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Peak Ground Acceleration and Earthquake Intensity Microzonation in Watukumpul, Pemalang Regency

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ABSTRACT

Watukumpul is located in Pemalang District, Central Java, which is adjacent to the fault seismotectonic line of Baribis fault in the north and subduction area of the Eurasian and Indies-Australian plates in the south. It makes Watukumpul often experiences an earthquake. This study aimed to map the peak ground acceleration calculated using the Kanai equation and earthquake intensity calculated using Wald equations in Watukumpul. This study used historical earthquake data occurred in 1988-April 2018 from the International Seismological Center and microtremor measurements of 33 points. Microtremor data were processed using the Horizontal to Vertical Spectral Ratio method and resulted the predominant period of study area ranged from 0.13 to 0.74 s. The results showed that the study area had a PGA value of 26.93 - 63.25 gal. The intensity calculation showed that the study area has the potential for earthquake damage with an III-IV MMI scale.

Keywords: Kanai, Watukumpul, Intensity, Earthquake

INTRODUCTION

Watukumpul is a sub-district in Pemalang Regency, Central Java, located close to the north coast of Java, passed through the Yogyakarta-Semarang seismotectonic transect in the form of the Baribis fault line (Soehaimi, 2008) and subduction zone between the Eurasian and Indo-Australian plates in the south of Java (Ashadi, 2015). There are active Faults in the Pemalang area, namely the Logeni-Rambut river fault, Wuluh river fault and the secondary fault of Logeni river which are estimated to cause earthquakes with magnitude 6.5 Mw (Badan Geologi, 2009). The potential of earthquake sources around the Watukumpul area, Pemalang Regency needs more attention so that it is necessary to map vulnerable areas of earthquake damage as a first step in disaster mitigation and spatial planning.

In this study, the mapping of earthquake-vulnerable areas was carried out based on Peak Ground Accelerance (PGA) values and earthquake intensity. The value of PGA is the largest land acceleration experienced by an area due to the vibration of the earthquake reaching the area (Broptopuspito, 2006). PGA calculations to determine the susceptibility of an area due to an earthquake have been carried out by various researchers using various attenuation equations including the Boore-Atkinson equation, Youngs (Eva, 2016), Kanai (Permatasari, 2016), Mc Guire (Marlisa, 2016), Fukushima-Tanaka (Saputra, 2010).

The study used Kanai equation because, in addition to the strength and distance of the earthquake, this equation takes into account the predominant period factor. The value of the predominant period describes the geological characteristics of the area (Marjiyono, 2014). The level of earthquake damage is not only caused by the strength, duration and period of the earthquake, but also by the characteristics of the soil layer in response to the vibration of the earthquake (geological conditions) (Nakamura, 1997). The parameters of the predominant period in this study were known from the results of the microtremor measurement of 33 points which were processed using the Horizontal to Vertical Spectral Ratio (HVSR) method.

The earthquake intensity describes the level of damage arising from an earthquake in an area (Prabowo, 2015) The earthquake intensity parameters illustrate the level of damage arising from an earthquake in an area so that the results of calculations of intensity are able using as a reference in urban planning and building according to SNI 1726: 2012.

METHOD

The PGA calculation in this study based on historical earthquake data and the microtremor measurement data. The earthquake data used in this study came from the International Seismological Center which earthquake magnitude above 3 and the earthquake source located at 106^0 to 115^0BT and -3^0 to -11^0 LS. The microtremor data used in this study were 33 measurement points (Figure 1) which were measured using a 3 component seismometer of MAE type with measurement duration of 20-40 minutes and a sampling rate of 100.

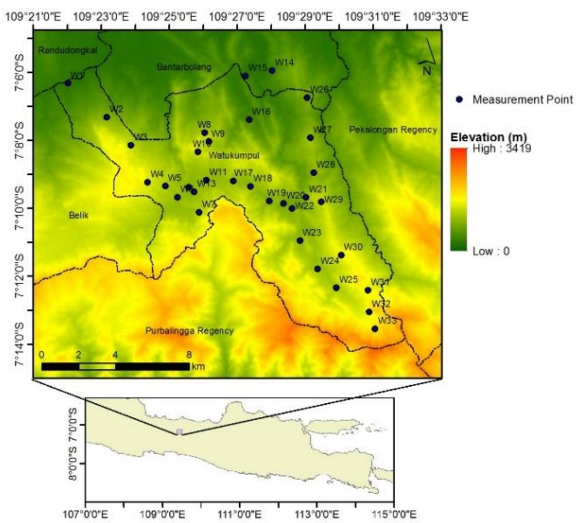

Figure 1. Microtremor Measurement Point

The microtremor measurements data were processed using Geopsy software based on the HVSR method and processing criteria from the Sesame Europan Research Project (Bard, 2005). In the HVSR method, the value of the predominant period is determined based on the peak frequency value of the comparison results of the vertical and horizontal component spectrum expressed in the equation as follows (Nakamura, 1989).

$$HVSR = \frac{\sqrt{H_{EW}^2 + H_{NS}^2}}{V} \quad (1)$$

with HVSR is the HVSR ratio spectrum, H_{EW} is the horizontal component spectrum in the east-west direction, H_{NS} is the spectrum of horizontal components in the north-south direction and V is the spectrum of vertical components.

The value of the predominant period and earthquake data was used to calculate the PGA based on the Kanai empirical equation as follows (Douglas, 2018)

$$a = \frac{5}{\sqrt{T}} 10^{\left[(0,61M) - \left(1,66 + \frac{3,60}{R}\right)\log_{10} R + \left(0,167 - \frac{1,83}{R}\right)\right]} \quad (2)$$

with a is the value of PGA (gal), T is the value of the predominant period (second), M is the magnitude of the earthquake in SR and R is the hypocenter distance of the earthquake.

Hypocenter length is calculated based on the length between hypocenter location and microtremor measurement point while earthquake magnitude data is in SR scale conversion (Tim Pusat Studi Gempa Nasional, 2018).

Earthquake intensity (IMM) was calculated based on the following equation (Wald, 1999)

$$IMM = 3,66 \ \log a - 1,66 \quad (3)$$

RESULT AND DISCUSSION

Predominant Period

The results of microtremor data processing using the HVSR method resulted in the value of the predominant period of land in the study area which ranged from 0.13-0.74 s (Figure 2). The value of the predominant period describes the thickness of the surface sediment (Ibs-von Seht, 1999).

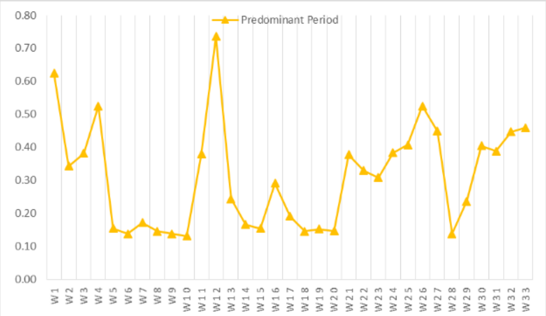

Figure 2. Predominant period of HVSR processing results.

In Figure 3, the study area with a low period value (<0.23 s) is located in Gapura, Watukumpul, and Jojogan village so that it depicts a thin surface sediment layer.

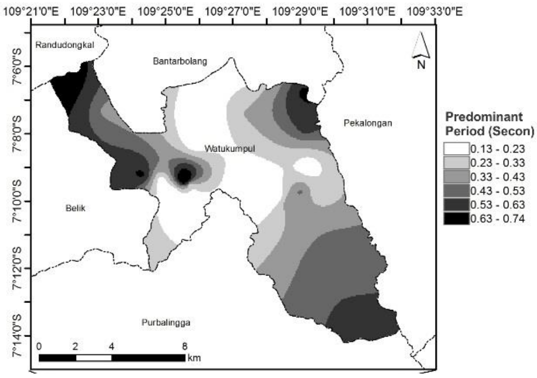

Figure 3. The predominant period of the research area

Peak Ground Acceleration (PGA)

The calculation results showed that the study area has a PGA value of 26.93 - 63.25 gal. The high PGA values are in Gapura, Watukumpul and Jojogan village (Figure 4) which have a low predominant period value. The predominant frequency value describes the local geological factors that affect the PGA value (Wibowo, 2016).

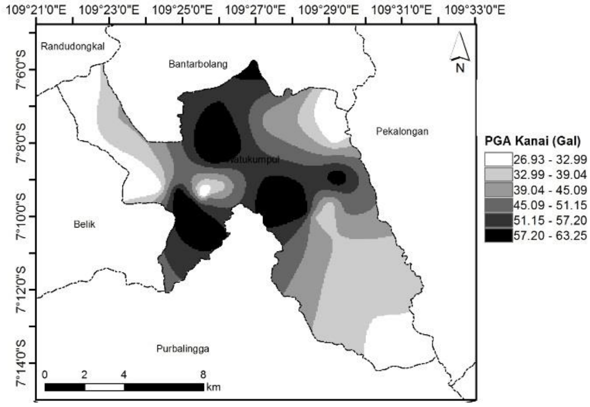

Figure 4. PGA research area

The PGA value of Watukumpul was used to determine earthquake vulnerability based on the classification showed in Table 1 and Table 2. Based on Table 1, the study area has very low to a 1st medium risk category and based on Table 2 the area has the low-risk level category. These results indicated that the study area tends to be safe when experiencing earthquake vibrations so that building in I to III categories can be made according to the risk categories of buildings and non-buildings for earthquake load SNI 1726, 2012.

Table 1. Classification of the level of earthquake risk (Fauzi, 2001)

No.	Risk Level	Value PGA (gal)
1	Very low	0- 25
2	Low	25 – 50
3	Medium I	50 – 75
4	Medium II	75 – 100
5	Medium III	100 – 125
6	High I	125 – 150
7	High II	150 – 200
8	High III	200 – 300
9	Very high I	300 – 600
10	Very high II	> 600

Table 2. Classification of the risk level of earthquake damages according to BNPB Regulatory Chief No. 2 of 2012

Disaster	Risk Level Class		
	Low	Medium	High
Earthquake	PGA <0,250g	0,2501g < PGA < 0,70g	PGA > 0,701g

Earthquake Intensity

The intensity calculation showed the study area has the potential for earthquake damage with a scale of III-IV MMI (Figure 5). The higher the level of intensity, the higher the potential damage in the area according to the BMKG criteria in Table 3.

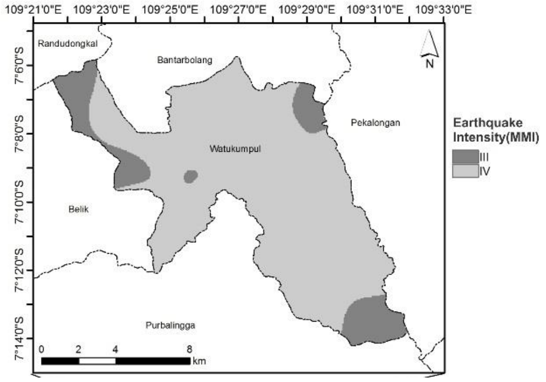

Figure 5. Earthquake intensity of the research area

Areas with moderate damage potential with an IV intensity scale are in the villages of Tundagan, Wisnu, and Medayu while other regions have mild damage potential with III intensity scale.

Table 3. BMKG Scale Intensity (Wibowo, 2017)

SIG BMKG Scale	Simple Description	Detail Description	MMI Scale	PGA (gal)
I	Not felt	Not felt or felt by some people but recorded by the device	I-II	<2,9
II	Felt	Many people felt it but did not cause damage. Light objects hung swaying, and the glass window shook	III-IV	2,9-88
III	Minor damage	Non-structural buildings have minor damage such as hair cracks on the walls, tiles shift down and some fall	VI	89-167
IV	Medium damage	Many cracks occurred on the walls of simple buildings, some collapsed, broken glass. Some plaster walls are loose. Most tiles shift down or fall. The structure of the building has minor to moderate damage	VII-VIII	168-564
V	Heavy damage	Most of the walls of permanent buildings collapsed. The structure of the building suffered severe damage. Railroad arches.	IX-XII	>565

CONCLUSION

Microtremor data was processed using the HVSR method and resulted the predominant period value of the study area which ranges from 0.13-0.74 s so the building in the area must has a higher predominant period.

The PGA value indicates that the study area is included in the category of low earthquake vulnerability with intensity scale of III-IV MMI so that the study area feels the vibration of the earthquake but does not cause damage.

The results of this study are expected to be material in the needs of earthquake disaster mitigation in the study area where the I to III building categories according to the risk categories of buildings and non-buildings for earthquake load SNI 1726, 2012 can be made in the study area. The building of IV category buildings is expected to be able to first carry out further studies on the level of quality of buildings and land by taking into account the slope conditions that are susceptible to landslides.

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