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THE ACCELERATION RESPONSE SPECTRUM AND EFFECTIVE DURATION OF LEBAK EARTHQUAKE JANUARY 23, 2018 IN JAKARTA REGION

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ABSTRACT

Jakarta as a capital city of Indonesia with a very high population density and varies of buildings distribution causes many areas of Jakarta to have a high vulnerability to natural disasters; one is an earthquake. It felt this year was Lebak Banten Earthquake January 23, 2018, with a magnitude 6.1 at 13.34 local time. It has the depth 61 km at -7.09° S - 106.03° E, in the South Indian Ocean of Java Island. The epicenter was 43 km from Cilangkahan Village, Malingping Sub-district, Lebak District, Banten. We analyze the ground motion characteristics in the Jakarta area using 3 component acceleration data at Jakarta City Hall Office (JAKO) and Tanjung Priok Maritime Station (JATA) with dynamic statistical analysis method. The effective duration and earthquake response spectrum are determined using the acceleration data. In this study, the effective length of the earthquake was calculated using the Trifunac and Brady method. The results show that the most significant acceleration spectrum at JAKO station is found in component E of 0.07742 g in the period of 0.54 s while for the largest acceleration spectrum JATA station found in component N of 0.04572 g in the period of 0.58 s. The effective duration obtained at JAKO stations was 56.76 s and JATA station 63.47 s. These results indicate that in the case of the Lebak earthquake, the further region from the epicenter of the earthquake has an effective duration which is relatively longer.

Keywords: acceleration response spectrum, Lebak earthquake, effective duration, Jakarta

INTRODUCTION

The population density is one of the factors that causes the vulnerability level of a region to a natural disaster will be higher because it is feared that a large number of fatalities and significant material losses. Jakarta as the largest city, which has an area of approximately 661.52 km² (with sea area: 6,977.5 km²), with a population of 9,607,787 inhabitants [1]. As a capital, it is reasonable if Jakarta has a high population density compared to other regions in Indonesia as well as the buildings. It caused Jakarta to be vulnerable to natural disasters, one of which was an earthquake. Jakarta is in the area affected by seismic sources, there is the subduction zone resulting from the subduction of the Indo-Australian and Eurasian plate collisions, on the east side there are local faults such as Cimandiri and Lembang in West Java that have a sinistral mechanism [2][3] also the Baribis fault [4]. On the other side, based on geological conditions, Jakarta is located on a basin of groundwater, known as the Jakarta Groundwater Basin where the entire land of the DKI Jakarta area consists of alluvial deposits in the Pleistocene era ± 50 m thick [5]. It causes we need disaster mitigation that is good at, after or before the occurrence of natural disasters.

On January 23th, 2018 there was a significant earthquake with the epicenter Lebak, Banten 7.13°S and 106.04°E at a depth of 61 km. The earthquake that occurred in the southern Java subduction area precisely 43 km south of Cilangkahan Village, Malingping District, Lebak Regency, Banten Province has an oblique mechanism that tends to rise and produces magnitude 6.1 Mw [6]. According to damage data obtained from the BPBD, this earthquake resulted in two minor injuries, six seriously injured and damaged many buildings, namely 1,231 buildings with details of 1,125 minor damage and 106 severe damage including 475 damaged housing units and one damaged house of worship [7]. From the events of the earthquake, mitigation efforts are needed to reduce casualties and losses due to the earthquake in the future.

The duration of strong ground vibrations during an earthquake make an important role in material response and foundation structure [8]. The duration of the strong ground vibration is one of the main parameters to analysis and design of earthquake resistant structures because the effects of earthquake damage, as well as the operational reliability of equipment, are often associated with duration of strong shock [9]. The total duration of the earthquake is not a single parameter that is good for potential damage caused by an earthquake. It prompted experts to develop the effective duration of the earthquake [10]. In general, peak ground acceleration (PGA) is used to measure ground motion. However, the preferred parameter is the earthquake acceleration spectrum. The earthquake spectrum response provides valuable information about the period in which acceleration reaches a maximum. The acceleration spectrum will be related to the maximum shear forces acting based on the structure [11]. The concept of acceleration spectrum response was first incorporated into US building codes in the end 1950s [12].

This study aims to analyze the characteristics of the Lebak earthquake January 23th, 2018 using records of earthquake acceleration of JAKO and JATA stations on Jakarta area. It reviewed are effective duration and spectrum of earthquake acceleration. The earthquake acceleration spectrum also compared with the earthquake spectrum response design that is calculated based on the provisions in SNI-1726: 2012 [13].

RESEARCH METHOD

The data comes from three-component accelerograph (E, N, Z) of two BMKG station recordings located at the Jakarta City Hall Office (JAKO) with coordinates 6.1815°S - 106.829° E and Tanjung Priok Maritime station (JATA) with coordinates 6.1079°S - 106.8804°E with 100 Hz sampling rate. The acceleration data obtained then used to see the effective duration and earthquake spectrum response using seismosignal software. Spectrum response is a dynamic statistical analysis method that measures the contribution of each natural mode of vibration to indicate the possibility of a maximum seismic response from an elastic base structure. The spectrum response is utilized to building design because it deals with the structure type of dynamic motion selection [14]. The acceleration value generated from accelerograph changed in unit *g* (acceleration). The results are then used as input to determine the response of the spectrum of three components of the earthquake, namely N, E, Z.

The responsive design of the acceleration spectrum at the JAKO and JATA station locations for different types of soil namely very dense soil and soft rock (SC), medium soil (SD), soft soil (SE) was determined based on the rules in SNI-1726: 2012. Besides that from the recorded acceleration data on both stations the effective duration was calculated. In this study, the effective duration of the earthquake was calculated using the Trifunac and Brady method [15] where the effective duration of an earthquake is the duration of accumulated squared integration values which are limited to 5% to 95% of the total value. The accumulated integration value of acceleration (in *g*) squared multiplied time interval (Δt). Generally, the time intervals which effective duration is needed as a comprehensive earthquake hazard assessment must include the expected estimated duration of strong motion, which first requires criteria to determine which part of the accelerogram is considered to represent a duration of strong ground motion [8].

To determine the spectrum response design based on the provisions SNI-1726: 2012, several calculation stages are used. S_s and S_1 data are needed at JAKO and JATA stations. S_s is the acceleration parameter of the MCE spectrum response from earthquake maps on short periods, and S_1 is the acceleration parameter of MCE spectrum response from earthquake maps on a long period. Then gradually calculate F_a, F_v, S_{MS}, S_{M1}, S_{DS}, S_{D1}, T_0, T_S to produce acceleration spectrum response design at both stations. TABLES 1 and 2 show the F_a and F_v determination.

TABLE 1. Site coefficient for F_a short periods

Station	F_a value for each S_s				
	$S_s \leq 0.25$	$S_s = 0.5$	$S_s = 0.75$	$S_s = 1.0$	$S_s \geq 1.25$
Ver dense soil and soft rock (S_c)	1.2	1.2	1.1	1.0	1.0
Medium soil (S_D)	1.6	1.4	1.2	1.1	1.0
Soft soil (S_E)	2.5	1.7	1.2	0.9	0.9

TABLE 2. Site coefficient for F_v long periods

Station	F_v value for each S_1				
	$S_1 \leq 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 \geq 0.5$
Ver dense soil and soft rock (S_C)	1.7	1.6	1.5	1.4	1.3
Medium soil (S_D)	2.4	2.0	1.8	1.6	1.5
Soft soil (S_E)	3.5	3.2	2.8	2.4	2.4

F_a is the site coefficient for short periods (0.2 seconds), and F_V is the site coefficient for a long period (1 second). If the F_a value and F_V value are in the range of two grades S_s or S_1, then the F_a value or F_V value can be searched by the interpolation method in EQ. 1.

$$Y = \frac{y_2 - y_1}{x_2 - x_1}(X - x_1) + y_1 \qquad (1)$$

with:

Y = F_a value or F_v value which search
X = S_s value or S_1 value from BMKG
x_2 = S_s upper limit or S_1 upper limit on table
x_1 = S_s lower limit or S_1 lower limit on table
y_2 = F_a upper limit or F_v upper limit on table
y_1 = F_a lower limit or F_v lower limit on table

S_{MS} is a parameter for MCE spectrum response acceleration in the short period 0.2 second that has been adjusted to the effect of the site class whereas S_{M1} is a parameter for MCE spectrum response acceleration in the long period of 1 second which has been adjusted to the effect of the site class, formulated in EQ. 2 and 3.

$$S_{MS} = F_a . S_S \qquad (2)$$

$$S_{M1} = F_V . S_1 \qquad (3)$$

The parameters for spectrum response acceleration in the short period S_{DS} and the spectral response acceleration parameters in period 1 second S_{D1} are determined using EQ. 4 and 5.

$$S_{DS} = \frac{2}{3} S_{MS} \qquad (4)$$

$$S_{D1} = \frac{2}{3} S_{M1} \qquad (5)$$

S_a is the acceleration value of Y-axis on the acceleration spectrum curve. If $T_S < T_0$, then S_a uses EQ. 6.

$$S_a = S_{DS\left(0.4 + 0.6\frac{T}{T_0}\right)} \qquad (6)$$

But if $T_0 > T_s$ then S_a uses EQ. 7

$$S_a = \frac{S_{D1}}{T} \qquad (7)$$

where T_0 and T_S are calculated based on EQ. 8 and 9.

$$T_0 = 0.2 \frac{S_{D1}}{S_{DS}} \quad (8)$$

$$T_S = \frac{S_{D1}}{S_{DS}} \quad (9)$$

Furthermore, the response spectrum acceleration of the Lebak earthquake January 23th, 2018 at JATA and JAKO stations were compared with the spectrum response design calculated using the provisions of SNI-1726: 2012 for several types of soil.

RESULTS AND DISCUSSION

The results showed that the acceleration spectrum of the Lebak earthquake January 23th, 2018 at JAKO station had the highest value in component E with a value about 0.07742 g in the period 0.54 seconds. At JATA station the highest acceleration spectrum is component N about 0.04572 g in the period 0.58 seconds. If the value is compared with the value of acceleration spectrum response design calculated based on the provisions of SNI-1726: 2012, the value of acceleration spectrum of Lebak earthquake at JAKO and JATA stations are still far below the spectrum response design for both locations, both for hard soil types (SC) , medium soil (SD), or soft soil (SE). FIGURE 1 shows the acceleration spectrum of the Lebak earthquake on January 23th, 2018 compared to the spectrum response design referring to SNI 1726: 2012 for JAKO stations, while FIGURE 2 is a comparison of the acceleration spectrum of Lebak January 23, 2018, with spectrum response design referring to SNI 1726: 2012 for JATA stations.

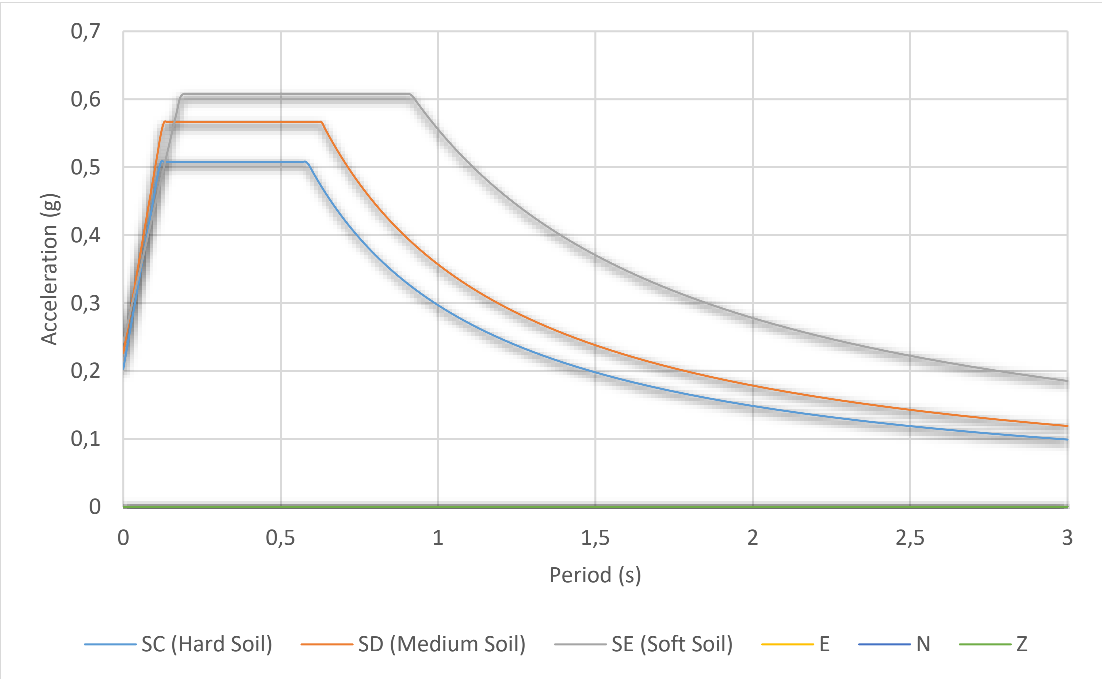

FIGURE 1. The comparison of spectrum response designs according to SNI-1726:2012 with the acceleration spectrum of the Lebak Banten earthquake January 23th, 2018 at JAKO station.

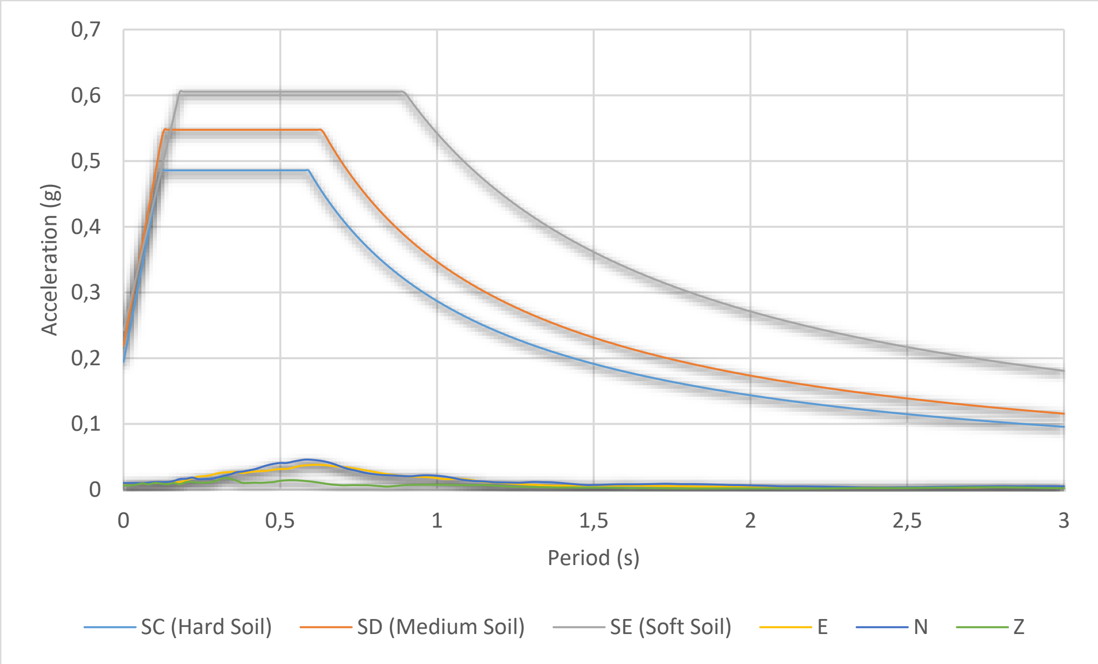

FIGURE 2. The comparison of spectrum response designs according to SNI-1726:2012 with the acceleration spectrum of the Lebak Banten earthquake January 23th, 2018 at JATA station.

The acceleration spectrum response design for JAKO and JATA stations at SC, SD, and SE sites refers to SNI 1726:2012 having similarities where the highest acceleration in soft soil type (SE) is followed by medium (SD), then hard soil (SC). There is a difference for acceleration spectrum response value SNI-1726:2012 for each site and short period (0.2 seconds) and long periods (1 second) as shown in TABLE 3. These indicate for different locations it is possible there is a difference in the value of the acceleration spectrum response design [10]. It determined based on SNI-1726:2012 are still much higher than the spectrum of the Lebak earthquake acceleration so that the effects on buildings are relatively small.

On the other side, the calculation of effective duration shows a correlation that is directly proportional to the distance of the epicenter. JATA Station has an epicenter distance that is farther than JAKO. The effective duration of the Lebak earthquake in the JATA station is much longer than the JAKO station (FIGURE 3). The farther the epicenter distance to the station, longer the effective duration produced (TABLE 4). It because it takes a longer time for the earthquake to reach the arias intensity of 5% - 95% [15].

TABLE 3. Comparison of the maximum value of the Lebak earthquake acceleration spectrum in three components E, N, Z and acceleration spectrum response design according to SNI-1726:2012 for S_C, S_D, S_E

Station	Component E	Component N	Component Z	S_C	S_D	S_E
JAKO	0.07742 g	0.06172 g	0.03092 g	0.50794 g	0.56652 g	0.60756 g
JATA	0.03790 g	0.04572 g	0.01783 g	0.48573 g	0.54747 g	0.60547 g

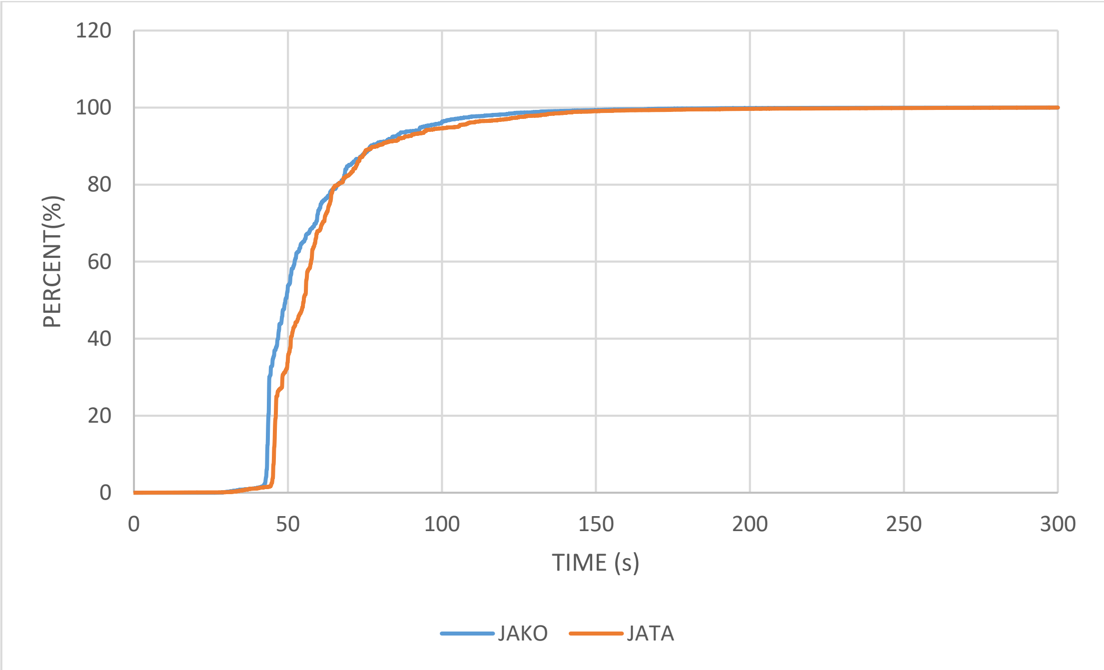

FIGURE 3. Effective duration of Lebak Banten earthquake January 23th, 2018 at JAKO and JATA stations.

TABLE 4. The comparison of the effective duration with the epicenter distance of the Lebak Banten earthquake January 23th, 2018 to JAKO and JATA stations

Station	Epicenter Distance (km)	Latitude (º)	Longitude (º)	Effective Duration (dt)
JAKO	134.295	-6.1815	106.829	56.76
JATA	144.2018	-6.1079	106.8804	63.47

The duration of a strong soil shock during an earthquake can play an important role in material response and foundation structure, especially when strength or stiffness degradation is encountered [8]. In the future, the acceleration spectrum of the earthquake, especially significant and destructive earthquakes, needs to be analyzed to review the earthquake hazard map in Indonesia. Research using other methods is also required to complement the results of the study as earthquake disaster mitigation, especially in the Jakarta area.

CONCLUSIONS

The acceleration spectrum of Lebak earthquake January 23th, 2018 at JAKO station reached a maximum of 0.07742 g in component E and period 0.54 seconds, while for the JATA station the maximum spectrum was 0.04572 g in component N and period 0.58 seconds. The acceleration spectrum response design calculated using the provisions of SNI-1726: 2012 at JAKO and JATA stations, on Jakarta area is still much higher than the acceleration spectrum of Lebak Banten earthquake January 23th, 2018 for hard soil types (SC), medium soil (SD), also soft soil (SE). The effective duration of the Lebak earthquake is directly proportional to the epicenter distance of the earthquake to both stations.

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