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MASW for the microzonation of earthquake hazard in Banjar City, West Java, Indonesia

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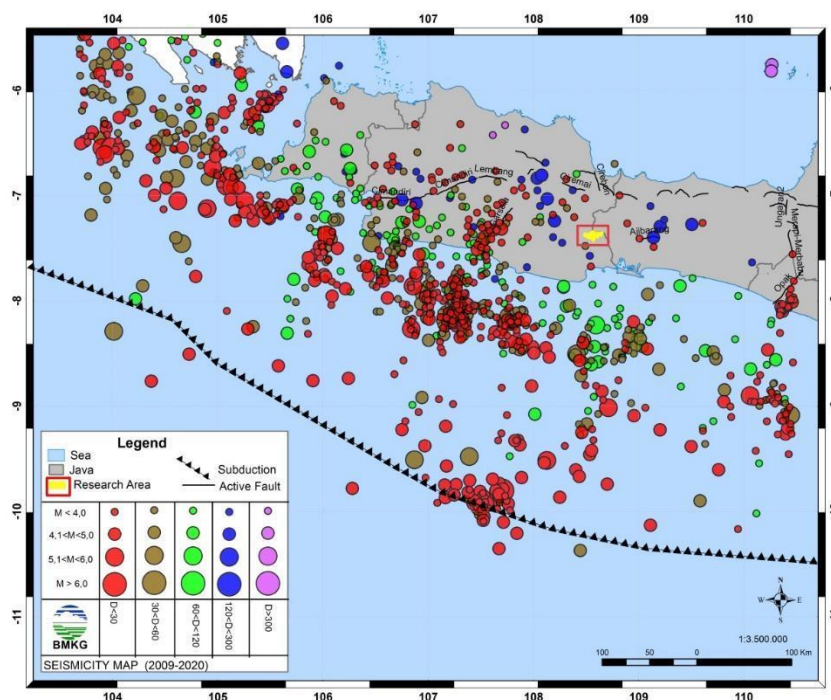
Abstract. Efforts to reduce the impact of earthquake disaster have been made by the government, continuously. To decrease the casualties, an effort to be done is to construct housings and public infrastructures following the earthquake-resistant role or building code, especially in cities with high vulnerability and population. For this reason, an earthquake hazard microzonation map is crucial. Microzonation of earthquake hazard in Banjar City, West Java, Indonesia, was conducted by mapping the surface soil classification. Banjar is an essential city in West Java, connecting Bandung and the cities in the southern part. The microzonation mapping was done using the MASW (Multichannel Analysis of Surface Waves) method. The fieldwork of Vs30 measurements has been conducted in February 2020. We recorded 31 MASW sites in the entire Banjar City area with the distance between the locations approximately 5km. The results of this study indicate the surface soil classification in Banjar City in detail and precisely. The eastern part of the city shows a relatively softer surface soil structure compared to the western part. Comparison of the microzonation map obtained from the measurements with empirical Vs30 map (average shear waves velocity down to 30m), geology structure, and topographic data, showing good agreement. The earthquake microzonation map is recommended to be considered one of the references for developing the building code.

1. Introduction

Lesson learned from the 8.1, 1985 Mexico earthquake [1,2] and several other similar events is that the building constructions have to consider the potential of ground shaking due to earthquake sources near the city and surface soil structure under the infrastructures or city being built. The damage caused by the earthquake was not only affected by the magnitude and distance of the earthquake source (3,4). The earthquake that occurred at approximately 400 km from Mexico City, has destroyed the city significantly. Meanwhile, another city relatively close to the earthquake source, did not experience significant damage (5). Many studies suggested that the severe damage occurred in Mexico City was caused by the side effects. The city is located on a thick sedimentary structure of ancient lakes (1,6). The soft soil structure trapped the seismic waves to experience resonance and caused the amplification or enlargement of ground shaking amplitude (7). Therefore, for the building construction efficiency, it considers the condition of surface soil structure. It is necessary to map the surface soil structure on a micro-scale or well known as the microzonation related to ground shaking's potential due to strong earthquakes.



Almost all Indonesia regions have the potential to experience ground shaking due to earthquakes, either originating from the nearby local faults or from the earthquakes that occur in subduction zones. Banjar City, which is located in West Java, is one of the cities that also have the potential to experience the shaking due to earthquakes originating from local faults such as the Citanduy [8], Ciremai and Cirebon faults [9], as well as the subduction zones in the southern part of Java island (Fig. 1). The city is one of the important cities in West Java that connects Bandung and other big cities in the South of West Java and Central Java, such as Pangandaran and Cilacap. The total population and area of Banjar City are approximately 178,000 people and 113 square km, respectively (Wikipedia, accessed September 2020). Several earthquakes were significantly felt in Banjar City i.e., the Mw 7.7, 2006 Pangandaran earthquake [10, 11], and the Mw 6.8, 2017 Tasikmalaya earthquake [12]. These earthquakes have caused casualties and damage in the city.



velocity of the surface wave propagation. In the case of hard rock, surface waves will propagate quickly, compensates with the relatively small amplitude. Likewise, on the other hand, in the case of soft soil, the waves propagate slowly, the amplitude compensation becomes large. This principle is used for the interpretation of the classification of the surface soil structure. Another principle is that the seismic waves with relatively low frequencies can reach deeper structures than the high-frequency waves. The dispersion curve shows the difference in seismic wave velocities at different frequencies and depths. The analysis of the dispersion curve produces a one-dimensional shear wave velocity model. This method is usually used to obtain the average velocity of shear waves down to a depth of 30 meters.

Measurement of the average velocity of shear waves down to a depth of 30m (V_{s30}) using the MASW method was conducted on 31 locations throughout the city of Banjar (Fig. 2). The average distance between one location and another was approximately 5km. We used the vertical component sensors with the application device from the DoReMi seismograph (Do Refraction Microtremor, Sara Electronic Instruments). Data processing was done using the WinMASW application [16]. Data processing results are the measurement location, elevation, the average value of V_{s30} , and the one-dimensional velocity model down to a depth of 30 meters.

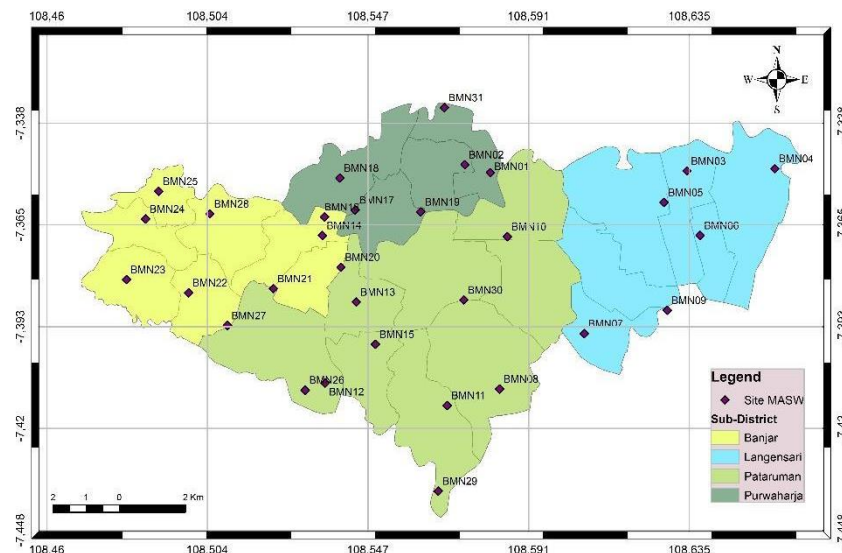


Figure 2. Location of V_{s30} measurement points in Banjar City. The measurement of V_{s30} using the MASW method was conducted at 31 points. The measuring point is marked with purple diamonds.

We used geological maps [17, Fig. 3], topography, and empirical V_{s30} [18,19, Fig. 4] as the references for the validation of data processing and results using the MASW method.

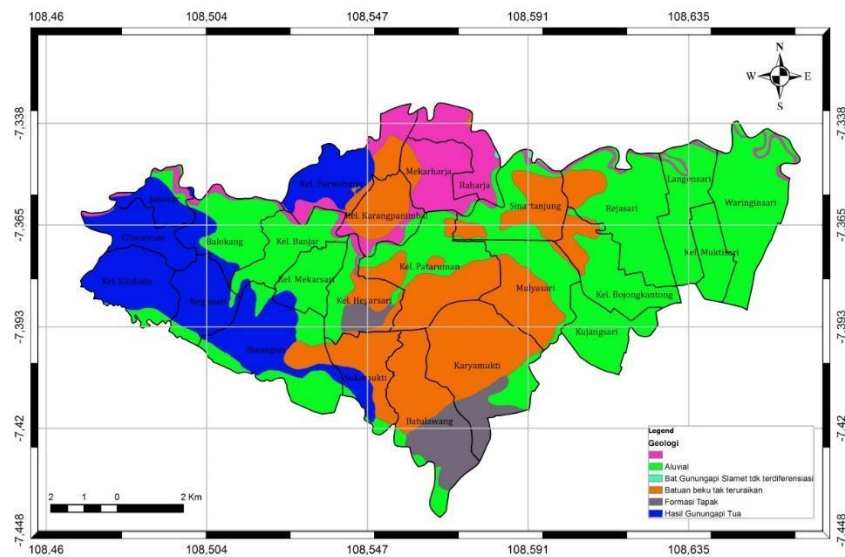


Figure 3. Geological map of Banjar City, West Java [17]. The colors in the legend indicate the rock types.

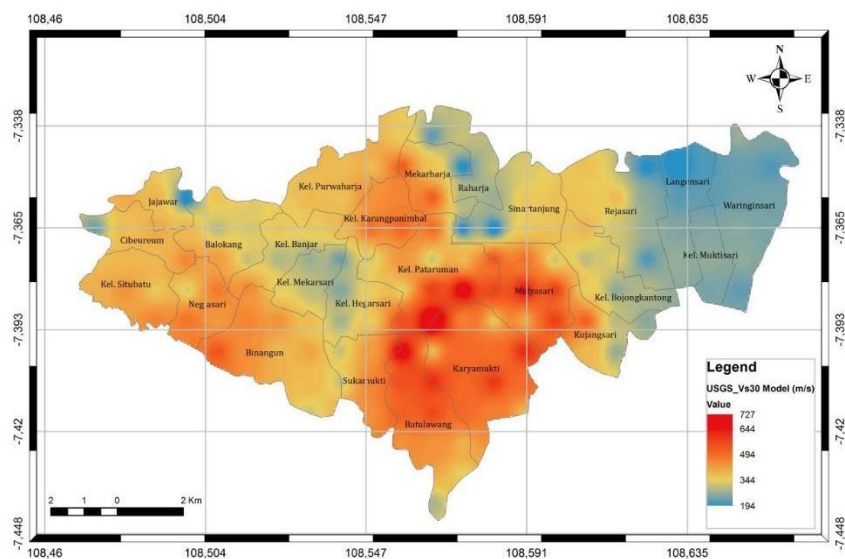


Figure 4. Empirical Vs30 based on slope topography data for Banjar City, West Java. This map has the same trends with topographic map in the region [USGS, 18, 19].

3. Results and discussion

In general, this study's results suggested that the eastern part of Banjar City has a relatively soft surface soil structure. The average Vs30 using the MASW method shows that in the eastern region of the city, the Vs30 was relatively lower than other areas (Fig. 5). The lowest average value of Vs30 was 118 m/s which was measured in Waringinsari village, Langensari at coordinates -7.35 S and 108.66 E (see Table 1). Actually, visual observations can be seen immediately that the eastern part of the city is generally a lower elevation area with mostly paddy fields.

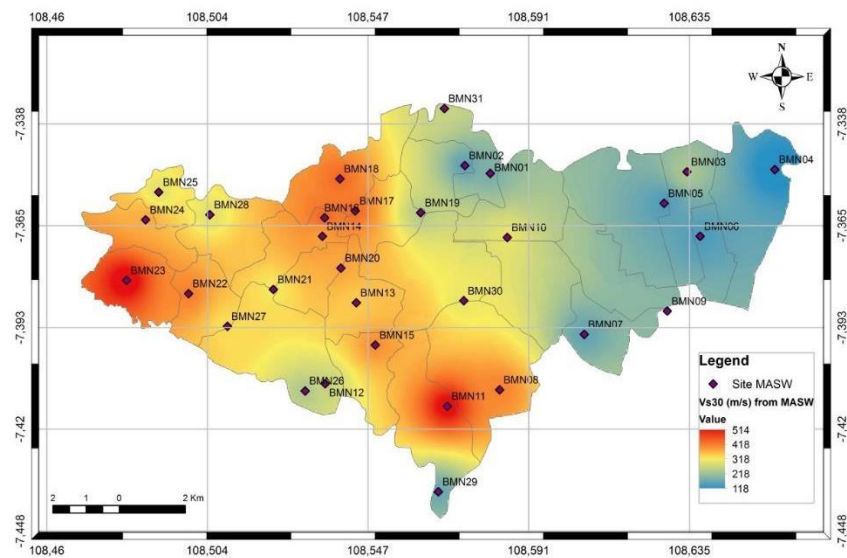


Figure 5. Contour map of the average shear wave velocity down to a depth of 30m (Vs30). The small purple diamonds indicate the locations of Vs30 measurements using MASW method.

Surprisingly, the microzonation map of earthquake hazard based on the average Vs30 from the measurements that we have conducted using the MASW method was in line with the geological map [17], topography, and the empirical Vs30 [18, 19]. A small number of specific parts indicates different types of surface soil structure compared to the reference maps. Of course, the surface soil classification that we obtained from the results of this study is more realistic because it results from direct measurements at the study area.

Table 1. The results of average Vs30 measured in Banjar City, West Java.

Station Code	Latitude	Longitude	Vs30 (ms ⁻¹)
BMN01	-7.35104	108.58054	184
BMN02	-7.34888	108.57366	161
BMN03	-7.35058	108.63394	233
BMN04	-7.34996	108.65777	118
BMN05	-7.35912	108.62773	151
BMN06	-7.36806	108.63750	148
BMN07	-7.39467	108.60603	165
BMN08	-7.40972	108.58306	410
BMN09	-7.38833	108.62861	198
BMN10	-7.36839	108.58519	299
BMN11	-7.41417	108.56889	507
BMN12	-7.40806	108.53569	262
BMN13	-7.38611	108.54417	346
BMN14	-7.36806	108.53500	382
BMN15	-7.39758	108.54933	397
BMN16	-7.36306	108.53556	438
BMN17	-7.36116	108.54389	432
BMN18	-7.35250	108.53972	433
BMN19	-7.36167	108.56167	244
BMN20	-7.37667	108.54000	379
BMN21	-7.38250	108.52167	320

BMN22	-7.38361	108.49861	412
BMN23	-7.38004	108.48180	514
BMN24	-7.36358	108.48699	377
BMN25	-7.35611	108.49056	294
BMN26	-7.41001	108.53028	236
BMN27	-7.39250	108.50917	330
BMN28	-7.36222	108.50444	291
BMN29	-7.43739	108.56645	172
BMN30	-7.38556	108.57333	305
BMN31	-7.33339	108.56807	262

4. Conclusion

This study produced a microzonation map of the earthquake hazard in Banjar City, West Java. The measurement and data processing results using the MASW method suggested the classification of soil structure types in the city, agrees with the geological maps, topography, and empirical Vs30. The eastern part of Banjar city shows a relatively softer surface soil structure compared to the western part.

This microzonation map can be used as a reference to estimate the amplification factor of the ground shaking due to strong earthquakes. Finally, it is expected that with this microzonation map, the building constructions, especially in Banjar City considers the zonation on the map. Building constructions will be more efficient and mitigate the earthquake disasters that might occur in the future.

Acknowledgements

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