Ground motion database for Lombok-Sumbawa back arc thrust in 2007-2021 period

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Abstract. The Back Arc Thrust Zone in northern part of Lombok- Sumbawa region is considered as destructive earthquake source due to 5th August 2018 event which cause high loss in West Nusa Tenggara Province. Hence, development of ground motion is necessary in hazard assesment. We present a database of ground motion from accelerograph recordings, together with metadata on earthquake source parameter and site condition. We also conducted magnitudo moment conversion and hypocenter relocation to increase the data quality. The database includes 136 event that have occurred in The Back Arc Thrust area for the period 2007-2021. It consists of 281 recorded accelerograph from five sites. This database improves significantly the uniformly metadata for use in ground-motion prediction equation (GMPE) development and other engineering applications

1. Pendahuluan

Lombok has one of an area of active seismicity. This condition is due to complex tectonic that Lombok area surrounded by four seismic source zones. For example; the southern part is subduction zone and the northern part is back arc thrust. Moreover, in the western & eastern part are Lombok Fault and Sumbawa Fault which have strike-slip fault trending NNE-SSW [1]. Based on historical destructive events, there were various earthquakes causing building collapse and fatalities. One of the most destructive was Lombok Earthquake 2018.

According to BMKG, Lombok Earthquake had two significant events. The sequence was occurred in the northern part of Lombok Island. The first mainshock began on 28 July with an Mw 6.4. Then, on 19 August 2018an Mw 6.9 earthquake. Overall, the earthquake caused 7.1 trillion economic loses [2]. For the future plan, it is a need to conduct investigation of local site characteristics, ground motion prediction equation, and seismic hazard analysis to estimate the damage in Lombok region accurately. One of the powerful tools to make them easier is the existence a strong-motion database of Lombok. Previously, there was a study related to strong motion analysis, but it only concerned on determination of attenuation relation in Mataram city [3]. Therefore, we conducted strong motion database analysis in larger area and spesific earthquake source, that is in Lombok Sumbawa back arc thrust zone.

2. Data and Method

In this study, we selected events within the broader Flores-Sumbawa back arc thrust region bounded by 7.72° - 8.56°S and 114.61° - 118.83° E, because our intention in the present work to include only earthquake triggered by thrusting mechanism. The earthquake classification was made on the basis of epicentral location to back arc thrust, depth and magnitude. There are three existing catalogues from BMKG, USGS, & ISC-EHB from 2007 to present and a relocated event between 2009 and 2017 from Mataram Geophysical Station using double-difference method [4]. The magnitude used to characterize the database is Moment Magnitude (Mw) using Taruna's formula [5]. Shear-wave velocity in the upper 30 m of the site (Vs30), is utilized to determine site condition. In this study, the value of Vs30 and the site categories following the BMKG's measurement and slope calculation from USGS.

In this study, we deliberately choose suitable data that match with Lombok-Sumbawa back arc thrust zone. It is causative role that a strong-motion database has to include particular type of earthquake, due different effect [6]. We focus on the event that have magnitude greater than 3.0 and epicenter distance ≤ 300 km. Specially for the 2018 Lombok earthquake, we used BMKG's catalogue because more accurately and completely determined.

Before using this input, we did the relocation because of the lack of finite fault data in Indonesia region. Therefore, determining earthquake hypocenter with better quality is needed. Relocating the earthquake hypocenter is applied double-difference algorithm to fix the better depth and distance earthquake-station [6]. The algorithm can repair a velocity model and create the relocation more sense than pre-relocation [7][8][9][10]. The basic calculation is based on the difference of travel time between two earthquakes to the station which the distance of earthquake is shorter than earthquake to the station.

$$\frac{\partial t_k^i}{\partial m}\,\Delta m^i - \frac{\partial t_k^i}{\partial m}\,\Delta m^j = dr_k^{ij} \qquad (1)$$

∂t_k^{ij} is the travel time of earthquake wave to the k station. Δm^{ij} is the change of relative hypocenter parameter. dr_k^{ij} is the residual between observed and calculated event at the same k station.

All existing catalogues provide various magnitude type. We did to convert magnitude scale into Moment Magnitude (Mw). The magnitude used to represent the earthquake size since it does not saturated [11][12]. We applied Taruna's formula [5] to convert the scale especially in West Nusa Tenggara region according to Table 1. Based on these steps, the composite catalogue is presented in figure 5.

Table 1. Correlation of Conversion for West Nusa Tenggara Region

No	Correlation Conversion	Range Mag
1	Mw = 1.0166M – 0.2207	2.93 ≤M≤7.16
2	Mw = 1.1993mb – 1.2261	3.67≤mb≤6.99
3	Mw = 0.6191Ms + 2.3965	2.8≤6.1

Mw is the moment magnitude, mb is body wave magnitude, and M is summary magnitude.

Ground motion amplitude in the surface is influenced by the shear wave velocity of near surface media [13]. Shear wave velocity in the top 30 m (Vs30) is able to characterize the site amplification [14]. In Indonesia, there is a lack of site condition information. So, we compose the Vs30 data based on Multi Analysis of Surface Wave (MASW) measurement conducted by BMKG and slope calculation from USGS [14]. Table 2 shows the NEHRP site classification [16]. There is also a table with Vs30 value obtained from previous ways.

Table 2. The NERP Site Classification

Category	**Soil Profile Name**	**Vs (30m) (m/sec)**
A	Hard Rock	Vs > 1524
B	Rock	762 < Vs ≤ 1524
C	Very dense soil and soft rock	366 < Vs ≤ 762
D	Stiff soil profile	183 < Vs ≤ 366

E	Soft soil profile	Vs < 183

The accelerometers deployed are mainly Trident sensors in West Nusa Tenggara. We are conducting ground motion measurements using three stations. Determining peak ground acceleration (PGA) is derived from the largest amplitude with peaks and valleys using obspy [17]. The amplitude begins from ground motion with units of counts. After that we applied baseline adjustment and multiplied by factor coefficient on each sensor. Figure 1 illustrates the example of raw data and the waveform after doing baseline adjustment and factor coefficient used in this study.

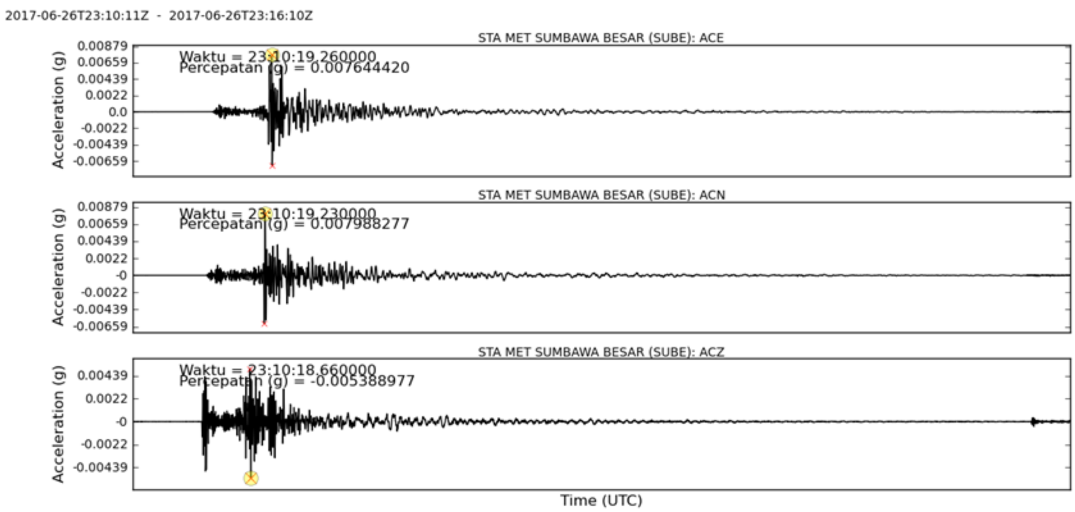

Figure 1. Example of accelerograms which is processed in this study

3. Data dan Analisa

a. Earthquake location

After the fixing process, we found 136 events which meet our criteria. Those events are presented in Figure 2 which showed distribution of back arc thrust eearthquake between 2007-2021. Most of events are located in northern part of Lombok Island due to the 5th August 2021 Lombok earthquake. Only few events are located in Bali and Northern part Bima-Sumbawa.

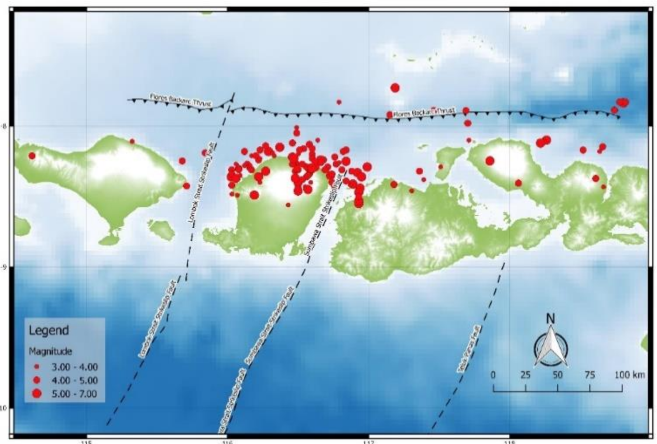

Figure 2. Map of earthquake data in Lombok-Sumbawa back arc thrust region used in this study

Fixing parameter also have contribution in increasing depth data quality, especially after relocation process which is shown in figure 3. We found that parameter from ISC-EHB and BMKG relocated earthquake had better quality than other catalogues which had fix depth parameter (10 Km). Besides, the magnitude data relatively decreased after being converted to moment magnitude, as we can see there were 2.9 Mw magnitude. Earthquake location, depth, and magnitude parameters had most significant influence in estimating strong motion. Recent study of strong motion also needed Finite fault solution, but these data are rarely found in this area.

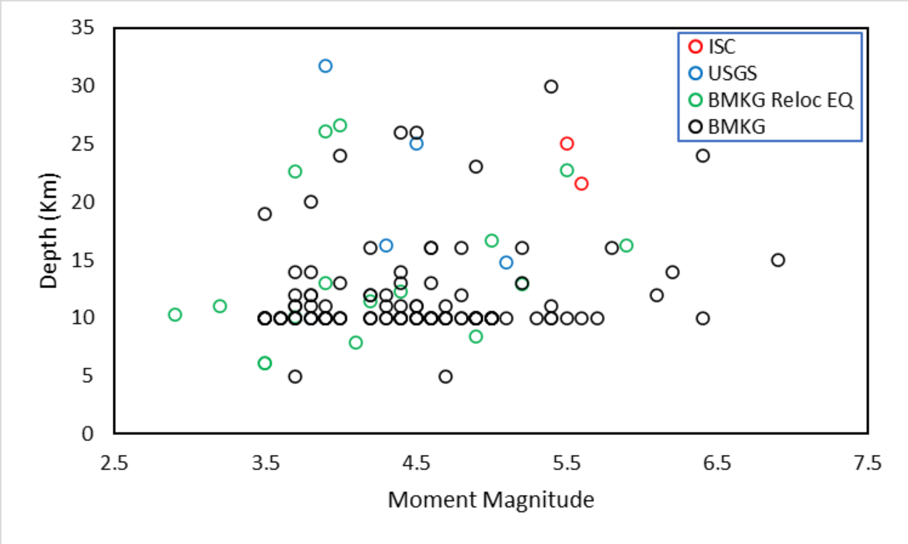

Figure 3. Depth distribution with respect to moment magnitude from various catalogue

b. Site Parameter

We collect Vs30 data from BMKG and USGS and found MASW (multichannel analysis of surface waves) measured data of 2 sensor and 7 Vs30 based on topographic slope. Vs30 data is used to classify site class of each sensor/station. So, we can estimate the amplification of ground motion. Some site class like soil type can produce higher peak ground acceleration in a site. Figure 4 shows distribution of accelerograph used in this study. Yellow circle present Vs30 value which is measured using MASW and triangle symbolize slope based Vs30 data. Generally, all of station had low Vs30 which can be interpreted as D or C site class based on NEHRP. These D or C class can amplify the strong motion of earthquake.

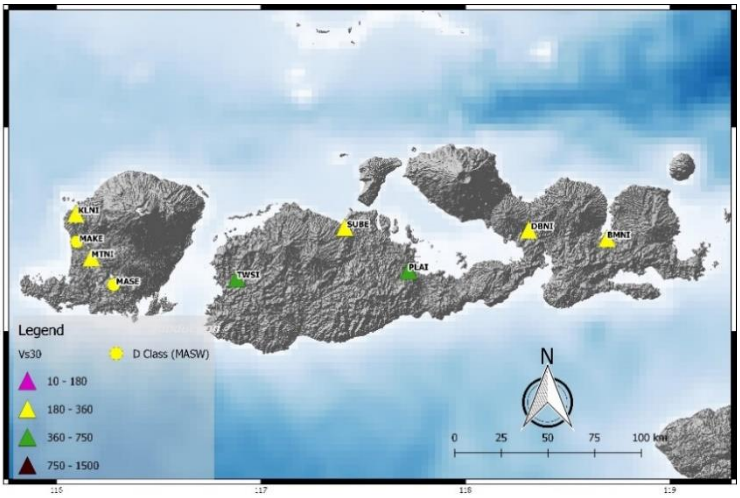

Figure 4. Distribution of accelerograph in West Nusa Tenggara

c. *Database anatomy*

In this study we collected 281 recordings from 136 events. Figure 5 shows the cumulative number of events and recordings in the database as a function of time. The majority of the records have been collected in 2018, producing 75% of the events. There were many significant events since the 2018 Lombok Earthquake. They tend to be poorly recorded due to the reduction of seismic activity other than 2018. In other side ratio of recording to number of event relatively increase in recent year and can be interpreted as improvement of sensor quantity and quality.

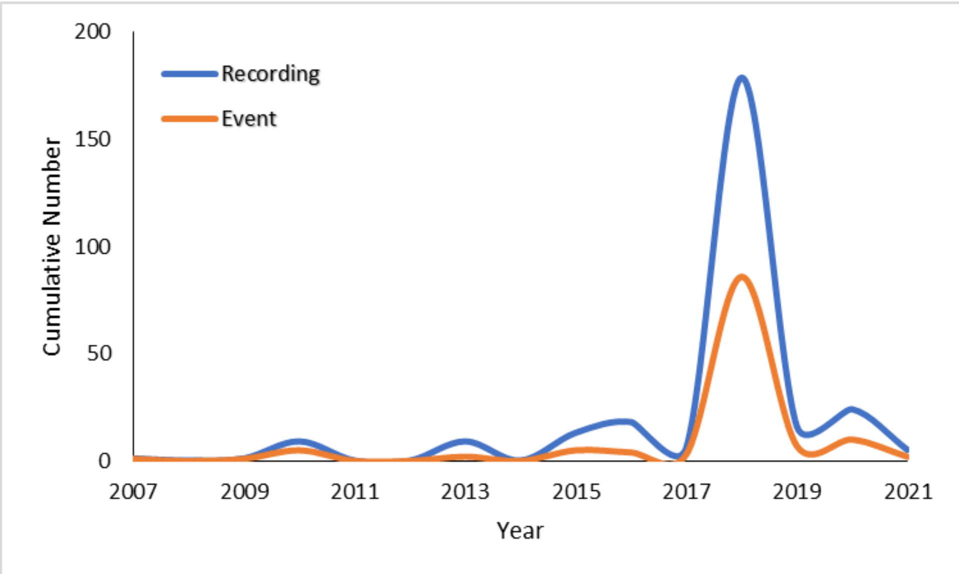

Figure 5. Cumulative numbers of accelerograph recording and earthquake events in 2007-2021 period

Figure 6 illustrates the attributes of event between hypo center distance and moment magnitude (Mw). The database is well populated for the 100-300 km distance range, for magnitude between about 2.5 and 7. There are very few recordings less than 20 km and the maximum distance for M >5,5 is 300 km.

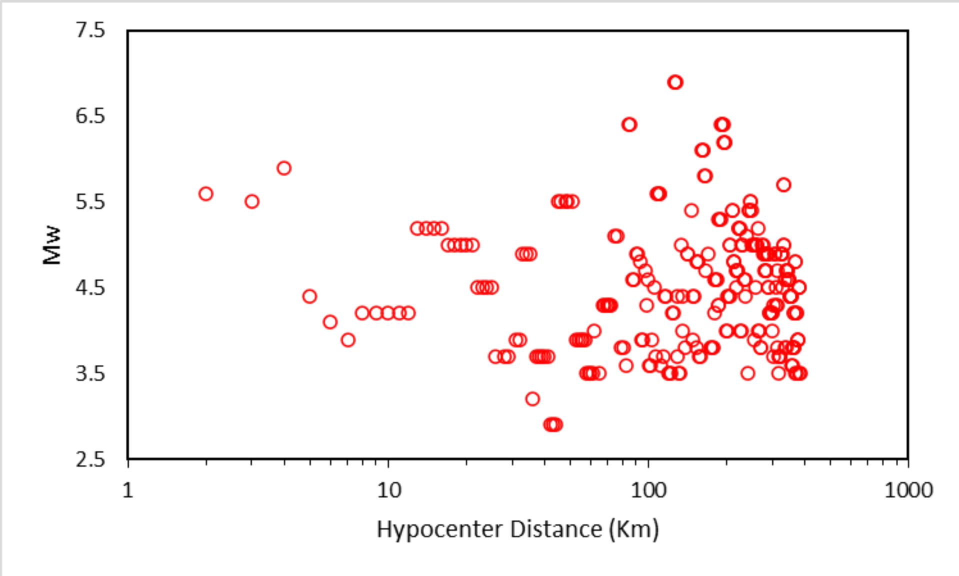

Figure 6. Distribution of Strong Motion Data in hypocenter distance vs Mw space

Stong motion should be atenuate in further distance. We present hypocenter distance to PGA graph to describe the attenuation of earthquake from several magnitude range. Figure 7 shows that all magnitude range generally decrease due to the grow of distance. The graph is also helpful in selecting the suitable ground motion model.

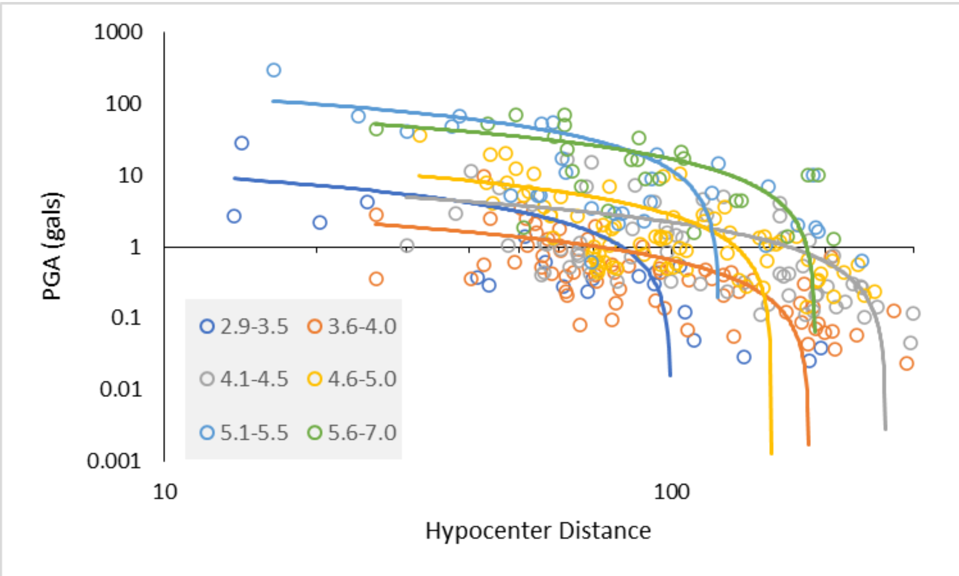

Figure 7. Distribution of PGA with respect to hypocentral distance for various moment magnitude category. Solid line descrive the attenuation trend for each category.

4. Conclusions

In this article, we describe a database of Lombok-Sumbawa grounf motion and related seismic source and site parameter. The result of this study is very necessary for selecting and generating ground motion model for Lombok-Sumbawa back arc thrust, which had no ground motion database before. We also gave good quality seismic source data by using relocated data and reliable earthquake catalogue, including uniforming the magnitude type into moment magnitude. Besides, we also compile Vs30 data in accelerograph station as site parameter data.

Our data from 2007-2021 vary for M>3.0 and hypocentral distance less than 300 km. We collected 281 ground motion recording from 136 events that should be enough to determine the appropriate ground motion model for Lombok-Sumbawa back arc thrust in the future.

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