	0.85443	0.03089	0.01544	0.00024	0.09900
Bolon	0.84907	0.03345	0.01720	0.00029	0.10000
Ngringinan	0.75472	0.02973	0.01528	0.00026	0.20000
Peni	0.84448	0.03611	0.01907	0.00034	0.10000
Karangasem	0.83729	0.04021	0.02208	0.00042	0.10000
Serut	0.83729	0.04021	0.02208	0.00042	0.10000

Discrete damage of Reinforced Masonry in scenario before earthquake.

Sub Village	None	Slight	Moderate	Extensive	Complete
Kadirojo	0.643	0.126	0.031	0	0.2
Karasan	0.69	0.167	0.046	0.001	0.097
Dagaran	0.579	0.169	0.053	0.001	0.2
Sumuran	0.687	0.169	0.047	0.001	0.097
Taskombang	0.658	0.186	0.057	0.001	0.099
Bolon	0.604	0.218	0.078	0.001	0.1
Ngringinan	0.536	0.194	0.07	0.001	0.2
Peni	0.582	0.23	0.088	0.001	0.1
Karangasem	0.478	0.277	0.142	0.003	0.1
Serut	0.507	0.266	0.126	0.002	0.1

Discrete damage of wood in scenario before earthquake

Tract	None	Slight	Moderate	Extensive	Complete
Sumuran	0.346	0.327	0.191	0.036	0.1
Taskombang	0.335	0.328	0.196	0.038	0.103
Bolon	0.328	0.329	0.201	0.039	0.103
Ngringinan	0.291	0.292	0.179	0.035	0.203
Karangasem	0.309	0.331	0.212	0.043	0.104

In HAZUS Scenario 1
Before earthquake.

Discrete damage of Unreinforced masonry

Sub Village	None	Slight	Moderate	Extensive	Complete
Kadirojo	0.102	0.144	0.237	0.188	0.33
Karasan	0.109	0.158	0.266	0.216	0.251
Dagaran	0.093	0.137	0.235	0.194	0.342
Sumuran	0.109	0.158	0.266	0.216	0.251
Taskombang	0.105	0.155	0.265	0.218	0.257
Bolon	0.1	0.152	0.263	0.22	0.264
Ngringinan	0.089	0.135	0.234	0.196	0.346
Peni	0.099	0.151	0.263	0.221	0.266
Karangasem	0.093	0.146	0.261	0.225	0.275
Serut	0.094	0.147	0.262	0.224	0.273

Discrete damage of reinforced

Sub Village	None	Slight	Moderate	Extensive	Complete
Kadirojo	0.163	0.102	0.253	0.235	0.247
Karasan	0.176	0.113	0.286	0.271	0.154
Dagaran	0.15	0.098	0.253	0.245	0.254
Sumuran	0.175	0.113	0.286	0.272	0.154
Taskombang	0.171	0.111	0.285	0.275	0.159
Bolon	0.163	0.108	0.284	0.281	0.164
Ngringinan	0.144	0.096	0.253	0.249	0.258
Peni	0.161	0.107	0.284	0.282	0.166
Karangasem	0.149	0.103	0.283	0.291	0.174
Serut	0.152	0.104	0.283	0.289	0.172

Discrete damage of wood

Tract	None	Slight	Moderate	Extensive	Complete
Sumuran	0.346	0.327	0.191	0.036	0.1
Taskombang	0.335	0.328	0.196	0.038	0.103
Bolon	0.328	0.329	0.201	0.039	0.103
Ngringinan	0.291	0.292	0.179	0.035	0.203
Karangasem	0.309	0.331	0.212	0.043	0.104

Scenario After Earthquake

Discrete damage of Unreinforced masonry

Sub Village	None	Slight	Moderate	Extensive	Complete
Karasan	0.153	0.208	0.302	0.182	0.154
Dagaran	0.134	0.187	0.278	0.17	0.231
Sumuran	0.152	0.207	0.301	0.182	0.159
Ngringinan	0.129	0.184	0.276	0.171	0.241

Discrete damage of reinforced masonry

Low Code.

Sub Village	None	Slight	Moderate	Extensive	Complete
Kadirojo	0.248	0.141	0.262	0.167	0.181
Karasan	0.264	0.155	0.293	0.192	0.097
Dagaran	0.234	0.14	0.27	0.18	0.176
Sumuran	0.262	0.154	0.292	0.192	0.101
Taskombang	0.256	0.153	0.292	0.195	0.104
Bolon	0.248	0.151	0.294	0.2	0.106
Ngringinan	0.225	0.138	0.268	0.183	0.186
Peni	0.245	0.151	0.295	0.202	0.107
Karangasem	0.235	0.149	0.297	0.21	0.11
Serut	0.237	0.15	0.297	0.208	0.109

Moderate Code.

Sub Village	None	Slight	Moderate	Extensive	Complete
Kadirojo	0.364	0.192	0.21	0.068	0.167
Karasan	0.383	0.214	0.242	0.082	0.079
Dagaran	0.337	0.197	0.228	0.08	0.159
Sumuran	0.38	0.213	0.241	0.082	0.084
Taskombang	0.369	0.213	0.246	0.086	0.086
Bolon	0.354	0.214	0.254	0.091	0.087
Ngringinan	0.322	0.195	0.232	0.083	0.168
Peni	0.35	0.214	0.256	0.092	0.087
Karangasem	0.331	0.215	0.266	0.1	0.089
Serut	0.335	0.215	0.264	0.098	0.088

Discrete damage of wood

Wood 1

Sub Village	None	Slight	Moderate	Extensive	Complete
Kadirojo	0.337	0.3	0.167	0.03	0.166
Karasan	0.356	0.335	0.195	0.037	0.078
Dagaran	0.312	0.308	0.186	0.036	0.157
Sumuran	0.352	0.334	0.195	0.037	0.082
Ngringinan	0.304	0.306	0.187	0.036	0.166
Peni	0.331	0.336	0.207	0.041	0.085
Karangasem	0.316	0.338	0.217	0.044	0.086

Wood 2

Sub Village	None	Slight	Moderate	Extensive	Complete
Kadirojo	0.258	0.311	0.236	0.027	0.169
Karasan	0.273	0.343	0.271	0.032	0.082
Sumuran	0.271	0.341	0.27	0.032	0.086
Karangasem	0.239	0.334	0.296	0.04	0.091
Serut	0.242	0.335	0.293	0.039	0.091

Discrete damage of concrete frame.

Sub Village	None	Slight	Moderate	Extensive	Complete
Karasan	0.318	0.221	0.293	0.079	0.089
Dagaran	0.279	0.2	0.271	0.075	0.177
Sumuran	0.315	0.22	0.292	0.079	0.095

Discrete Damage of Light Steel

Sub Village	None	Slight	Moderate	Extensive	Complete
Karasan	0.174	0.2	0.351	0.181	0.095

In HAZUS Scenario 2

Discrete damage of Unreinforced masonry in scenario before earthquake

Sub Village	None	Slight	Moderate	Extensive	Complete
Kadirojo	0.222	0.194	0.235	0.135	0.215
Karasan	0.233	0.214	0.268	0.159	0.126
Dagaran	0.19	0.184	0.237	0.145	0.245
Sumuran	0.233	0.214	0.268	0.159	0.126
Taskombang	0.226	0.212	0.269	0.163	0.131
Bolon	0.21	0.208	0.271	0.169	0.142
Ngringinan	0.181	0.181	0.238	0.149	0.252
Peni	0.209	0.207	0.272	0.17	0.142
Karangasem	0.185	0.199	0.274	0.181	0.161
Serut	0.193	0.202	0.274	0.177	0.154

Discrete damage of reinforced masonry in scenario before earthquake

Sub Village	None	Slight	Moderate	Extensive	Complete
Kadirojo	0.238	0.125	0.258	0.199	0.181
Karasan	0.256	0.138	0.291	0.231	0.085
Dagaran	0.214	0.118	0.256	0.207	0.205
Sumuran	0.256	0.138	0.292	0.231	0.084
Taskombang	0.251	0.136	0.292	0.234	0.088
Bolon	0.239	0.133	0.293	0.241	0.095
Ngringinan	0.207	0.116	0.256	0.211	0.21
Peni	0.238	0.133	0.293	0.241	0.095
Karangasem	0.223	0.129	0.293	0.25	0.105
Serut	0.229	0.131	0.293	0.247	0.101

Discrete damage of wood in scenario before earthquake

Sub Village	None	Slight	Moderate	Extensive	Complete
Sumuran	0.526	0.287	0.116	0.018	0.054
Taskombang	0.517	0.29	0.119	0.018	0.056
Bolon	0.498	0.296	0.127	0.02	0.06
Ngringinan	0.433	0.26	0.112	0.017	0.179
Karangasem	0.466	0.306	0.14	0.022	0.066

The correlation of Murakami with Miura from pearson correlation.
Standard error of estimate using SPSS -17

Pearson correlation is design as standardize coefficient

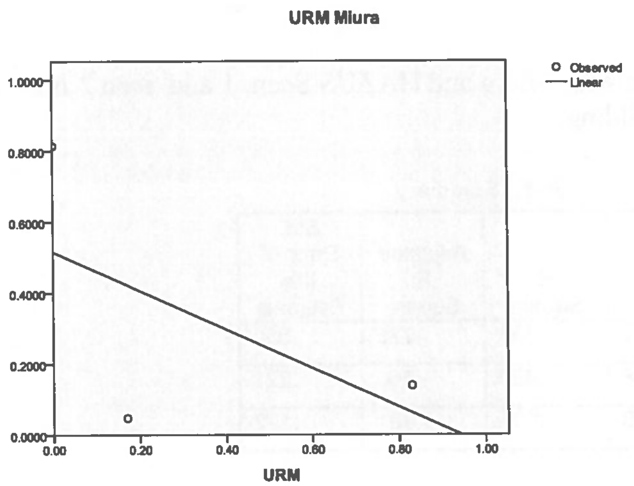
Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.572	.328	-.345	.486

The independent variable is URM Murakami.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
URM	-.547	.783	-.572	-.698	.612
(Constant)	.516	.383		1.346	.407

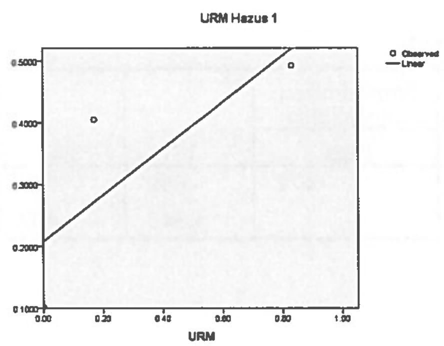


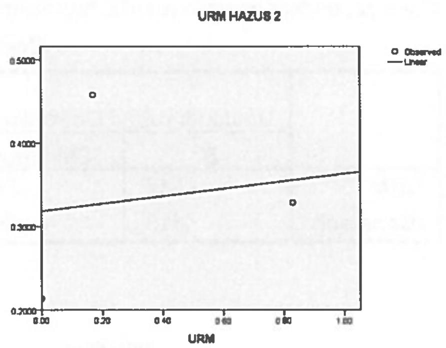
The correlation of Murakami with HAZUS Scen. 1 and Scen 2 from pearson correlation in URM building.

Model Summary

Scenario	R	R Square	Adjusted R Square	Std. Error of the Estimate
HAZUS Scen1	.804	.647	.294	.172
HAZUS Scen2	.161	.026	-.948	.170

UrM Building	Unstandardized Coefficients		Pearson Correlation		
	B	Std. Error	Beta	t	Sig.
HAZUS Scen 1	.377	.278	.804	1.354	.405
HAZUS Scen 2	.045	.275	.161	.163	.897



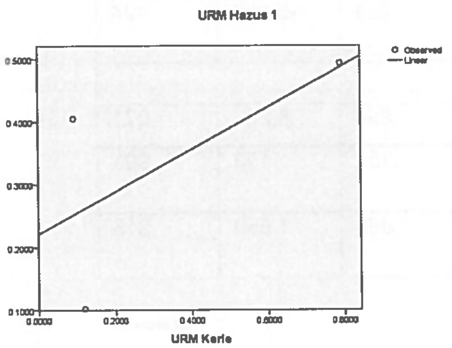


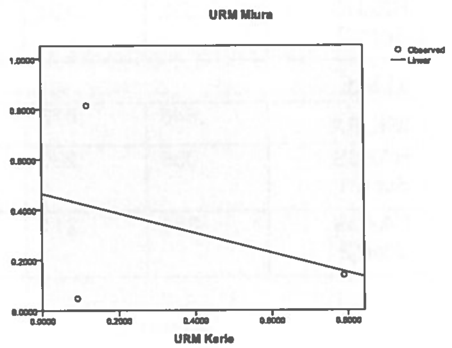
The correlation of Kerle with Miura and HAZUS Scen. 1 and Scen 2 from pearson correlation in URM Building.

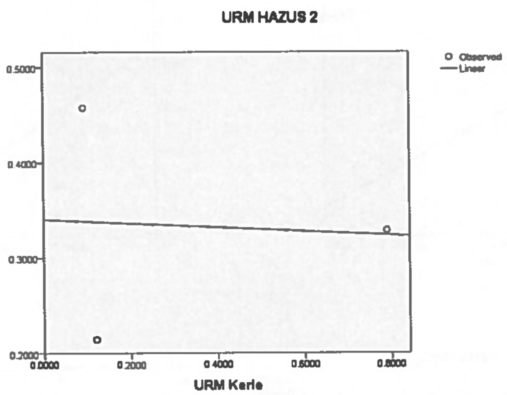
Model Summary

Scenario	R	R Square	Adjusted R Square	Std. Error of the Estimate
Miura	.371	.137	-.725	.550
HAZUS Scen1	.648	.420	-.160	.221
HAZUS Scen2	.068	.005	-.991	.172

URM Building	Unstandardized Coefficients		Pearson Correlation		
	B	Std. Error	Beta	t	Sig.
Miura	-.393	.984	-.371	-.399	.758
HAZUS Scen 1	.337	.396	.648	.851	.551
HAZUS Scen 2	-.021	.308	-.068	-.068	.957





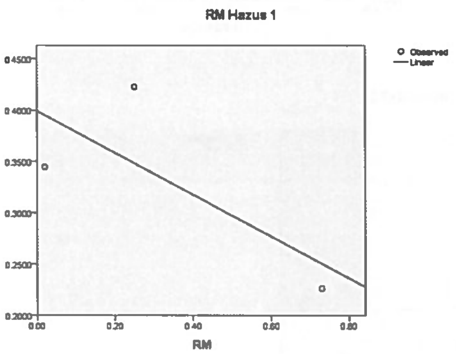


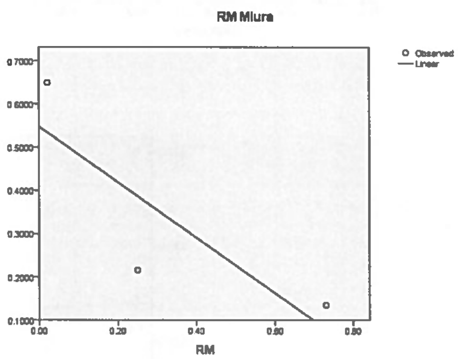
The correlation of Murakami, Kerle with Miura and HAZUS Scen. 1 and Scen 2 from pearson correlation in URM Building.

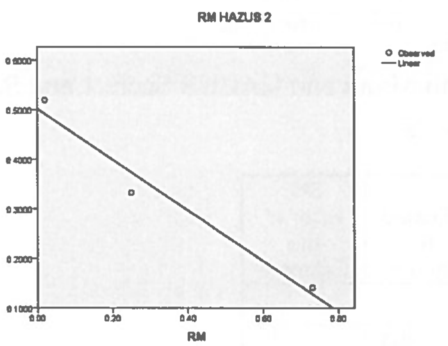
Scenario	R	R Square	Adjusted R Square	Std. Error of the Estimate
MURAKAMI				
Miura	.838	.702	.404	.214
HAZUS Scen1	.746	.556	.112	.093
HAZUS Scen2	.981	.963	.925	.052

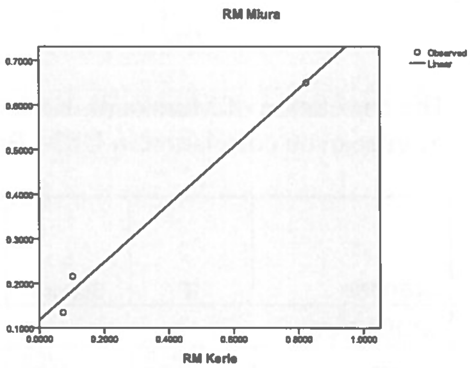
KERLE				
Miura	.994	.987	.975	.044
HAZUS Scen1	.151	.023	-.954	.138
HAZUS Scen2	.880	.774	.548	.127

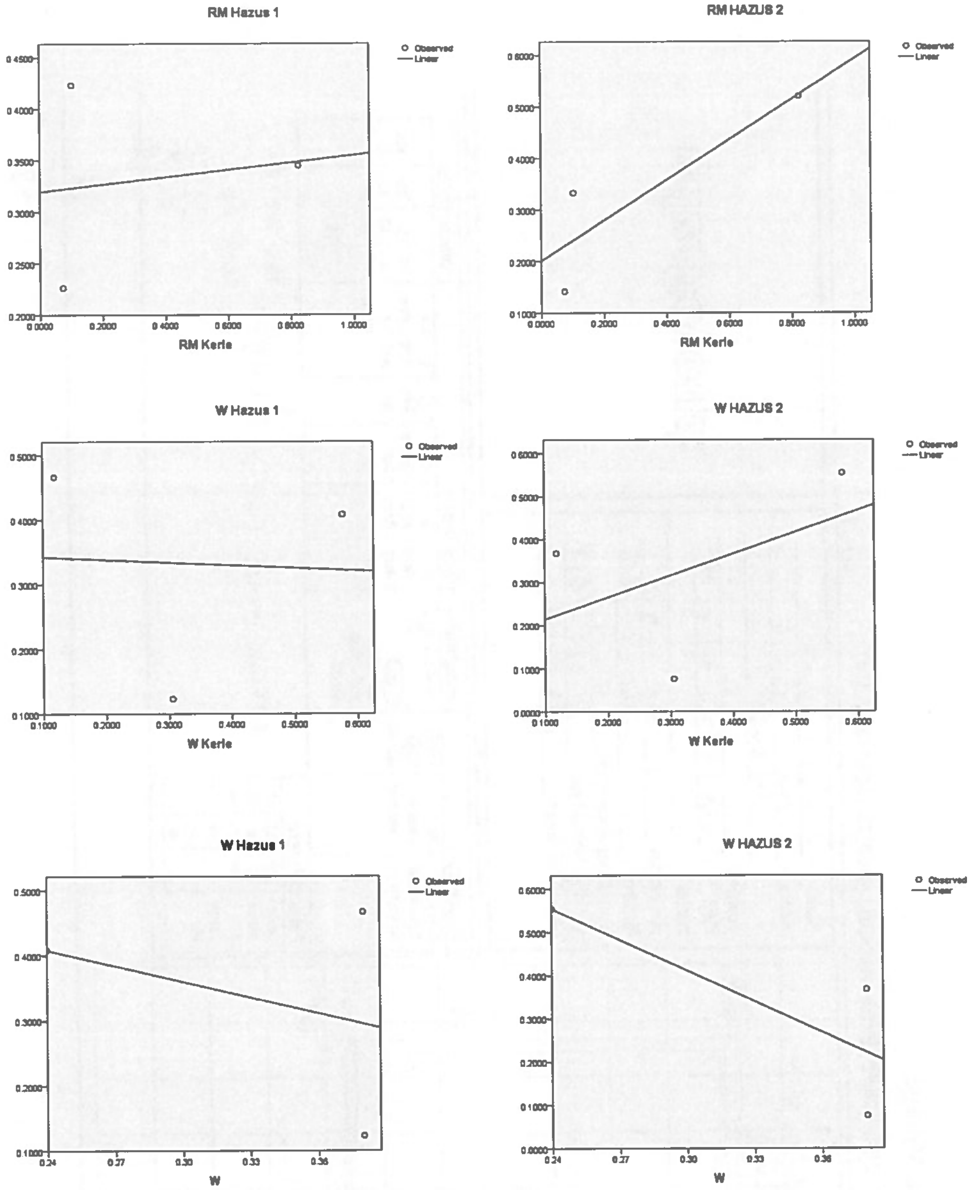
RM Building	Unstandardized Coefficients		Pearson Correlation		
MURAKAMI	B	Std. Error	Beta	t	Sig.
MIURA	-.642	.418	-.838	-1.535	.368
HAZUS Scen 1	-.204	.182	-.746	-1.119	.464
HAZUS Scen 2	-.512	.101	-.981	-5.081	.124
KERLE					
MIURA	.648	.073	.994	8.867	.071
HAZUS Scen 1	.035	.230	.151	.153	.903
HAZUS Scen 2	.391	.211	.880	1.850	.315









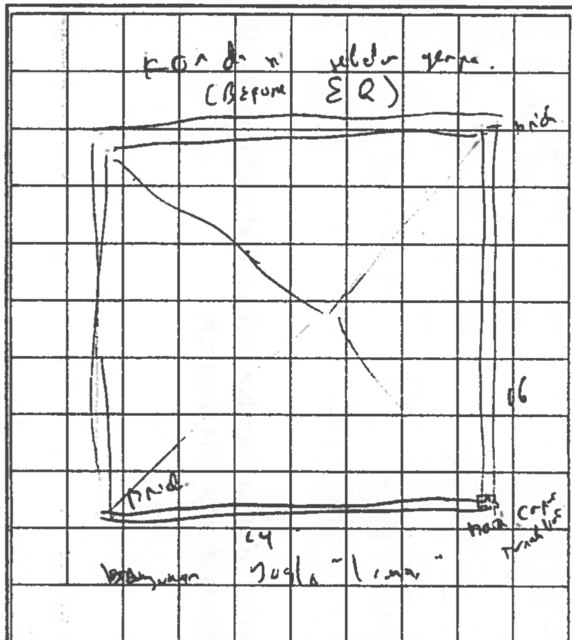


The graphic curves of Pearson correlation from RM building and Wood building in Palbapang village with previous research.

APPENDIX 12.

Building Survey In Palbapang Village

RAPID VISUAL SCREENING OF BUILDING FOR POTENTIAL HAZARD (ADOPTED FROM FEMA 154) No.5



Scale:
1 :

Name : Muji Raharja
Address : Jeruk RT 06
Palbapang.
Position: /
GPS : [illegible] / [illegible]
Name :
No. Stories: 1 Built: 1960
Screener: Date: / /2010
Total Floor Area(sq/m²): 16 x 14
Building Name/Type: Limas / [illegible]
Use of Building : [illegible]

photograph

ccupancy			Population	Soil Type						Water Table			
Assembly Commercial Emer_servic	Govt Historic Industrial	Office Res School	Total : 3 0-10 11-100 101-1000 >1000	A Hard Rock	B Avg Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	<5 ft	5-10 Ft	10-15 Ft	>15 ft

Falling Hazard			
Unreinforced Chimney	Parapets	Cladding	Other

AMBRUK TOTAL (TOTALY DESTROYED) - TH. : 2260
t_2 : 62
-30 32
56 88
226
88
1,38

Low SEISMICITY:

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S															
BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	7.4	6.0	4.6	4.8	4.6	4.8	5.0	4.4	4.8	4.4	4.4	4.6	4.8	4.6	4.6
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.2	-0.2	+0.4	-0.2	-0.4	N/A	-0.2	-0.4	-0.2	-0.6
High Rise (>7 stories)	N/A	N/A	+1.0	+1.0	N/A	+1.0	+1.2	+1.0	0.0	-0.4	N/A	-0.2	N/A	0.0	N/A
Vertical Irregularity	-4.0	-3.0	-2.0	-2.0	N/A	-2.0	-2.0	-1.5	-2.0	-2.0	N/A	-1.5	-2.0	-1.5	-1.5
Plan Irregularity	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
Pre-Code	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Post-Benchmark	0.0	+0.2	+0.4	+0.6	N/A	+0.6	N/A	+0.6	+0.4	N/A	+0.2	N/A	+0.2	+0.4	+0.4
Soil Type C	-0.4	-0.4	-0.6	-0.4	-0.4	-0.4	-0.4	-0.6	-0.4	-0.4	-0.4	-0.2	-0.4	-0.2	-0.4
Soil Type D	-1.0	-0.8	-1.4	-1.2	-1.0	-1.4	-0.8	-1.4	-0.8	-0.8	-0.8	-1.0	-0.8	-0.8	-0.8
Soil Type E	-1.8	-2.0	-2.0	-2.0	-2.0	-2.2	-2.0	-2.0	-2.0	-2.0	-1.8	-2.0	-1.4	-1.6	-1.4

MODERATE SISMICITY

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	5.2	4.8	3.6	3.6	3.8	3.6	3.6	3.0	3.6	3.2	3.2	3.2	3.6	3.4	3.4
Mid Rise (4 to 7 stories)	N/A	N/A	+0.4	+0.4	N/A	+0.4	+0.4	+0.2	+0.4	+0.2	N/A	+0.4	+0.4	+0.4	-0.4
High Rise (>7 stories)	N/A	N/A	+1.4	+1.4	N/A	+1.4	+0.8	+0.5	+0.8	+0.4	N/A	+0.6	N/A	+0.6	N/A
Vertical Irregularity	-3.5	-3.0	-2.0	-2.0	N/A	-2.0	-2.0	-2.0	-2.0	-2.0	N/A	-1.5	-2.0	-1.5	-1.5
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-0.2	-0.4	-0.4	-0.4	-0.4	-0.2	-1.0	-0.4	-1.0	-0.2	-0.4	-0.4	-0.4	-0.4
Post-Benchmark	+1.6	+1.6	+1.4	+1.4	N/A	+1.2	N/A	+1.2	+1.6	N/A	+1.8	N/A	2.0	+1.8	N/A
Soil Type C	-0.2	-0.8	-0.6	-0.8	-0.6	-0.8	-0.8	-0.6	-0.8	-0.6	-0.6	-0.6	-0.8	-0.6	-0.4
Soil Type D	-0.6	-1.2	-1.0	-1.2	-1.0	-1.2	-1.2	-1.0	-1.2	-1.0	-1.0	-1.2	-1.2	-1.2	-0.8
Soil Type E	-1.2	-1.8	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6

HIGH SEISMICITY

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	4.4	3.8	2.8	3.0	3.2	2.8	2.0	2.5	2.8	1.6	2.6	2.4	2.8	2.8	1.8
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8
FINAL SCORE, S															1

COMMENTS: Building made of mud BRICK, the quality is not good. because the material only mix without reinforced. the building is ideally collapse.

Detailed Evaluation Required: YES NO

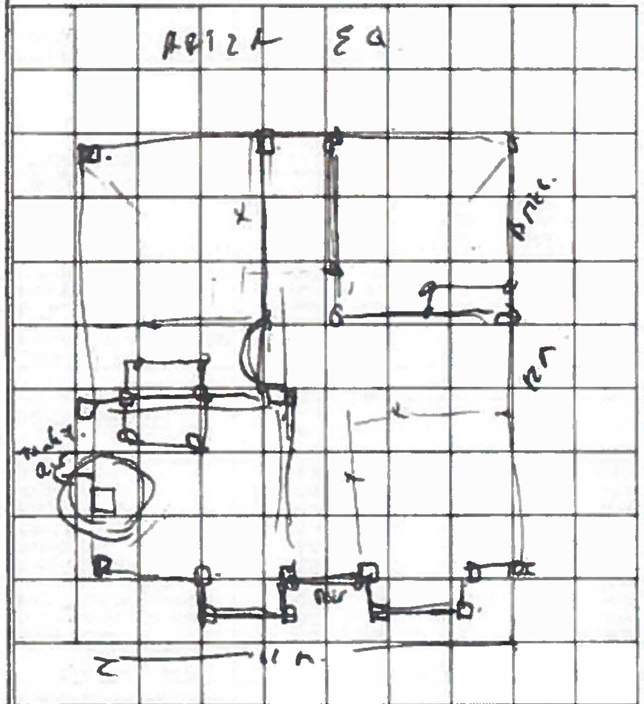
* = Estimated, subjective, or unreliable data
DNK = Do Not Know

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

RAPID VISUAL SCREENING OF BUILDING FOR POTENTIAL HAZARD (ADOPTED FROM FEMA 154)



Scale:
1 :

Name : [illegible]
Address : [illegible]
Position: /
GPS : 0926732 / 3125576
Name :
No. Stories: 1 Built: 2008
Screener: [illegible] Date: / /2010
Total Floor Area(sq/m²): [illegible]
Building Name/Type: RM B
Use of Building : [illegible]

ccupancy			Population	Soil Type						Water Table			
Assembly Commercial Emer_servic	Govt Historic Industrial	Office Res (circled) School	Total : 2 1-10 (circled) 11 - 100 101 – 1000 >1000	A Hard Rock	B Avg Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	<5 ft	5-10 Ft	10-15 Ft	>15 ft

Falling Hazard			
Unreinforced Chimney	Parapets	Cladding	Other

[illegible]

Low SEISMICITY:

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	7.4	6.0	4.6	4.8	4.6	4.8	5.0	4.4	4.8	4.4	4.4	4.6	4.8	4.6	4.6
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.2	-0.2	+0.4	-0.2	-0.4	N/A	-0.2	-0.4	-0.2	-0.6
High Rise (>7 stories)	N/A	N/A	+1.0	+1.0	N/A	+1.0	+1.2	+1.0	0.0	-0.4	N/A	-0.2	N/A	0.0	N/A
Vertical Irregularity	-4.0	-3.0	-2.0	-2.0	N/A	-2.0	-2.0	-1.5	-2.0	-2.0	N/A	-1.5	-2.0	-1.5	-1.5
Plan Irregularity	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
Pre-Code	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Post-Benchmark	0.0	+0.2	+0.4	+0.6	N/A	+0.6	N/A	+0.6	+0.4	N/A	+0.2	N/A	+0.2	+0.4	+0.4
Soil Type C	-0.4	-0.4	-0.8	-0.4	-0.4	-0.4	-0.4	-0.6	-0.4	-0.4	-0.4	-0.2	-0.4	-0.2	-0.4
Soil Type D	-1.0	-0.8	-1.4	-1.2	-1.0	-1.4	-0.8	-1.4	-0.8	-0.8	-0.8	-1.0	-0.8	-0.6	-0.8
Soil Type E	-1.8	-2.0	-2.0	-2.0	-2.0	-2.2	-2.0	-2.0	-2.0	-2.0	-1.8	-2.0	-1.4	-1.6	-1.4

MODERATE SISMICITY

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	5.2	4.8	3.6	3.6	3.8	3.6	3.6	3.0	3.6	3.2	3.2	3.2	3.6	3.4	3.4
Mid Rise (4 to 7 stories)	N/A	N/A	+0.4	+0.4	N/A	+0.4	+0.4	+0.2	+0.4	+0.2	N/A	+0.4	+0.4	+0.4	-0.4
High Rise (>7 stories)	N/A	N/A	+1.4	+1.4	N/A	+1.4	+0.8	+0.5	+0.8	+0.4	N/A	+0.6	N/A	+0.6	N/A
Vertical Irregularity	-3.5	-3.0	-2.0	-2.0	N/A	-2.0	-2.0	-2.0	-2.0	-2.0	N/A	-1.5	-2.0	-1.5	-1.5
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-0.2	-0.4	-0.4	-0.4	-0.4	-0.2	-1.0	-0.4	-1.0	-0.2	-0.4	-0.4	-0.4	-0.4
Post-Benchmark	+1.6	+1.6	+1.4	+1.4	N/A	+1.2	N/A	+1.2	+1.6	N/A	+1.8	N/A	2.0	+1.8	N/A
Soil Type C	-0.2	-0.8	-0.6	-0.8	-0.6	-0.8	-0.8	-0.6	-0.8	-0.6	-0.6	-0.6	-0.8	-0.6	-0.4
Soil Type D	-0.6	-1.2	-1.0	-1.2	-1.0	-1.2	-1.2	-1.0	-1.2	-1.0	-1.0	-1.2	-1.2	-1.2	-0.8
Soil Type E	-1.2	-1.8	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6

HIGH SEISMICITY

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	4.4	3.8	2.8	3.0	3.2	2.8	2.0	2.5	2.8	1.6	2.6	2.4	2.8	2.8	1.8
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.8	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8
FINAL SCORE, S								1.2						2.2	

COMMENTS

the dealin op. Material is good. because the owner is wealthy. 2.2.
even he also receive fund from pokmas.
the foundation is deep. abut 50 cm.

Detailed Evaluation Required

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Sample of Building survey in Kadirojo Sub Village Palbapang.

ID	Nama	Alamat	X	Y	Built	Storey	Total Area	BT Codes	Occupancy Class	Population	Built By	basic Score	Vertical Irregularity	Plan Irregularity	Q-Construction	Cladding	Soil	High.Seis	Building Codes	Probability of Complete Damage
102	Rejo Mulyono	Kadirojo RT 03	424175	9127002	2006	1	54	RM2L	Residential 1	3	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
103	Isman	Kadirojo RT 03	424159	9127025	2006	1	36	RM2L	Residential 1	3	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
104	Wahid	Kadirojo RT 03	424147	9127027	2006	1	36	RM2L	Residential 1	3	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
105	Sudiarjo	Kadirojo RT 03	424138	9127038	2006	1	93	RM2L	Residential 1	4	Pokmas	2.8	0	-0.5	0	0	-0.6	1.70	Low Code	0.02
106	wahid	Kadirojo RT 03	424145	9127034	2006	1	42	W1	Government 2	4	PMI	4.4	0	0	0	0	-0.6	3.80	Low Code	0.00
107	Masjid Al Fatah	Kadirojo RT 03	424138	9127019	2005	1	64	RM2L	Religious 1	15	JRF	2.8	0	0	0	0	-0.6	2.20	Low Code	0.01
108	Ponirah	Kadirojo RT 03	424118	9127019	2006	1	27	RM2L	Residential 1	1	JRF	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
109	Slamet	Kadirojo RT 03	424106	9127025	2006	1	42	RM2L	Residential 1	3	Pokmas	2.8	0	-0.5	0	0	-0.6	1.70	Low Code	0.02
110	Perwadiharjo	Kadirojo RT 03	424107	9127038	2006	1	36	RM2L	Residential 1	2	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
111	Sugipranoto	Kadirojo RT 03	424195	9127031	2006	1	54	RM2L	Residential 1	3	Pokmas	2.8	0	0	-0.25	0	-0.6	1.95	Moderate Code	0.01
112	Partodirojo	Kadirojo RT 03	424194	9127059	2006	1	36	RM2L	Residential 1	2	Pokmas	2.8	0	0	-0.25	0	-0.6	1.95	Moderate Code	0.01
113	Suhardi	Kadirojo RT 03	424175	9127043	2006	1	84	RM2L	Residential 1	3	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
114	Kardiyono	Kadirojo RT 03	424169	9127053	2006	1	54	RM2L	Residential 1	4	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
115	Wirodirejo	Kadirojo RT 03	424177	9127079	2006	1	64	RM2L	Residential 1	3	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
116	Sugeng Ono	Kadirojo RT 03	424173	9127077	2006	1	27	RM2L	Residential 1	3	JRF	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
117	Hadiutomo/Wakijan	Kadirojo RT 03	424156	9127072	2006	1	48	RM2L	Residential 1	4	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
118	Temu	Kadirojo RT 03	424144	9127108	2006	1	36	RM2L	Residential 1	2	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
119	Karyo Utomo	Kadirojo RT 03	424129	9127106	2006	1	27	RM2L	Residential 1	3	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
120	Maryadi	Kadirojo RT 03	424118	9127126	2006	1	58	RM2L	Residential 1	4	Pokmas	2.8	0	-0.5	0	0	-0.6	1.70	Low Code	0.02
121	Mardi Widodo	Kadirojo RT 03	424119	9127079	2006	1	120	RM2L	Residential 1	4	Pokmas	2.8	0	-0.5	0	0	-0.6	1.70	Low Code	0.02
122	Rindarti	Kadirojo RT 03	424114	9127070	2006	1	27	RM2L	Residential 1	3	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
123	Sogi	Kadirojo RT 03	424116	9127071	2006	1	36	RM2L	Residential 1	3	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
124	Bambang Kuntoro	Kadirojo RT 03	424104	9127064	2006	1	48	RM2L	Residential 1	4	Pokmas	2.8	0	-0.5	0	0	-0.6	1.70	Low Code	0.02
125	Muji raharjo	Kadirojo RT 03	424151	9127055	2006	1	48	RM2L	Residential 1	3	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
126	Dewi Sulastri	Kadirojo RT 03	424155	9126972	2006	1	27	RM2L	Residential 1	2	JRF	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
127	Dina Istanto	Kadirojo RT 03	424159	9126943	2006	1	27	RM2L	Residential 1	4	JRF	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
128	Joko Widodo	Kadirojo RT 03	424115	9126932	2006	1	27	RM2L	Residential 1	3	JRF	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
129	Parjiyem	Kadirojo RT 03	424170	9127081	2006	1	27	RM2L	Residential 1	3	JRF	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
130	Sukamto	Kadirojo RT 03	424090	9126972	2006	1	27	RM2L	Residential 1	3	JRF	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
131	Supriyono	Kadirojo RT 03	424088	9126973	2006	1	27	RM2L	Residential 1	4	JRF	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
132	SD Palbapang	Kadirojo RT 06	424776	9126807	2000	1	400	RM2L	Education 1	200	self-supporting.	2.8	0	0	0	0	-0.6	2.20	Low Code	0.01
133	TK Aisiayah	Kadirojo RT 06	424802	9126774	2000	1	90	RM2L	Education 1	30	self-supporting.	2.8	0	0	0	0	-0.6	2.20	Low Code	0.01
134	SD Aisyiah	Kadirojo RT 06	424783	9126665	2000	2	120	RM2L	Education 1	140	self-supporting.	2.8	0	0	0	0	-0.6	2.20	Low Code	0.01
135	Suparno	Kadirojo RT 08	424558	9126558	2006	1	27	RM2L	Residential 1	3	JRF	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
136	Ngadi Widodo	Kadirojo RT 09	424642	9126496	2006	1	27	RM2L	Residential 1	3	JRF	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
137	Ngadi Widodo	Kadirojo RT 09	424638	9126496	2006	1	30	W2	Residential 1	0	self-supporting.	3.8	0	0	-0.5	-0.5	-0.6	2.20	Low Code	0.01
138	Painah	Kadirojo RT 09	424628	9126510	2006	1	12	W1	Residential 1	1	self-supporting.	4.4	0	0	-0.5	-0.5	-0.6	2.80	Low Code	0.00
139	Dalikom Mrimo	Kadirojo RT 09	424617	9126503	2006	1	49	RM2L	Residential 1	5	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
140	Wasiati	Kadirojo RT 09	424597	9126515	2003	1	54	RM2L	Residential 1	3	Pokmas	2.8	0	0	0	0	-0.6	2.20	Low Code	0.01
141	Ribut	Kadirojo RT 09	424606	9126506	2009	1	54	RM2L	Residential 1	4	self-supporting.	2.8	0	-0.5	0	0	-0.6	1.70	Low Code	0.02
142	Anang	Kadirojo RT 09	424599	9126508	2009	1	48	RM2L	Residential 1	3	self-supporting.	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
143	Pak RT	Kadirojo RT 09	424596	9126510	2006	1	48	RM2L	Residential 1	5	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
144	Priyayi	Kadirojo RT 09	424589	9126509	2006	2	78	RM2L	Residential 1	1	self-supporting.	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
145	Wahid maryanto	Kadirojo RT 09	424624	9126485	2006	1	56	RM2L	Residential 1	5	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
146	Kartodimejo	Kadirojo RT 09	424616	9126520	2006	1	36	RM2L	Residential 1	4	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
147	Harno/Sarbini	Kadirojo RT 09	424647	9126523	2006	1	36	RM2L	Residential 1	5	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
148	Paidjah	Kadirojo RT 09	424646	9126525	2006	1	30	RM2L	Residential 1	6	Pokmas	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
149	Marijo	Kadirojo RT 09	424646	9126537	2006	1	50	RM2L	Residential 1	4	Pokmas	2.8	0	-0.5	0	0	-0.6	1.70	Low Code	0.02
150	Agus Sugiyanto	Kadirojo RT 09	424657	9126473	2006	1	27	RM2L	Residential 1	5	JRF	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
151	Ibnu Saud	Kadirojo RT 09	424623	9126440	2006	1	27	RM2L	Residential 1	3	JRF	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
152	Mujiyono	Kadirojo RT 09	424597	9126434	2006	1	27	RM2L	Residential 1	5	JRF	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01
153	Mujiyono	Kadirojo RT 09	424573	9126462	2006	1	27	RM2L	Residential 1	2	JRF	2.8	0	0	0	0	-0.6	2.20	Moderate Code	0.01

APPENDIX 13.

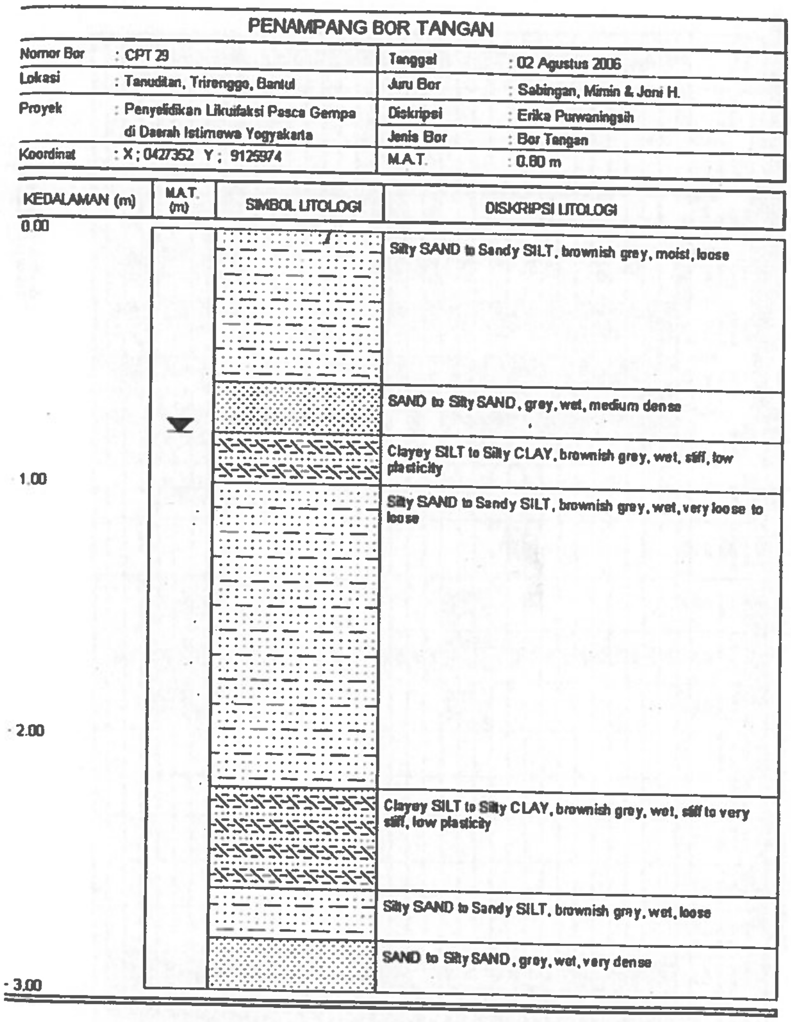
Some of Bore hole data in Palbapang Village and Surrounding Area. (Geology Agency)

KLIEN : Tim Jogyakarta
LOKASI : Jogyakarta (Bantul)

No.	Lab.	Contoh (sample)	Desa/ Kecamatan (location)	Jenis Batuan/ Formasi Batuan (Rock)	Kedalaman contoh (Depth) (m)	Koordinat UTM X	Koordinat UTM Y	Kadar Air (Water Content) w (%)	Berat Jenis (Specific gravity) Gs (-)	Asli (Bulk density) γ	Kering (Dry density) γd	Angka pori (Void ratio) e (-)	Porositas (Porosity) n (%)	Derajat Jenuh (Degree saturation) Sr (%)	Batas Cair (Liquid limit) LL (%)	Batas Plastis (Plastic limit) PL (%)	Indeks Plastis (Index plasticity) PI (%)	Batas Susut (Shrinkage limit) Ls (%)	Lempung (Clay)	Lanau (Silt)	Pasir Halus (Fine Sand)	Pasir Sedang (Medium Sand)	Pasir Kasar (Coarse Sand)	Kerikil Halus (Fine Gravel)	Kerikil Kasar (Coarse Gravel)	Kerakal (Cobble)	Group Symbol
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	21	22	23	24	25	26	27	28	29
1		R. 1	Candan			429617	9124040	9.84	2.723							NP				8.00	55.00	37.00					SM
2		R. 2	Petalan			429106	9124940	41.07	2.487							NP				29.00	63.00	8.00					SM
3		R. 3	Petalan			429012	9124590	11.44	2.764							NP				2.00	50.00	45.00	3.00				SM
4		R. 4	Dermah			426850	9123378	14.52	2.495							NP				2.00	71.00	27.00					SM
5		R. 5	Biro			426801	9117849	8.11	2.741							NP				5.00	14.00	66.00	10.00	5.00			SM
6		R. 6	Pertemuan sungai Oyo			429871	9120482	1.82	2.812							NP				2.00	7.00	91.00					SM
7		R. 7	Ngambeh			424282	9121493	31.21	2.453							NP				6.00	53.00	41.00					SM
8		R. 8	Ngambeh			424282	9121493	10.89	2.483							NP				11.00	56.00	27.00	3.00	3.00			SM
9		R. 9	Panjangrejo			428843	9118842	9.98	2.716							NP				3.00	65.00	28.00	4.00				SM
10		R. 10	Panjangrejo			428894	9118782	1.77	2.787							NP				6.00	88.00	6.00					SM
11		R. 11	Petrobayan			429484	9120780	9.50	2.779							NP				3.00	48.00	40.00	6.00	3.00			SM
12		R 12	Petrobayan			420471	9120633	41.56	2.544						53.64	29.39	24.27		26.00	59.00	15.00						MH
13		R 13	Munggur			442383	9138261	50.68	2.466						28.33	25.45	2.88		7.00	28.00	20.00	31.00	14.00				ML
14		R 14	Baleng kidul			434758	9133075	26.68	2.421						38.13	25.62	12.51		10.00	43.00	31.00	13.00	3.00				ML
15		R. 15A	Baleng kidul			434897	9129636	7.34	2.765							NP					16.00	64.00	12.00	8.00			SW
16		R. 15B	Pangkuran			434860	9129567	2.97	2.771							NP				8.00	35.00	49.00	8.00				SM
17		R 16	Trimulyo			433331	9129986	0.53	2.84							NP					4.00	35.00	14.00	37.00	10.00		SW
18		R. 17A	Gedangan			426679	9120311	6.71	2.823							NP				1.00	21.00	58.00	11.00	9.00			SM
19		R. 17B						2.06	2.490							NP				6.00	52.00	34.00	5.00	3.00			SM
20		R.18/S.19	Demangan			432800	9131468	31.85	2.842						38.46	25.59	12.87		16.00	39.00	20.00	17.00	6.00	2.00			ML
21		R.18/S.20	Panegaran			435560	9131397	18.49	2.576							NP				1.00	17.00	50.00	15.00	17.00			SM
22		R. 20	Druwo			430142	913334	29.24	2.491							NP			7.00	9.00	9.00	12.00	9.00	40.00	14.00		SM
23		R. 21	Kasongan			428848	9132844	36.71	2.484						51.43	33.19	18.24		11.00	45.00	32.00	10.00	2.00				MH
24		R. 22	Ngimbang			427830	9129306	26.28	2.449						31.73	23.91	7.82		10.00	38.00	35.00	14.00	3.00				ML
25		R. 23	Tunjungan			418948	9121308	37.67	2.449						36.46	22.81	13.65		22.00	20.00	18.00	40.00					ML
26		R. 24	Bungas			418542	9118724	50.14	2.574						43.52	27.38	16.14		23.00	29.00	14.00	12.00	7.00	15.00			ML
27		R. 25	Melangan			420848	9117644	48.58	2.543						48.1	31.67	20.43		30.00	22.00	12.00	16.00	13.00	7.00			ML
28		R. 26	Bunglaus			422948	9115244	41.94	2.552						52.46	29.76	22.70		27.00	47.00	17.00	7.00	2.00				MH
29		R. 27	Manding			428080	9127228	27.93	2.611						50.81	29.7	21.11		21.00	32.00	17.00	13.00	9.00	8.00			MH
30		R. 28	Tanuditan			427852	9125974	37.83	2.431						50.64	28.74	21.9		15.00	43.00	27.00	12.00	3.00				MH
31		R. 29	Sumberbolakan			429318	9128940	41.58	2.408						53.67	29.69	23.98		16.00	50.00	24.00	7.00	3.00				MH
32		R. 30A	Banaran			430857	9127857	29.02	2.483						23.81	21.44	2.07		10.00	33.00	38.00	15.00	4.00				ML
33		R. 30B						18.04	2.685							NP				4.00	21.00	37.00	13.00	21.00	4.00		SM
34		R. 31	Semail			430943	9131988	17.13	2.460							NP				8.00	54.00	35.00	3.00				SM

Bandung, November 2006
Ka Sub Bidang Laboratorium,

Ir. [illegible], M.Sc.
NIP. 100006788


PENAMPANG BOR TANGAN
Nomor Bor : CPT 29
Lokasi : Tanuditan, Trirenggo, Bantul
Proyek : Penyelidikan Likuifaksi Pasca Gempa di Daerah Istimewa Yogyakarta
Koordinat : X ; 0427352 Y ; 9125974
Tanggal : 02 Agustus 2006
Juru Bor : Sabingan, Mimin & Joni H.
Diskripsi : Erika Purwaningsih
Jenis Bor : Bor Tangan
M.A.T. : 0.80 m
KEDALAMAN (m)
M.A.T. (m)
SIMBOL LITOLOGI
DISKRIPSI LITOLOGI
0.00
1.00
2.00
3.00
Silty SAND to Sandy SILT, brownish grey, moist, loose
SAND to Silty SAND, grey, wet, medium dense
Clayey SILT to Silty CLAY, brownish grey, wet, stiff, low plasticity
Silty SAND to Sandy SILT, brownish grey, wet, very loose to loose
Clayey SILT to Silty CLAY, brownish grey, wet, stiff to very stiff, low plasticity
Silty SAND to Sandy SILT, brownish grey, wet, loose
SAND to Silty SAND, grey, wet, very dense

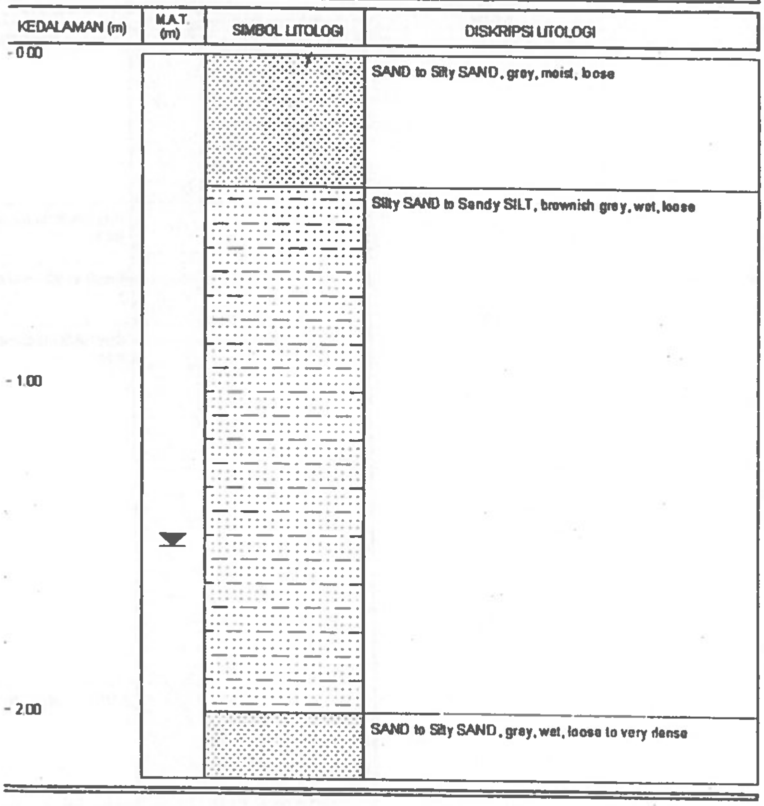
PENAMPANG BOR TANGAN

Nomor Bor	: CPT 18	Tanggal	: 29 Juli 2006
Lokasi	: Gedangan, Palbapang, Bantul	Juru Bor	: Sabingan, Mimin & Joni H.
Proyek	: Penyelidikan Likuifaksi Pasca Gempa di Daerah Istimewa Yogyakarta	Diskripsi	: Erika Purwaningsih
		Jenis Bor	: Bor Tangan
Koordinat	: X ; 0424559 Y ; 9124761	M.A.T.	: 1.50 m

KEDALAMAN (m)	M.A.T. (m)	SIMBOL LITOLOGI	DISKRIPSI LITOLOGI
- 0.00			SAND to Silty SAND, grey, dry, loose
			Silty SAND to Sandy SILT, brownish grey, dry, very loose to loose
			SAND to Silty SAND, grey, moist, loose to medium dense
- 1.00	▼		Silty SAND to Sandy SILT, brownish grey, wet, very loose to loose
- 2.00			SAND to Silty SAND, grey, wet, dense

PENAMPANG BOR TANGAN

Nomor Bor	: CPT 31	Tanggal	: 02 Agustus 2006
Lokasi	: Banaran, Sumberagung, Jetis	Juru Bor	: Sabingan, Mimin & Joni H.
Proyek	: Penyelidikan Likuifaksi Pasca Gempa di Daerah Istimewa Yogyakarta	Diskripsi	: Erika Purwaningsih
		Jenis Bor	: Bor Tangan
Koordinat	: X ; 0430667 Y ; 9127657	M.A.T.	: 1.50 m



PENAMPANG BOR TANGAN

Nomor Bor	: CPT 02	Tanggal	: 26 Juli 2006
Lokasi	: Canden, Jetis, Bantul	Juru Bor	: Sabingan, Mimin & Joni H.
Proyek	: Penyelidikan Likuifaksi Pasca Gempa di Daerah Istimewa Yogyakarta	Diskripsi	: Erika Purwaningsih
		Jenis Bor	: Bor Tangan
Koordinat	: X ; 0429449 Y ; 9123961	M.A.T.	: 1,20 m

KEDALAMAN (m)	M.A.T. (m)	SIMBOL LITOLOGI	DISKRIPSI LITOLOGI
0.00			Silty SAND to Sandy SILT, blackish brown, dry, loose
1.00			Clayey SILT to Silty CLAY, dark brown, moist, soft, low plasticity
	▼		Silty CLAY to CLAY, dark brown, wet, soft - very soft, medium plasticity
			Silty SAND to Sandy SILT, brownish grey, wet, loose
2.00			Clayey SILT to Silty CLAY, brown, wet, soft, medium plasticity
			Silty SAND to Sandy SILT, brown, wet, loose
			Clayey SILT to Silty CLAY, brown, wet, firm, medium plasticity
3.00			Silty SAND to Sandy SILT, grey, wet, loose
4.00			SAND to Silty SAND, grey, wet, medium dense
			Silty SAND to Sandy SILT, grey, wet, loose
5.00			SAND to Silty SAND, grey, wet, loose
			Silty SAND to Sandy SILT, grey, wet, loose
			Clayey SILT to Silty CLAY, brown, wet, stiff, medium plasticity
6.00			Silty SAND to Sandy SILT, grey, wet, medium dense
			SAND to Silty SAND, grey, wet, very dense
7.00			

PENAMPANG BOR TANGAN

Nomor Bor	: CPT 28	Tanggal	: 01 Agustus 2006
Lokasi	: Manding, Trirenggo, Bantul	Juru Bor	: Sabingan, Mimin & Joni H.
Proyek	: Penyelidikan Likuifaksi Pasca Gempa di Daerah Istimewa Yogyakarta	Diskripsi	: Erika Purwaningsih
		Jenis Bor	: Bor Tangan
Koordinat	: X ; 0428875 Y ; 9127258	M.A.T.	: 4.0 m (sumur gali setempat)

KEDALAMAN (m)	M.A.T. (m)	SIMBOL LITOLOGI	DISKRIPSI LITOLOGI
0.00			Silty SAND to Sandy SILT, brownish grey, dry, verry loose to loose
1.00			SAND to Silty SAND, grey, dry, loose to medium dense
			Silty SAND to Sandy SILT, brownish grey, dry, loose
- 2.00			SAND to Silty SAND, grey, dry, loose
			Silty SAND to Sandy SILT, brownish grey, dry, loose
- 3.00			SAND to Silty SAND, grey, moist, loose to medium dense