

# EARTHQUAKE DAMAGE ASSESSMENT: APPLICATION AND VERIFICATION OF THE RADIUS METHOD TO YOGYAKARTA EARTHQUAKE 2006

Kusworo Darpito\*  
MEE09193

Supervisor: Kenji OKAZAKI\*\*  
Shin KOYAMA\*\*\*

## ABSTRACT

In order to reduce earthquake disasters, Indonesia needs a regional planning based on the disaster mitigation. It is also necessary to make people aware of the risk of earthquakes. By using tool that can simulate the damage caused by an earthquake, an increase in the public awareness of earthquake hazards can be expected and it will enrich the regional planning based on disaster mitigation.

This study focused on the Yogyakarta Earthquake that occurred on May 27, 2006. This study employed an application of RADIUS program to estimate the damage of the buildings and number of casualties in Klaten Regency. The estimated number of the damaged buildings was much smaller than the actual damage while the number of casualties was rather close.

Considering the limitation of the RADIUS method and the conditions in Indonesia, we made some revision of the RADIUS program, such as: the effect by the movement of the fault into attenuation, the higher vulnerability function of the brick masonry houses, the smaller casualty coefficient of the temporary and semi-temporary houses, and the definition of the day time, considering the actual intensities, construction methods, and life style in Klaten Regency. After these revisions, the RADIUS estimate came to be much closer to the actual damage. The revised RADIUS program is more suitable for Indonesia. It is expected that the revised program will be used in other areas in Indonesia with slight modification, considering the differences in local conditions.

**Keywords:** Earthquake damage estimate, Yogyakarta Earthquake, RADIUS Program.

## 1. INTRODUCTION

In the phenomena of natural disasters, earthquakes occur almost every year in Indonesia, causing many deaths and injuries and extensive property damage. However the impact of these earthquakes can be reduced by disaster mitigation. For disaster mitigation, the participation of government and society is required. The government needs to raise public awareness of those who live in this earthquake-prone country: a big earthquake in populated areas could cause damages in many residential houses. Many local people build their house without complying with earthquake resistant standards. This study is expected to produce a program that can simulate the amount of damages caused by an earthquake, reflecting the conditions in Indonesia.

## 2. DATA

For this study, we take data from the Klaten Regency in the Central Java Province before earthquakes on Year 2005 and actual damages caused by Yogyakarta earthquake in 2006, as follows:

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\* Ministry of Public Work, the Republic of Indonesia.

\*\* Professor, National Graduate Institute for Policy Studies (GRIPS), Tokyo Japan.

\*\*\* International Institute of Seismology and Earthquake Engineering (IISEE), BRI, Japan.

- Total population and distribution by districts;
- Total number of the buildings, building types and their distribution by districts;
- Ground condition (soil type);
- Casualties and damage of the building;

The data can be obtained from several sources, such as Media Center, the statistic agency (BPS) and National Coordination Agency for Surveys and Mapping. The Data include the number of houses, type of houses and their distribution in each district; we make some assumptions because of limited information, while for the ground condition we can obtain information from the Local Statistic Agency of Klaten and Geological Map of the Surakarta – Giritontro Quadrangles, Jawa release by the National Coordination Agency for Surveys and Mapping (BAKOSURTANAL).

### 3. METHODOLOGY

This study employs an application of RADIUS program to estimate the damage of the buildings and number of casualties based on the earthquake, ground condition, demographic data and vulnerabilities functions. The program is very suitable for developing countries like Indonesia. Earthquake Hazard will be estimated from parameters of the scenario earthquake and ground conditions. Damage will be estimated from hazard and the existing structures in the area calculated from not only by the number of structures, but also by types of the buildings. Casualties such as deaths and injuries are also estimated from the number of damaged buildings.

This study focuses on the Yogyakarta Earthquake that occurred on May 27, 2006, with magnitude of 6.3 Richter scale, at 5:54 morning in Java local time. The depth was 10 KM, in South West direction of Klaten Tengah, with epicenter at 31 Km from Klaten Regency (data source from USGS).

As for Klaten Regency the data on year 2005 are obtained, and we put into RADIUS program for estimation, and then the estimation result will be compared with the actual damage caused by the Yogyakarta Earthquake 2006. After comparison, we will make some proposal for revision of the RADIUS program.

### 4. DAMAGE ESTIMATION

The earthquake hazard is estimated from the earthquake scenario and ground conditions. Damage is estimated from the hazard and the existing structure in the area, which depends not only on the number of structure, but also on the types of the building or life line facilities, by using vulnerability functions derived for each type of structure. Vulnerability functions reflect the relationship between seismic intensity and degree of structure; casualty is estimated from the number of damaged buildings with information on the number of people inside building during the day and night. In Figure 1 , a general flow of earthquake damage estimation by RADIUS Program, is shown

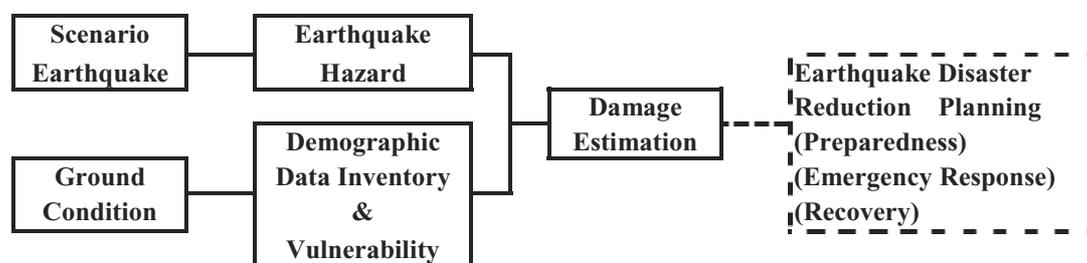


Figure 1. General flow of earthquake damage estimation

While to estimate the damage caused by the earthquake, step by step as follow:

**Step 1: Basic Data Inventory**

**1.1 Target region identification**

Population in Klaten Regency as of 2005 : 1,286,058

Total number of buildings as of 2005 : 331,890

For identification Klaten Regency divided into 5 (five) regions, as in figure:

**1.2 Mesh/Grid :**

For this case study the scale mesh/grid is divided into 1 km<sup>2</sup>, with total area of 656 km<sup>2</sup>.

**1.3 Mesh numbering**

In this case study the meshes are numbered using integers between 1 and 656.

**1.4 Mesh ID**

The RADIUS program automatically assigns Mesh ID values to meshes from left to right and top to bottom.

**1.5 Area ID**

26 areas were defined, so that they represent each district.

**1.6 Mesh weight**

Mesh weight classification is related with building density in Klaten Regency, based on the authors view.

- 1 = between 100 and 400 building per km<sup>2</sup>
- 2 = between 400 and 750 building per km<sup>2</sup>
- 3 = between 750 and 1,500 building per km<sup>2</sup>
- 4 ≥ 1,500 building per km<sup>2</sup>

**Step 2: Soil Amplification Setting**

The user enters the local soil type classifications in the Basic Input Data sheet, for each of the mesh in the target region, such that:

- 0 = Unknown
- 1 = Hard Rock/Bed Rock
- 2 = **Soft Rock**
- 3 = **Sedimentary Rock/Average Stiff Soil**
- 4 = Soft Soil/ Land Fill/ Reclaimed Land

**Step 3: Structure inventory setting**

Because the data is not complete enough, to obtain the number of houses in each district, an assumption has to be made.

**Building Classes**

In the Klaten Regency building classes are divided into 7 types of buildings.

**Step 4: Arranging population distribution**

Klaten regency is divided into 26 districts with different number of population and density. Total of population in 2005 is 1,286,058.



Figure 2. Map of Klaten Regency

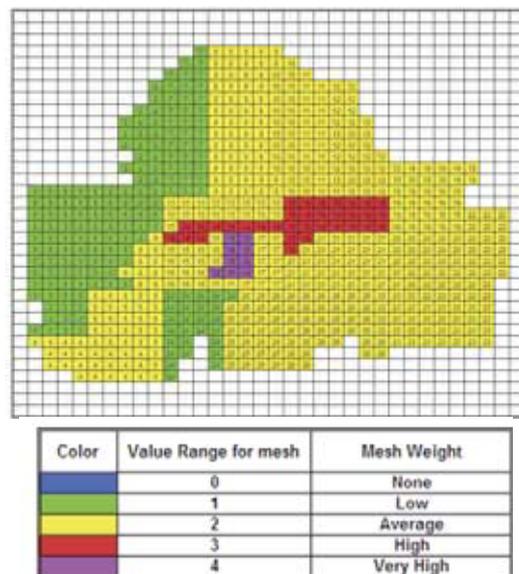


Figure 3. Mesh weight distribution

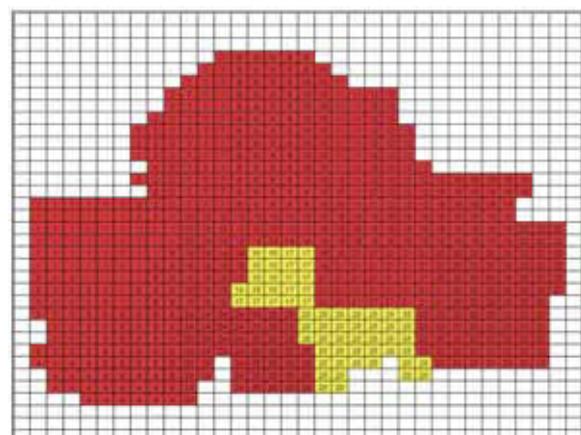


Figure 4. Soil Type Distribution Map in the Klaten Regency

**Step 5: Defining Scenario Earthquake**

For this case study we used the attenuation equation from Joyner & Boore, because this attenuation equation is used for shallow earthquakes (Yogyakarta earthquake is relatively shallow). For the scenario earthquake, we used the Yogyakarta Earthquake in May 27, 2006, with magnitude of 6.3, at 5:54 AM local time in Java, and the depth was 10 km, and epicenter 31 km with direction in the South West of Klaten Regency according to the source data from USGS. The reference mesh is determined as 289, which is supposed to the center (down town) of Klaten Regency.

**Step 6: Calculation of base rock motion and surface motion and converted into PGA, and converted into MMI**

By using the attenuation equation from Joyner & Boore, the maximum intensity was in the Prambanan District with the average MMI of 7.2. For the minimum intensity was in the Wonosari, Klaten Tengah, Kalikotes, Juwiring, Karang Dowo and Bayat Districts with the average MMI of 5.9. The differences of the intensity are influenced not only by the distance from the epicenter but also by the local soil conditions.

**Step 7: Calculate damage to the building**

The number of buildings damaged is 20,231. The result shows the highest damage percentage and total number of buildings damaged in Ramadan District, and the lowest in Kalikotes District.

**Step 8: Calculate Casualties**

It is described that there are about 12,642 people (approximately 0.98 % of the total population) who will be injured and about 861 people (approximately 0.07 % of the total population) will be dead by the earthquake. In this estimate, buildings were damaged largely in Prambanan District. Thus, the casualties in this district are also larger than other districts.

**Step 9: Summarize Results**

The largest damaged buildings, deaths and injuries are found in Prambanan District and the lowest in Kalikotes District.

**5. COMPARISON**

The damages calculated by the RADIUS Program are both collapse and heavy damage, light damage is not considered. In this study, comparison will be made based on building collapse and major damage data from media center. Thus, lifeline damage is not considered.

In some district the media center data is greater than RADIUS result, and the largest damaged was Gantiwarno District (11,919 buildings damaged) but the largest damaged based on RADIUS result was in Prambanan District (2,140 buildings damaged). Overall comparison found difference of 75,534 about the buildings damage, which is approximately 78.87 %, as shown in table 1.

RADIUS results for casualty are close to the actual events (table 2). In the data of death toll from Media Center, the biggest death toll was found in Wedi (319 people) and for injury it was in Gantiwarno District (9,136 people). From RADIUS Program, however, the highest casualties are found in Prambanan District (death 163 people and injury 2,061 people).

Total Number of Building Damage Media Center	Major Damaged & collapse Media Center	Radius Building Damage	A/B
	A	B	
339,245	95,765	20,231	4.7

Table 1. Comparison of damage of the buildings

Media Center		Radius		A/C	B/D
Death	Injury	Death	Injury		
A	B	C	D		
994	18,128	861	12,642	1.2	1.4

Table 2. Comparison of casualties

## 6. PROPOSED REVISION OF RADIUS PROGRAM

### 6.1 Attenuation Equation

The USGS data on the event of the Yogyakarta Earthquake says that result of the average MMI in the Klaten Regency is 9, the average intensity observed by Dwikorita Karnawati et al. are also higher than RADIUS Program (between 7.3 and 8.3), but the result of this program is about 6.28 MMI. In reality, there is a movement of the fault from epicenter to the Klaten Regency, particularly in the Gantiwarno District and Prambanan District, but the RADIUS program does not consider this condition. In the case that the earthquake is very close and shallow, the adjustment of attenuation equation is necessary. In order to simplify this process, it is attempted to make changes to the epicenter distance from 31 km to 20 km to obtain the similar intensity.

### 6.2 Building Damage Coefficient

To conform to the condition in Indonesia, we replaced vulnerability coefficient function for damage to the building type RES 2. The replacing coefficient of vulnerability function for damage to the building adjusted to the conditions in Java. References used to replace this coefficient are based on the paper written by K. Meguro. In the paper, the relation between buildings collapse and intensity for masonry houses obtained from the field surveys is shown as the figure 5. Because the curves only represent the masonry house, we decide to change to the coefficient of vulnerability function for the RES 2 in the program.

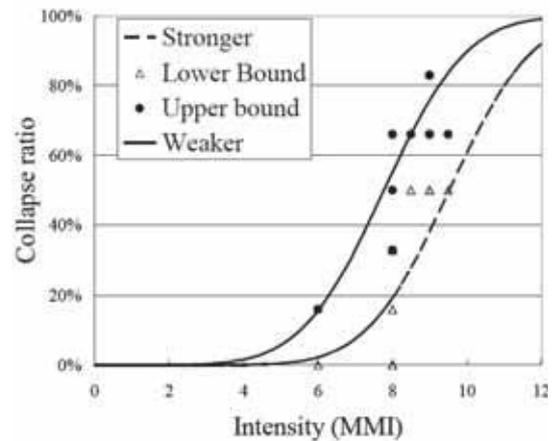


Figure 5. Fragility function of masonry houses in Java by K. Meguro

### 6.3 Death Coefficient Ratio

According to the building condition in Klaten Regency, people commonly build their house by utilizing the light materials for the roof and walls, such as bamboo, woods, zinc tile and clay tile which is made by the traditional method in Indonesia. It is expected that less people will be killed by collapse of this type of buildings. Therefore, it is attempted to change the casualty coefficients in the RADIUS Program by decreasing the coefficients of the RES1 by half.

### 6.4 Definition of Day Time

In Indonesia most people are Muslims, so in the early part of days, they go to a mosque to pray. Then, their activities are usually outside the house starting from early morning around 5 am. Therefore a change of the day-time, adjusting to the habits of the society in Klaten Regency, is needed. Day time in the RADIUS Program is defined as from 6 AM to 6 PM and night time is defined as from 6 PM to 6 AM, but with regards to the habits of society in Klaten District we change day time from 5 AM to 6 PM and night time from 6 PM to 5 AM.

### 6.5 Result after revision

After making changes in above, the results of the damage amount came much closer to the actual damage amount from 20,231 to 54,148, as shown in table 3. Changes in the day-time adjusted to the actual life style of local communities and also in the coefficient of casualty can be affecting to the number of the death and injured are quite close to the actual event, as shown in table 4.

Media Center Data A	RADIUS Original	RADIUS Modification B	A/B
95,765	20,231	54,148	1.8

Table 3. Comparison of damage of the buildings

Media Center		Original		Modification		A/C	B/D
Death A	Injury B	Death	Injury	Death C	Injury D		
994	18,128	861	12,642	1,116	22,271	0.6	0.8

Table 4. Comparison of casualties

## 7. CONCLUSION

We calculated building damage and casualties caused in Klaten Regency which was severely hit by Yogyakarta earthquake 2006. RADIUS estimate is smaller than actual buildings damage and casualty was close to the actual damage, however there are some revisions to be made, as follows:

1. The effect of the movement fault from the epicenter towards the Klaten Regency during the earthquake was not reflected in the RADIUS program. In this program, attenuation equation would not represent the actual intensity well as the epicentre is very close and shallow. Therefore it is necessary to consider this kind of effect in the RADIUS program.
2. Vulnerability functions of the buildings damage in this program need some change to adapt to the conditions on Klaten Regency. We increased the coefficient of RES 2 so that it becomes 30 % more fragile than the original condition.
3. According to the building condition in Klaten Regency houses are made by light materials, therefore we decreased the death coefficients RES1 to half.
4. The day time must be adapted to the actual life style in Klaten Regency

We made some changes in the vulnerability coefficient function for damage of the building, the intensity, casualty of death coefficients and the day time in the RADIUS Program so that it can be adapted to the conditions in Indonesia. Tentatively this program may be used for Klaten Regency and Java Island, where the housing condition are similar to Klaten Regency, but we still need other case studies to ensure that this revised program can be used for all over in Indonesia. It is expected that the program is disseminated to raise public awareness on the seismic risk in Indonesia.

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## REFERENCES

- Karnawati D., Pratumijoyo S., Anderson R., Husein S., 2008, the Yogyakarta Earthquake of May 27, 2006.
- Meguro, K., 2008, "Technological and Social Approaches to achieve Earthquake Safer Non-Engineered Houses", Journal of the World Conference on Earthquake Engineering October 12-17, Beijing, China,
- BAPPENAS (National Development Planning Agency), 2006, Preliminary Damage and Loss Assessment Yogyakarta and Central Java Natural Disaster, A Joint Report from BAPPENAS, the Provincial and Local Governments of D.I.Yogyakarta, the Provincial and Local Governments of Central Java, and international partners, June 2006.
- Kaneko F., OYO International Corporation, RADIUS Program Methodology
- BPS- Statistics of Klaten Regency, Klaten in Figure 2005