Approximation of Shear Wave Velocity Using MASW Method for Seismic Hazard Mitigation: A Preliminary Study of Banda Aceh City Indonesia

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Abstract. Earthquake 9.1 SR happened in the Aceh Province Indonesia that followed tsunami on December 2004. After this event, the development of infrastructures in Banda Aceh city has shown rapidly progress. Therefore, learning of the experience of this natural event that has caused many casualties and infrastructures, the Banda Aceh city has been been initiative as a city that is friendly of disasters. The research objective analysed of influence sedimentation behaviour at buildings. The shear wave velocity parameters using MASW method were used for sediment characteristic assessment. The sediment characteristics are very soft, soft, dense and very dense that it’s have level different of shaking, respectively. The detail of 1D profiles of shear wave velocity have obtained. In this case, we analysed VS30 parameters of eleven locations of all measurements at the Ulee Kareng Sub District, Banda Aceh city. The ground shaking level of sediment layer depend of sedimentation characteristics. The sediment characteristic of Ulee Kareng Sub District, Banda Aceh has shown medium dense and soft soil.

1. Introduction
The geomorphology of Sungai Krueng Aceh basin was formed by the Sumatra fault. In geomorphological dynamic, the basin has filled by sediment material with different age of geology. The surface of the sedimentation layers have formed by geomorphic fluvial process within halocen period. The sedimentation layers are heterogenous and anisotropic. Knowledge of the sediment material characteristic and its spatial distribution within the basin area are thing interesting to study in earthquake hazard mitigation and urban infrastructures planning. In seismic active zone such as the Sungai Krueng Aceh basin, detail estimation of shear wave velocity parameters (Vs) of sedimentation layer are important part of the earthquake hazard assessment of infrastructure safety. Recently, there are two main approximation of determination of the near surface geological structures: one of them is invasive method such as bore hole, standard penetration test (SPT), cone penetration test (CPT) while the other method is non-invasive. The non-invasive method is multichannel analysis of surface wave (MASW). The borehole, SPT and CPT methods were used and accepted by geotechnical engineers in order to estimate of the characterization and stiffness of the soil columns in the site. Recently, the development of seismic exploration technology such as MASW is a promising solution for near surface investigation. The method is relative cheap, fast and can be implemented in urban
environment. In seismic wave theories, there are two types of wave velocity: compressive wave velocity \((V_p)\) and shear wave velocity \((V_s)\). However, in the geotechnical and geohazard assessment, \(V_s\) parameter from MASW method is rarely using. The Active and passive surface waves methods have used to characterize sediment layers at Himalayan mountains in the context of earthquake hazard microzonation analysis [1]. For other applications, the surface wave’s method for geotechnical characterization of dyke in the central Europe [2] has used. Gun et al. [3] have used surface wave’s method to measure the dynamic stiffness characteristics of railway embankment. For bridge design purpose, Jamaluddin et al. [4] also have used surface method. The shear wave velocity parameters for earthquake hazard analysis in Takengon basin Aceh Province was analysed by [5]. The research objective is to obtain sediment characteristics using \(V_s\) detail for earthquake hazard assessment. In sediment materials, earthquake waves can be occur attenuation and wave amplification. The one dimensional of shear wave velocity was obtained for the interpretation of heterogeneous material behavior based from Uniform Building Code (UBC) and Eurocode 8 (EC8) standards (Table 1).

### Table 1: Vs30 based on UBC and EC8 [11]

| Ground Profile of Subsoil (soil) type (UBC) or Subsoil Class (E8) | Ground Description Stratigraphic Profile (UBC) | Shear Wave Velocity Vs30 (m/s) |
|---------------------------------------------------------------|-----------------------------------------------|--------------------------------|
| SA (UBC) or SB (EC8) Hard Rock                               | Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface | >1500 (UBC)                     |
| SC (UBC) or B (EC8) Very dense soil and soft rock            | Deposit of very dense sand, gravel or very stiff clay, at least several tens of m in thickness, characterized by a gradual increase of mechanical properties with depth | 760-1500 (UBC) or > 800 (EC8)   |
| SD (UBC) or C (EC8) Stiff soil                               | Deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of m | 360-760 (UBC) nor 360-800 (EC8) |
| SE (UBC) or D (EC8) Soft soil                                | Deposits of loose-to medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to cohesive soil | <180 (UBC and EC8)              |

### 1.1. Field description and local geology

This research has been carried out in the Ulee Kareng Subdistrict, Banda Aceh city. The location of Ulee Kareng subdistrict is in northern of the Sungai Krueng Aceh river. The sungai Krueng Aceh river is main river in Banda Aceh basin. This region is urban area which the types of infrastructure are roads, housing and educational buildings. The Ulee Kareng Subdistrict is part of the Banda Aceh basin which had limited by two faults: the Seulimeum fault and the Aceh fault. Both Seulimeum and Aceh faults are the segment of Sumatra fault. Therefore, Banda Aceh city is the active seismic region. The sedimentary layer of the Banda Aceh area is fluvial landscape. Generally, sediment material from the fluvial process such as clay, silt, sand and gravel. These fluvial deposits are the quaternary unit. The informations about geology of Banda Aceh were studied by [6-7].
2. Methodology

Data acquisition of MASW active field seismic testing was done similar to seismic reflection testing layout. Record signal used 24 channel PASI 16S-24P seismograph. The frequency of vertical geophone was used 10 Hz which was plotted linearly with a space of 1 m. This space had considered the effect of possible signal aliasing between geophone. Surveys that had been carried out along the linear array used the fixed along mode method with a sampling time of 250 micro seconds with a total record length of 1024 milli second for each signal record. Source offset from the first geophone 5 m. Sledgehammer 7 kg was used with a height of approximately 1.5 m falling with a metal plate size 25 cm x 25 cm and 2.5 cm thick. To produce a 2-D profiles, a sledgehammer beat was done at offset and along between the geophone. Figure 1 show locations about MASW testing. The study of 2D profile data in detail has been studied by [8]. Configuration of MASW testing is showed at Figure 2.

![Figure 1: The locations of measurement of shear wave velocity (Ulee Kareng-Banda Aceh)](image1)

![Figure 2: Geophone configuration of the MASW measurement [5].](image2)

The surface wave dispersion curve was obtained from MASW data through processing carried out with the SeisImager program. Raw seismic data was processed in the data format with a combination of all shots from a single file. The processing of seismic record in the form of overtone images where represented amplitudo is a function of the frequency with the phase velocity. From image, the dispersion curve was identified by reference to the frequency and maximum phase velocity. In surface wave analysis, a 2-3 Hz signal frequency could be recorded with 4.5 Hz geophone. [9] say investigations using a 10 Hz geophone can detect 5 Hz frequency of wave. It was observed that low frequency wave detection was not limited by the natural frequency of the geophone. The use of a 10 Hz geophone gave results that were almost identical to the 4.5 Hz geophone [10]. Figure 3 shown Rayleigh wave data at offset position that was aquisited at Gampong Doi village.
3. Results and Discussion

The acquisition of seismic data, in the eleven locations at Ulee Kareng Sub district as preliminary study for Banda Aceh city, had been adjusted due to the field condition. The locations of acquisition data were chosen at the open field and avoid from noise that can reduce the accuracy of the seismic data. The acquisitions were not due to the direction of north but randomly carried out according to the field situation. The signal processing was carried out through waveform dispersion and followed by inversion of the dispersion curve. The results of the inversion process are a one-dimensional (1-D) Vs curve and its information is shear wave velocity and depth. In the framework of this research, it only was taken up to depth of 30 meters from the earth surface. The shear wave velocity (Vs30) is average of Vs from surface until 30 meters. The surface wave data processing used SeisImager program. Figure 4 is shown 1-D Vs profiles. The results of 1-D Vs data were shown three locations only. The data are Lambhuk village location, Poltek Aceh location and Lamglumpang village location. The Vs data of three locations that the Vs average show smaller from 150 m/s. It show soft soils layer and another data of Vs also show soft soil. The results of Vs30 have calculated from average of shear wave velocity from each layers (Equation 1). The \( d_i \) parameter is depth of each layer and \( n \) is total of layer. However, the Vs30 was obtained from the eleven locations and they was analysed further using the Arcgis program. The Vs30 data distributed or mapping that was calculated by linear interpolation is shown in the Figure 5. However, the research is a preliminary study of Banda Aceh city that is eleven locations data only. The paper can not conclude overall of Banda Aceh city area but the information can be early information for natural hazard reduction of Banda Aceh city.

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Vs30 = \frac{\sum_{i=1}^{n} d_i \frac{d}{d_i}}{\sum_{i=1}^{n} \frac{d}{d_i}}
\]  

(1)
Figure 4: 1-D Vs data of three locations: a). Lambhuk location, b). Lamglumpang location, c). Poltek Aceh location.

Figure 5: Vs30 value distribution was obtained of Ulee Kareng Subdistrict, Banda Aceh for eleven locations measurement.
At Figure 5, it can be seen that the distribution of parameters Vs30 consists of three colours, namely redness, yellowish and greenish. The style of colours was resulted by linear interpolation of Vs30 values at each location using MASW method. According to Figure 4 for redness, the range Vs30 are 160 m/s until 210 m/s. For yellowish the range Vs30 are 140 m/s until 159 m/s and greenish range are 65 m/s until 140 m/s. Based on UBC and EC8, the theirs Vs30 range were categorized into two soil characteristics for amplification assessment. The reddish was inserted into the medium dense and the green and yellowish were inserted into soft soil where these soil type have an impact on amplification. The amplification level is relative small in the soils which have high until very high hardness level. In the geotechnic, the value of SPT of high to very high hard soils is 40 until 60. These soil would be less risk of amplification. The building construction on hard soil will also be safe against failure due to amplification behaviour.

Figure 6 shows the results of the seismic vulnerability of Vs data that classified based UBC and EC8 standarts. The results show that there are two seismic susceptibility zones which are dense medium for zone I and soft soil for zone II. The study of material behaviour against natural hazard of seismic waves is paramount important in the civil engineering problem. A occurence of strong earthquake can be many victims due to the collapse of buildings that were not built due to seismic building code. A structure engineer designs the building with very strong according to the strength of concrete material but they do not understand that there are other factors that can be the building failure when the earthquake occure. Those factors are geology, seismic waves and the locally material conditions where the building is constructed [11]. Therefore, the assessment of the seismic hazard of building is things that is very important to reduce casualties of human when catastrophic earthquake occure in a region. However, knowledge of geomorphology and geology also very important of assessment of earthquake behaviour of sedimentation layers. The old layers are a good stiffness and turn the layers will be resistant of earthquake wave amplification.

Figure 6: The seismic vulnerability zonation map of Ulee Kareng Subdistrict Banda Aceh that is classified under UBC and EC8.
4. Conclusions
The research was carried out at Ulee Kareng Subdistrict, Banda Aceh city using the MASW method to obtain shear wave velocity and Vs30 parameters. The results were obtained Vs30 map and soil vulnerability zonation map at Ulee Kareng subdistrict based on UBC and EC8 standards. The classification of the soil layers is two zones, namely medium dense (zone I) and soft density soil (zone II). The soft soil was more amplified by earthquake seismic waves than medium dense soil, hard and very hard soils. The medium dense soil was distributed at around of the central of the Ulee Kareng Subdistrict, Banda Aceh city.

5. References
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