

# The Effect of Cyclic Loading of Liquefaction on Palu Sands

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## ABSTRACT

Liquefaction is a phenomenon where soil loses its strength. The phenomenon of liquefaction occurs on non-cohesive soils with medium to fine grains. The phenomenon of liquefaction occurs during an earthquake, the ground experiences shaking vibrations. Palu, Central Sulawesi, Indonesia is one of the areas affected by the liquefaction phenomenon which causes damage to infrastructure in the area. The Palu earthquake that occurred on September 28, 2018, at 18:02:44 WITA with a magnitude of  $M_w = 7.4$ , centered on 26 km north of Donggala, Central Sulawesi. One aspect of the assessment for soil susceptibility to potential liquefaction is laboratory tests. One common laboratory test that can be performed is the cyclic triaxial test. The factors affecting the liquefaction resistance of saturated sand are the relative density and cyclic stress ratio (CSR). The susceptibility of each relative density (30%, 50% and 70%) of the soil experiencing liquefaction and the cyclic stress ratio of 0.15 to see the amount of cyclic load needed until the soil experiences liquefaction, the load frequency to represent the earthquake load is 1 Hz with sinusoidal waves. This study will test the fine sands from Palu, Central Sulawesi, Indonesia, to determine their respective behavior when the soil is given a cyclic load.

**Keywords:** Cyclic Triaxial, Liquefaction, Cyclic Stress Ratio, Relative Density, Fine Sands.

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## 1. Introduction

Liquefaction is a phenomenon where soil loses its strength. The phenomenon of liquefaction occurs on non-cohesive soils with medium to fine grains. The phenomenon of liquefaction occurs during an earthquake, the ground experiences shaking vibrations. Palu, Central Sulawesi, Indonesia is one of the areas affected by the liquefaction phenomenon which causes damage to infrastructure in the area. The Palu earthquake that occurred on September 28, 2018, at 18:02:44 WITA with a magnitude of  $M_w = 7.4$ , centered on 26 km north of Donggala, Central Sulawesi. One aspect of the assessment for soil susceptibility to potential liquefaction is laboratory tests. One common laboratory test that can be performed is the undrained cyclic triaxial test. Cyclic triaxial test performed to see the susceptibility of soil to liquefaction. Factors that affect liquefaction resistance in saturated sand are relative density, initial effective stress, and cyclic stress ratio (CSR) (Zhang, Muraleetharan et al. 2016). This study is addressed to know

liquefaction potential on a reconstituted sand. This study also conducted to see the effect of relative density and cyclic stress ratio.

## 2. Palu Earthquake

Palu is one of the areas affected by the liquefaction phenomenon which causes damage to infrastructure in the area.

The Palu earthquake that occurred on September 28, 2018, at 18:02:44 WITA with a magnitude of  $M_w = 7.4$ , centered on 26 km north of Donggala, Central Sulawesi. The Palu Earthquake series started at 14:00 local time with a magnitude of 5.9, then was followed by an earthquake with a 5.0 magnitude at 14:28 local time, followed by an earthquake with magnitude 5.3 at 15:25 local time, at 17:02 local time experienced the largest magnitude with a value of 7.4, then The aftershock occurred at 17:14 local time and ended at 17:25 local time with a Magnitude of 5.9.

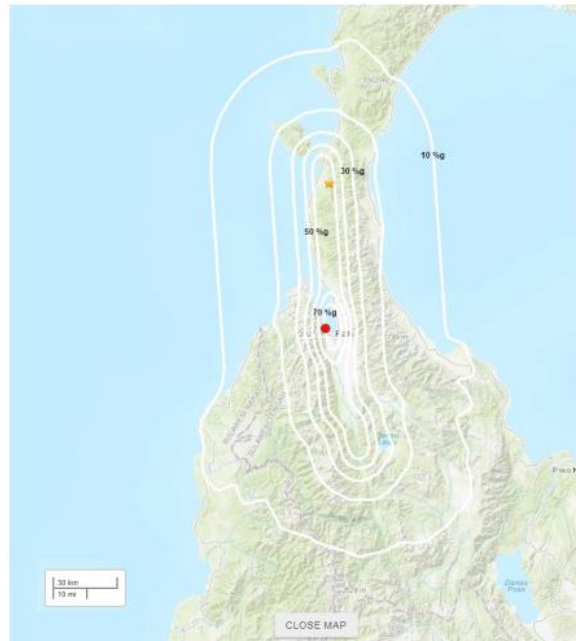


Figure 1. Peak ground acceleration (PGA) Palu Earthquake, 2018

Source : Geotechnical Extreme Events Reconnaissance, 2019

## 3. Testing Details

The cyclic triaxial test is used to measure the dynamic properties of the soil at a high strain test. The results of the cyclic triaxial test are used to evaluate the ability of the soil to withstand the shear stress that occurs in the soil mass during an earthquake or other cyclic load. The cyclic triaxial stress-controlled method was tested using the ASTM D5311-13 standard.

Fractions of Palu sands consisted of 86% sand and 14% non-plastic silt with minimum relative density of  $1.382 \text{ g/cm}^3$  and maximum relative density of  $1.786 \text{ g/cm}^3$ . Cyclic triaxial testing procedures in this study are shown in Figure 4.

Table 1. Physical properties of Palu Sands

|                                                        |       |
|--------------------------------------------------------|-------|
| Specific gravity                                       | 2.63  |
| Maximum dry density, $Dr_{max}$ , (g/cm <sup>3</sup> ) | 1.786 |
| Minimum dry density, $Dr_{min}$ , (g/cm <sup>3</sup> ) | 1.392 |
| Fines content, $F_c$ (%)                               | 14    |

Triaxial Cyclic Test performed using GDS ELDyn (Entry Level Dynamic Triaxial Testing), testing is carried out using loading frequency of 1 Hz to represent earthquake load, specimens were saturated first and consolidated at initial effective confining pressure of 100 kPa, variations in relative density of 30%, 50% and 70%, sample prepared using moist tamping with 5% moisture content. The load is cycled until either the cyclic double amplitude vertical strain exceeds 20%, the single amplitude strain in either extension or compression exceeds 20%, 500 load cycles or the number of load cycles required in the testing program are exceeded.

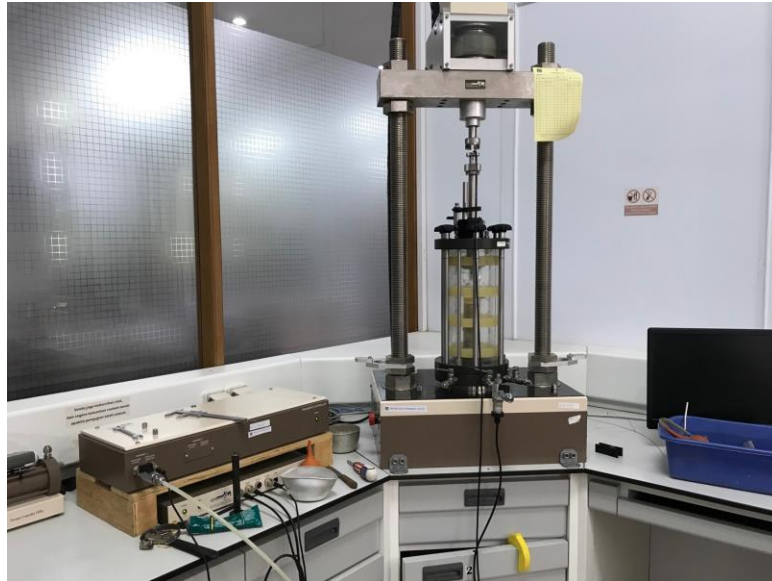


Figure 2. Cyclic Triaxial Apparatus GDS ELDyn

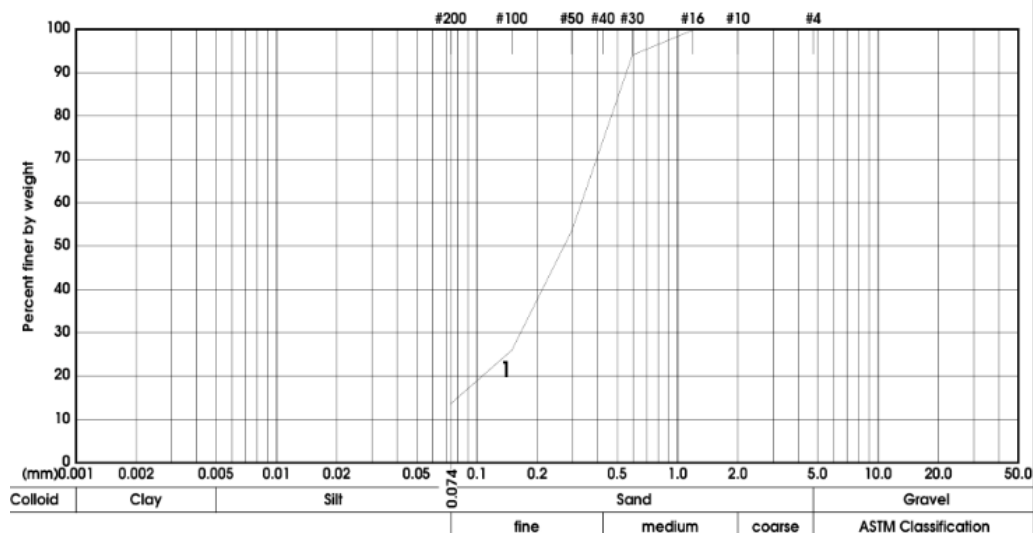


Figure 3. Grain Size Distribution of Palu Sands

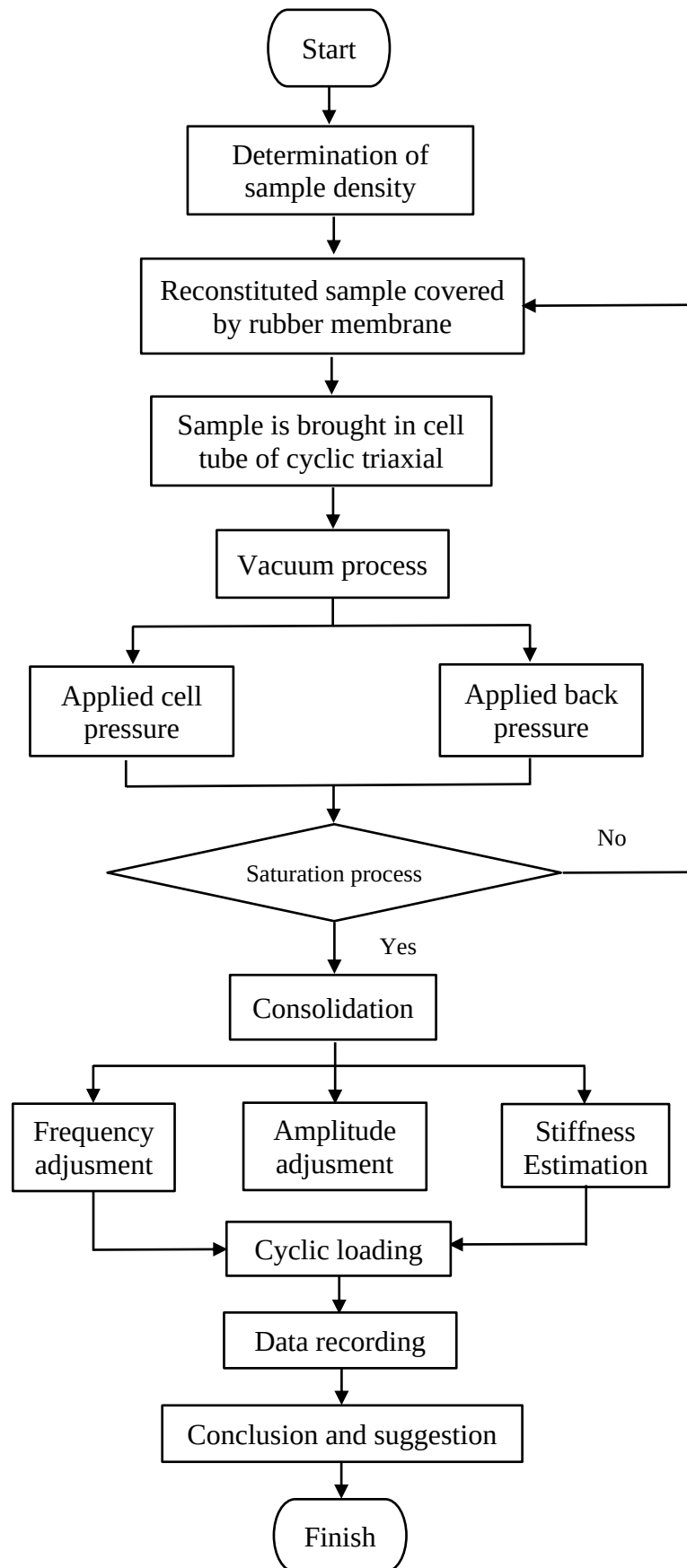


Figure 4. Cyclic triaxial test procedure

#### 4. Test Results and Discussion

Generally, Figure 3 shows number of cycle when sand sample liquefied is very dependend on cyclic stress ratio and relative density. Based on Figure 3, with increasing cyclic stress ratio applied on every sample will make the specimen easier to liquefy. And with increasing relative density will make sample more difficult to liquefy.

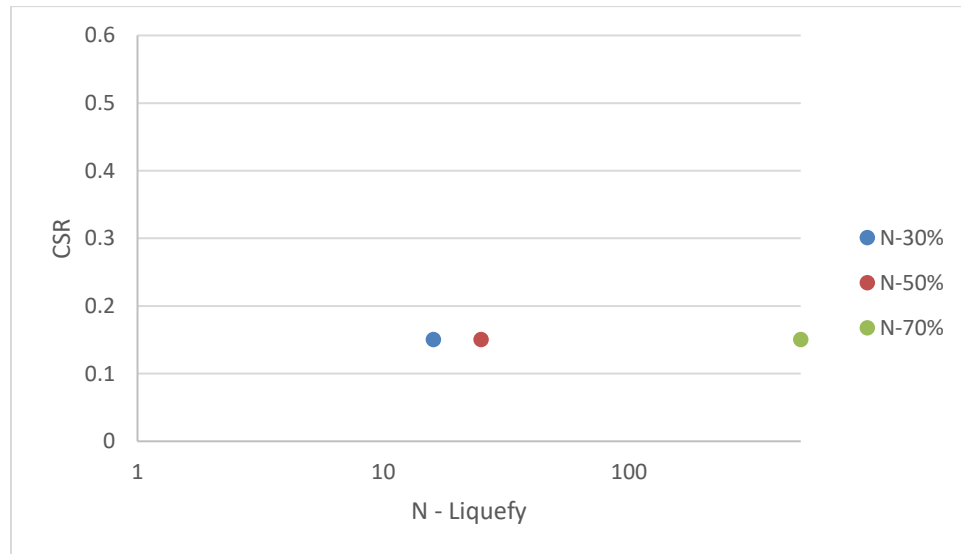


Figure 3. Relationship between CSR and number of cycles (N-Liquefy)

#### 5. Conclusion

1. Relative density 30% easier to liquefy than others (DR 50% and DR 70%)
2. Relative density 30% with CSR 0.15 would liquefy in 16 cycles, relative density 50% with CSR 0.15 would liquefy in 25 cycles, and relative density 70% with CSR 0.15 did not liquefy until 500 cycles.

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