ABSTRACT

This study aims to estimate seismic hazards with regards to the future earthquakes. East Nusa Tenggara province in the eastern Indonesia was chosen as a site of interest and was classified as highly susceptible of seismic hazard zone because it has been struck several times by the earthquakes. The study area, Ende, is located at Ende Regency that is one of five regencies on the island of Flores in East Nusa Tenggara Province. Eastern Indonesia belongs to a high tectonically active region where is a place of interaction between the Pacific, Eurasian and Indian-Australian Plates. Additionally, Flores Island, as a segment of the volcanic inner Banda Arc, has several active volcanoes and with respect to earthquakes the region must also be considered an area with high levels of seismic activity. These geological hazards pose a serious threat not only to people's life but also to the social and economic development of Ende Regency. The City of Ende was frequently affected by natural disasters in the past: Especially, many earthquakes shook Flores Island damaging many houses all over the Island. For example, Flores earthquake with the moment magnitude of 7.8 at a depth of about 28 km in Eastern Indonesia, which occurred on 12th December, 1992 at 13:29 local time (6:29 GMT). At least 2,080 fatalities or missing people, including 1,490 in Maurnere, Flores, and 700 on Babi Island were caused by the earthquake and tsunami. More than 500 people were severely injured and 90,000 were left homeless. 30,789 homes, 808 schools, 188 churches and mosques were destroyed and damaged structures. Estimated losses are ± $100 million.

Geological field observation and microtremor measurements were performed in this study directly on September, 2014, in Ende area. Geological field observation was carried out in the study area, Ende. The field equipment such as Brunton-Compass, Garmin GPS (global positioning system), Geological hammer and Digital Camera were used to measure stratigraphic section during the geological field work. A three-component accelerometer with data logger, GPL-6A3P was used. With the overdamping type accelerometer (frequency: 0.07 Hz to 100 Hz) used as its detector, this instrument is most suitable for detecting earthquake motions, ground vibration, and vibration characteristics

(waveform) of buildings. Single station observation points (161 points) with the interval of about 250 m measurements have done. In some cases, microtremor measurements were unable to provide an estimate of dominant frequency. We found no clear peak for these points and cancelled some of them without clear peak. Therefore, results from 92 sites show resonant fundamental periods from 0.7 s to 1.3sec. Then, analyses continued with soil-Structure Resonance Study on Discrete Wavenumber Method. The purpose of this analyses is to estimate the simple ground profile by Discrete Wavenumber Method (DWM: Aki-Larner Method) based on the horizontal-to-vertical spectral ratios (HVSR) of the single microtremor data. The method is applied to several models of 'soft basins,' and also useful for the engineering-seismological study of earthquake motions of soft superficial layers of various cross sections. We calculated numerical analysis for the value of the Shear wave velocity, the depth of the basin and calculated response functions by using DWM. The shear wave velocity of the basement is fixed as 400m/s. Shear wave velocity of the basin (V_1), the depth (D) and the length of the basin bottom (B) were randomly changed from within the range of 100 m/s~200m/s, 50m~500m and 1km ~ 3km that depend on each profile line. We generated 1000 random numbers for those parameters within the ranges.

Then, we selected the best fit parameters by comparing the predominant frequency from H/V result. Finally, we proposed a possible two-layered simple model in the study area and could estimate average shear wave velocity (156m/s) and sediment thickness (30~51 m) from this method. Using single microtremor data, Period map and seismic vulnerability index, PGA distribution maps in the surface soil layer, ground shear strain and seismic intensity map was described for the future earthquake damage potentials in the study area. Finally, we made Seismicity Microzonation map based on all of this information using Simple Additive Weighting Method. Total scores of Microzonation map range between 1.5 and 53. High value shows high earthquake disaster. In addition, the high level of earthquake dangerous areas are at Mautapaga Bawah, ENDE, Koponggena, Lapangan Terbang Ipi, Ipi, Pelabuhan Ipi, Watujara,Bajawa, Panorogo, Potulando, Ambudi, Pelabuhan Ende, Mbongawani, Aembonga, Kotabaru and Rukunlima Bawah. Moreover, we compared the damage area from the historical earthquakes with microzonation map from this research in order to estimate the future earthquake hazard of the study area, it is to see whether there are similarities between the higher level of earthquake dangerous areas from this research and damage area of Ende area in 1992 earthquake. We found that the high risk are situated on the very soft sediment layer such as sand, river deposits and iron sand and the high risk indicates that these regions have a high potential for damage in case of earthquakes. Additionally, some parts along the faults are included at the high risk areas.

Generally, the results show for future earthquake potentials. The detailed seismic hazard works and microzonation studies are required to provide earthquake disaster mitigation in the study area. Using this study from seismic analysis, we need to disseminate as information or supporting literature in earthquake disaster to the public and district administration in Ende.

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SARI

Penelitian ini bertujuan untuk menduga bahaya seismik berkaitan dengan gempa bumi di masa depan. Lokasi yang dijadikan tempat penelitian adalah Kabupaten Ende Provinsi Nusa Tenggara Timur yang berada di Indonesia bagian timur, merupakan lokasi yang menarik dan dikategorikan sebagai zona yang sangat rentan dari bahaya seismik karena telah mengalami beberapa kali gempa bumi, serta dikontrol tektonik aktif yang tinggi karena adanya interaksi antara lempeng-lempeng Pasifik, Eurasia dan India-Australia. Selain itu, Pulau Flores merupakan bagian busur vulkanik dari Banda Arc, yang memiliki beberapa gunung api aktif serta berkaitan dengan aktifitas seismik gempa bumi yang tinggi.

Bahaya geologi ini menimbulkan ancaman serius tidak hanya untuk kehidupan masyarakat tetapi juga sosial dan ekonomi di Kabupaten Ende, salahsatu kota yang sering terkena bencana alam di masa lalu. Misalnya: gempa Flores pada tanggal 12 Desember 1992 pukul 13.29 waktu setempat (06:29 GMT) dengan *magnitude* 7,8 SR pada kedalaman sekitar 28 km berada di bagian utara Pulau Flores yang disertai Tsunami. Sekurang-kurangnya, menelan jiwa 2.080 orang tidak termasuk korban hilang, 1.490 jiwa di Maurnere, Flores dan 700 jiwa di Pulau Babi, serta lebih dari 500 orang terluka parah dan 90.000 orang kehilangan tempat tinggal, kerusakan infrastruktur meliputi 30.789 rumah, 808 sekolah, 188 rumah ibadah (gereja dan masjid) dengan kerugian diperkirakan sebesar ± $ 100 juta. Di Maurnere juga mengalami kerusakan, anatara lain beberap rumah penduduk dan kantor pemerintahan rusak.

Pengamatan lapangan di Kota Ende dan pengukuran *microtremor* di lokasi penelitian dilakukan pada Bulan September tahun 2014. Adapun peralatan yang digunakan meliputi kompas geologi (Brunton-Compass), GPS tipe Garmin (*Global Positioning System*), palu geologi dan kamera digital yang digunakan untuk mengukur bagian stratigrafi, satu unit *accelerometer* dengan tiga komponen data *logger*, GPL-6A3P jenis *overdamping accelerometer* (frekuensi: 0,07 Hz sampai 100 Hz) digunakan sebagai detektor, alat ini paling cocok untuk mendeteksi gerakan gempa, getaran tanah dan karakteristik getaran (gelombang) dari bangunan. Pengamatan menggunakan stasiun tunggal dengan jumlah 161 titik serta interval sekitar 250 meter, Dalam beberapa kasus, pengukuran *microtremor* tidak dapat memberikan perkiraan frekuensi dominan, dimana tidak ditemukan titik-titik puncak yang signifikan sehingga beberapa titik-titik tersebut dihilangkan. Oleh karena itu, hasil dari 92 tempat menunjukkan periode mendasar resonansi dari 0,7 s untuk 1,3 sec. Kemudian, analisis dilanjutkan dengan Studi resonansi struktur-tanah dengan metode *discrete* bilangan gelombang. Tujuan dari analisis ini adalah untuk memperkirakan profil tanah dengan *Discrete Metode* bilangan gelombang (DWM: *Aki-Larner Method*) berdasarkan *Horizontal-Vertical Spectral Ratio* (HVSR) dari data *microtremor* tunggal. Metode ini diterapkan untuk beberapa model cekungan, dan juga berguna untuk studi rekayasa-seismologi dari gerakan gempa lapisan dangkal berbagai lintasan serta dilakukan perhitungan analisis numerik untuk nilai geser (*shear*), kecepatan gelombang, kedalaman lembah dan fungsi respon dengan menggunakan DWM. Kecepatan gelombang geser dari dasar adalah tetap sebesar 400 m/s. Kecepatan gelombang geser dari cekungan (V1), kedalaman (D) dan panjang bagian bawah cekungan (B) berubah secara acak dalam kisaran 100 m / s ~ 200 m / s, 50 m ~ 500 m dan 1km ~ 3 km tergantung pada setiap baris profil, serta dihasilkan 1000 nomor acak untuk parameter-parameter dalam rentang.

Selanjutnya, pemilihan parameter terbaik dilakukan dengan cara membandingkan frekuensi dominan dari hasil H/V, sehingga diperoleh model sederhana dua-lapis untuk daerah penelitian yang dapat memperkirakan kecepatan rata-rata gelombang geser (156 m/s) dan ketebalan sedimen (30 ~ 51 m). Menggunakan data *microtremor* tunggal, peta periode dan indeks kerentanan seismik, peta distribusi PGA di lapisan permukaan tanah, regangan tanah geser dan seismik, peta intensitas, menggambarkan potensi kerusakan gempa di masa mendatang di wilayah penelitian. Akhirnya, diperoleh peta seismisitas mikrozonasi berdasarkan semua informasi ini menggunakan *Simple Additive Weighting Method*. Total skor dari mikrozonasi berbagai peta antara nilai tinggi 1,5 dan 53 yang menunjukkan bencana gempabumi yang tinggi. Selain itu, tingkat bahaya gempabumi yang tinggi berada di daerah Mautapaga bawah, Ende, Koponggena, Lapangan Terbang Ipi, Ipi, Pelabuhan Ipi, Watujara, Bajawa, Panorogo, Potulando, Ambudi, Pelabuhan Ende, Mbongawani, Aembonga, Kotabaru dan Rukunlima Bawah. Selain itu, membandingkan daerah kerusakan berdasarkan sejarah gempabumi pada tahun 1992 dengan peta mikrozonasi dari penelitian terdapat kesamaan untuk daerah beresiko diketahui pada daerah berlapisan sedimen seperti pasir, endapan sungai dan pasir besi.