INTISARI

Provinsi Sulawesi Tengah merupakan wilayah dengan tingkat kerawanan tinggi terhadap gempa bumi akibat aktivitas tektonik pada Sesar Palu Koro. Gempa bumi 28 September 2018 bermagnitudo 7,5 *Mw* menimbulkan dampak geotektonik yang signifikan, terutama di wilayah Balaroa, Kota Palu. Fenomena likuefaksi yang terjadi menyebabkan pergeseran tanah masif, keruntuhan infrastruktur, dan korban jiwa dalam jumlah besar. Penelitian ini bertujuan untuk mengevaluasi karakteristik tanah, potensi likuefaksi, tingkat bahaya seismik, menganalisis mekanisme longsoran sebelum dan sesudah gempa melalui pendekatan integratif berbasis data geoteknik dan mikrotremor. Penelitian ini juga memetakan tingkat kerentanan likuefaksi dan risiko bahaya seismik sebagai dasar perencanaan mitigasi bencana di masa mendatang.

Penelitian ini dilakukan melalui serangkaian pengujian lapangan pada 10 titik *hand boring*, 10 titik *Cone Penetration Test* (CPT), 6 titik *Standard Penetration Test* (SPT), 29 titik *Swedish Weight Sounding* (SWS), dan 31 titik mikrotremor. Titik pengujian ditentukan dengan metode *systematic grid sampling* sejajar arah longsoran. Lokasi CPT ditempatkan berdekatan dengan titik SWS dan *hand boring* agar hasilnya dapat dibandingkan secara langsung. Kriteria tanah berpotensi likuefaksi dianalisis menggunakan kriteria Cina, kriteria tambahan, dan kurva Tsuchida. Nilai N_{sw} dan W_{sw} dari SWS dikonversi menjadi *N*-SPT melalui persamaan korelasi dan divalidasi dengan uji SPT. Berdasarkan nilai *N*-SPT, kelas situs wilayah Balaroa ditentukan mengacu pada SNI 1726:2019, sedangkan nilai percepatan puncak gempa (PGA) diperoleh dari laman Desain Spektra Indonesia. Analisis potensi likuefaksi dilakukan dengan menghitung *Factor of Safety* (FS) berdasarkan data SWS, CPT, SPT serta dihitung *Liquefaction Potential Index* (LPI) sebagai dasar penyusunan peta kerentanan. Evaluasi bahaya seismik menggunakan analisis mikrotremor pada 31 titik yang memiliki lokasi relatif sama dengan 29 titik SWS. Pemetaan dilakukan dengan ArcGIS, sedangkan simulasi stabilitas lereng dianalisis secara numerik dengan perangkat lunak *SLOPE/W* dan *QUAKE/W*.

Hasil penelitian menunjukkan wilayah Balaroa memiliki karakteristik tanah yang tergolong rentan terhadap likuefaksi. Hasil pengujian menunjukkan bahwa tanah di wilayah Balaroa didominasi oleh pasir berlanau (SM) dengan konsistensi sangat lunak dan kondisi *very loose–loose* hingga kedalaman ±7 meter berdasarkan nilai *cone resistance* (q_c) dari CPT. Nilai rata-rata *N* hasil SWS diperoleh angka yang sangat rendah dibandingkan SPT, sehingga diklasifikasikan sebagai tanah lunak (SE), dengan muka air tanah yang umumnya dangkal. Data CPT, SWS, serta *borehole* (BH-1, BH-2, dan BH-5) memperlihatkan tingkat kerentanan sangat tinggi, sedangkan wilayah di luar zona terdampak menunjukkan kerentanan rendah hingga sangat rendah. Analisis mikrotremor menghasilkan nilai f_0 0,2 hingga 1,34 Hz dan T_0 0,74 hingga 3,35 detik, mencerminkan sedimen alluvial lunak dengan ketebalan >30 m serta indeks kerentanan seismik (K_g) umumnya > 6, sehingga menunjukkan bahwa lokasi penelitian berada pada kategori rawan likuefaksi apabila mengalami guncangan seismik. Nilai *Ground Shear Strain* (GSS) pada PGA_M 0,6 g berkisar $1{,}240 \times 10^{-3}$ hingga $2{,}591 \times 10^{-2}$, menunjukkan kondisi *elasto-plastic*. kecepatan gelombang geser (V_s) berada pada rentang 154 hingga 344 m/detik, dengan lapisan tanah sedang hingga lunak (V_s < 350 m/detik) setebal 9 hingga 53 m, sedimen V_s < 750 m/detik setebal 82 hingga 430 m, dan kedalaman lapisan V_s = 1 km/detik mencapai 137 hingga 1374 m. Simulasi stabilitas memperlihatkan lereng sebelum gempa 2018 stabil secara statis, tetapi faktor keamanan menurun drastis akibat beban dinamik sehingga kelongsoran dipicu oleh *flow liquefaction* dan tekanan air pori berlebih. Lereng pascagempa masih stabil tanpa gempa, namun berpotensi longsor jika terjadi guncangan serupa, terutama akibat perubahan geometri lereng yang lebih terjal. Secara keseluruhan, hasil penelitian menegaskan bahwa integrasi data geoteknik dan mikrotremor menghasilkan pemahaman komprehensif mengenai mekanisme likuefaksi dan instabilitas lereng di Balaroa. Temuan ini diharapkan menjadi dasar ilmiah dalam penyusunan peta mikrozonasi seismik serta strategi mitigasi bencana di wilayah rawan gempa Sulawesi Tengah.

Kata kunci: Pemetaan, Likuefaksi, PGA_M, SWS, CPT, SPT, LPI, mikrotremor, longsoran

ABSTRACT

Central Sulawesi Province is an area with a high level of vulnerability to earthquakes due to tectonic activity on the Palu Koro Fault. The September 28, 2018 earthquake with a magnitude of 7.5 *Mw* caused significant geotectonic impacts, especially in the Balaroa area of Palu City. The liquefaction phenomenon that occurred caused massive ground displacement, infrastructure collapse, and a large number of casualties. This study aims to evaluate soil characteristics, liquefaction potential, seismic hazard levels, and analyze landslide mechanisms before and after the earthquake through an integrative approach based on geotechnical and microtremor data. This study also maps liquefaction vulnerability and seismic hazard risk levels as a basis for future disaster mitigation planning.

This research was conducted through a series of field tests at 10 hand boring points, 10 Cone Penetration Test (CPT) points, 6 Standard Penetration Test (SPT) points, 29 Swedish Weight Sounding (SWS) points, and 31 microtremor points. The test points were determined using the systematic grid sampling method parallel to the direction of the landslide. The CPT locations were placed close to the SWS and hand boring points so that the results could be compared directly. The criteria for soil with liquefaction potential were analyzed using the Chinese criteria, additional criteria, and the Tsuchida curve. The N_{sw} and W_{sw} values from SWS were converted to *N*-SPT using a correlation equation and validated with SPT tests. Based on the *N*-SPT values, the site class of the Balaroa area was determined with reference to SNI 1726:2019, while the peak ground acceleration (PGA) values were obtained from the Indonesian Spectrum Design website. Liquefaction potential analysis was carried out by calculating the Factor of Safety (FS) based on SWS, CPT, and SPT data, and the Liquefaction Potential Index (LPI) was calculated as the basis for preparing a vulnerability map. Seismic hazard evaluation uses microtremor analysis at 31 points that have locations relatively similar to 29 SWS points. Mapping is done with ArcGIS, while slope stability simulation is analyzed numerically with *SLOPE/W* and *QUAKE/W* software.

The results of the study show that the Balaroa area has soil characteristics that are classified as vulnerable to liquefaction. Test results show that the soil in the Balaroa area is dominated by sandy silt (SM) with a very soft consistency and *very loose–loose* conditions to a depth of ±7 meters based on the *cone resistance* (q_c) value from CPT. The average *N* value obtained from SWS is very low compared to SPT, so it is classified as soft soil (SE), with a generally shallow water table. CPT, SWS, and borehole (BH-1, BH-2, and BH-5) data show a very high level of vulnerability, while areas outside the affected zone show low to very low vulnerability. Microtremor analysis produced values of f_0 0.2 to 1.34 Hz and T_0 0.74 to 3.35 seconds, reflecting soft alluvial sediments with a thickness >30 m and a seismic vulnerability index (K_g) generally > 6, indicating that the study site is prone to liquefaction in the event of seismic shocks. The Ground Shear Strain (GSS) value at PGA_M 0.6 g ranged from 1.240×10^{-3} to 2.591×10^{-2}, indicating elastoplastic conditions. The shear wave velocity (V_s) was in the range of 154 to 344 m/second, with medium to soft soil layers (V_s < 350 m/sec) 9 to 53 m thick, sediment V_s < 750 m/sec 82 to 430 m thick, and V_s = 1 km/sec layer depth reaching 137 to 1374 m. Stability simulations show that the slope before the 2018 earthquake was statically stable, but the safety factor decreased dramatically due to dynamic loads, causing landslides triggered by flow liquefaction and excess pore water pressure. The post-earthquake slope is still stable without an earthquake, but has the potential to slide if a similar shock occurs, mainly due to changes in the steeper slope geometry. Overall, the research results confirm that the integration of geotechnical and microtremor data provides a comprehensive understanding of the mechanisms of liquefaction and slope instability in Balaroa. These findings are expected to form the scientific basis for the preparation of seismic microzonation maps and disaster mitigation strategies in earthquake-prone areas of Central Sulawesi.

Keywords: Mapping, Liquefaction, PGA_M, SWS, CPT, SPT, LPI, microtremor, landslide