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Evaluation of Particle Grain Size of Sand Embankment for Liquefaction Above Peat Against Vibration

Soewignjo Agus Nugroho,^{*1} Agus Ika Putra,¹ Muhamad Yusa,² Syawal Satibi,² Gunawan Wibisono,¹ Ferry Fatnanta,² Rinaldi,¹ and Putra S Hasibuan³

¹Department of Civil Engineering, Faculty of Engineering, Universitas Riau Kampus Bina Widya, Jl HR Subrantas KM 12 Pekanbaru 28293, Indonesia

²Magister Teknik Sipil, Civil Engineering Department, Universitas Riau, Jl HR Subrantas KM 12 Pekanbaru 28293, Indonesia

³Geotechnical Engineer staff of Riau Padang Tol Way, PT Hutama Karya Infrastructure, Indonesia

*Corresponding author. Email: nugroho.sa@eng.unri.ac.id

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Abstract

Liquefaction is the transformation of soil into a liquid. The vibrating table in this study moves in a horizontal direction and the opposite manner in a vertical direction utilizing modelling. Acceleration variations of 0.25 g and 0.32 g were employed. The dirt was 10 centimetres thick. The sand clusters were 15 cm thick, with differences in debris gradient size and water surface on the sample. The uniform load that was employed was 40 kg/m². Examine the drop of the ground surface and the rising of the porous water for signs of liquefaction. A 0.5mm diameter glass pipe was used to measure the porous water pressure. The test findings revealed that with higher acceleration, effective vertical voltage, and porous water ratio values, the rate of particle graduation has a major influence on the occurrence of liquefaction potential. The test results revealed that poorly graduated fine sand experienced maximum effective vertical stress and elevated porous water ratio values (Ru), whereas well-graded sand tended to be more stable.

Keywords: Liquefaction, excess pore water pressure, shaking table, grain size write

1. Introduction

The earthquakes that smashed Aceh (Muksin et al. 2019), Nias (Mustafa 2010) and Padang (Yusfania, Anjasmara, and Sanjiwani 2016) were natural disasters that caused massive damage to buildings. Vibration is one of the causes of structures damage. Wave retardation might result in probable liquidations, forcing the building's foundation to break down. The 1964 earthquakes in Niigata and Alaska impacted many sloping buildings and caused subsidence, triggering the collapse of buildings over the surface. Liquidation research is being examined and taken for consideration in building design. Liquefaction is a phenomenon that occurs where soil strength rapidly disappears due to the vibration induced by an earthquake or blasting. Liquefaction is the loss of soil strength caused by increased pore water tension caused by cyclical loads or vibrations that cause soil to behave like a liquid. Liquefaction happens when soil is soaked with water. In the most extreme instances, the effective voltage is zero. When there is a contact style between particles of sand, an effective pressure

is produced. The inability of such a contact style is indicated by the effective pressure zero. The value of the effective stress zero can result in a loss of foundation strength, resulting in structural failure of the building and ambles to the ground's surface. A vibrating table instrument can be used for liquid analysis, which is one of various ways (shaking table). M. Gupta (1977) and A. K. Gupta (2009) did study on the potential of liquefaction by proposing the notion of the parameter ratio of increase in porous water voltage that is detected with r_u . The equation r_u compares the porous air voltage owing to dynamic loading (u) to the effective soil pressure (p'_O).

According to Aldi (2011), findings out of the calculation of the effective vertical pressure of the soil reveal that the bigger the load, the longer it takes for the ground to lose its support.

Vesariany (2012) claimed that the sample full soaked condition has the potential for a fall in the surface of the ground and a greater rise in the pores of water due to the influence of the water content.

According to Mase, Fathani, and Adi (2013) and Mase, Likitlersuang, and Tobira (2022), the test was conducted by simulating the maximum earthquake accelerations in the Kali Opak Imogiri area of 0.3g, 0.35g, and 0.4g with a vibration frequency of 1.6 Hz and a vibration time of 32 seconds. The investigation revealed that increasing maximum accelerations resulted in a rise in the ratio of increased porous water pressure ($R_u > 1$), and increasing maximal accelerators resulted in an increase in the time intervals (durations) of liquefaction.

2. Research Methodology

This study examines the scope of testing as well as the processes needed to carry it out, such as literature reviews, location reviews, sampling, soil characteristics testing, tool preparation, sample preparation, and one-way vibrating table modelling tests. A one-way vibrating table with a test box of 100 cm length, 50 cm wide, and 35 cm high was the tool used in the investigation. The test container walls were made of 0.5 cm thick acrylic material as can be seen in Figure 1.

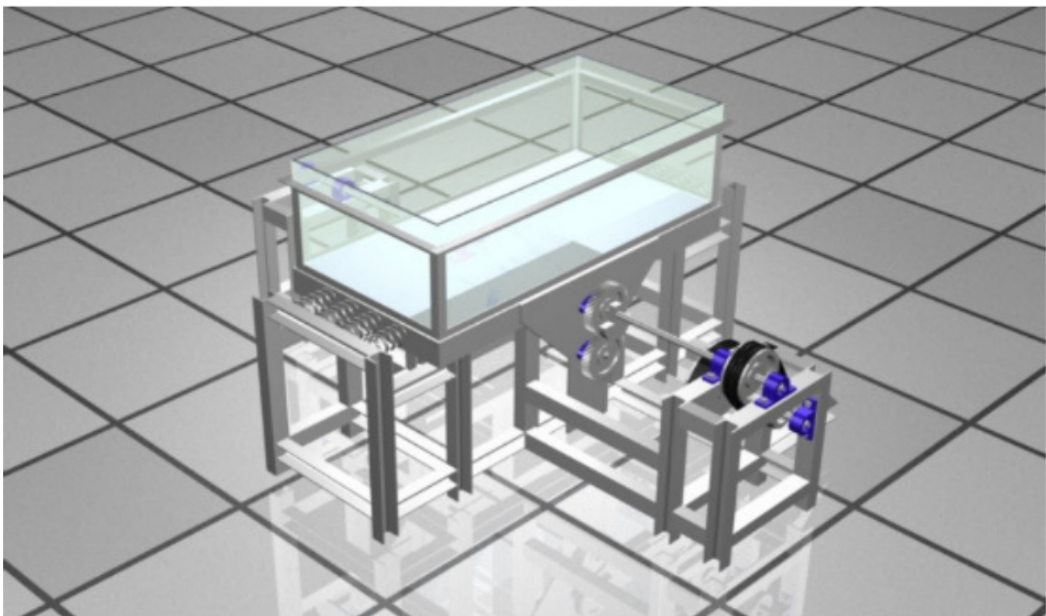


Figure 1. 1-D Shaking Table

The vibration table system shown above is powered by a 220V;50Hz induction engine. Then,

according to the study, it is coupled with a pulley to control the acceleration. The shape of the vibrating table above is simply a horizontal pattern that is manipulated by the bandit, causing the vibration table to shift. The sand used in this investigation originated from the Kampar region of Rimbo Panjang. The soil sample is an interrupted sand that was taken from the quarry to the Riau University Soil Mechanics Laboratory. Before use, soil samples are examined for physical characteristics (Nugroho et al. 2019).

3. Soil Sample

The sand used in this study is from the 6th Km Air Hitam region of Pekanbaru City (see Figure 2 and Figure 3). Sand and soil samples delivered from the quarry to the Universitas Riau's Soil Mechanics Laboratory for analysis of their attributes.



Figure 2. Peat sample from Rimbo Panjang

The curvature gradients of sand (coarse grain, medium grain, fine grain, and well-graded) as debris are varied in the tests. Sandy soils are classified as rough sand (pass sieve #4 and retained sieve #10), moderate sand (pass sieve #10 and retained sieve #40), and fine sand (pass sieve #40 and retained sieve #200) by the Unified Soil Classification System (USCS).

4. Test Model

Modeling Experiments Soil characteristics testing are performed prior to laboratory modelling tests. (Sand and peat). The following are the results of modelling studies with a one-way vibrating table:

- Fill the vibrated table test container with material soil to a thickness of 10 cm.
- As its cluster, the material introduced into the test tank is filled with sand. Fill the shaking table test carefully with sand on top of clay soil with a sand layer thickness of 15 cm based on sand gradation variations (rough sand, moderate sand, fine sand, and well graded).
- Place the glass pipe measuring the rise of the pores in the center of the sand cluster is as deep as 7.5 cm.
- Provide a uniform load of 0.4 kN/m^2 over the shaking table test modelling.
- A 220 V/50 Hz induction machine attached to the pulley drives the one-way vibration table test.



Figure 3. Sand sample from 6th Km Air Hitam

- For 120 seconds, data from the one-directional vibration desk test is collected by reading the growth of the water pores and the total ground decrease.

5. Result and Discussion

This study's findings include soil qualities (haired and sandy), effective vertical tension, and soil deterioration, all of which are presented in the form of tables and graphs. The peat employed in this study originated in the Rimbo Panjang region of the Kampar district. Table 1 shows the outcomes of the tests. The Sapric-peat soil (fibrous peat) is the outcome of the clay test qualities based on ASTM D 4427-92 (ASTM 2007) clay soil classification employed in this study.

The peat has high water content (442.933%) due to its high organic matter, fibrous and porous structure, and low bulk density. All these factors allow it to hold and retain a large volume of water.

Table 1. Rimbo Panjang's Peat Characteristics

Physical properties	unit	value
water content, w	%	442.933
bulk density, γ_b	kN/m^3	1.011
Specific Gravity, G_s	-	1.48
ash content, A_C	%	0.797
organik content, O_C	%	99.203
Fibrous content	%	1.183

5.1 Characteristic of Sand

The sand characteristics used in this study are from the Black Water KM 6 area of Pekanbaru City. Table 2 shows the outcomes of the assessment. Poor gradation sand (rough sand, moderate sand, and fine sand) and good gradation sand are two types of sand.

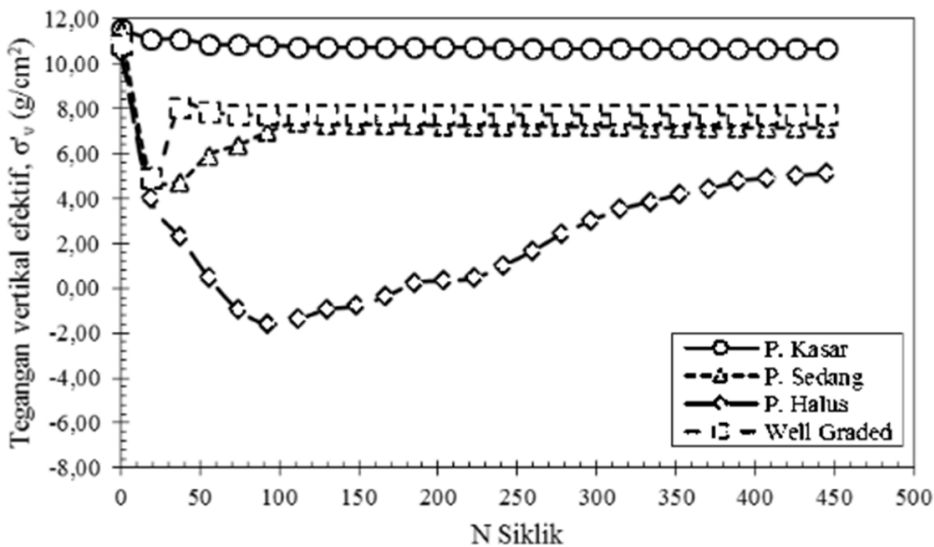
Table 2. Air Hitam's Sand characteristics

Grain/Description	Mechanics Grain Size Analysis for Sand			
	coarse grain	medium	fine grain	well graded
Gravel (%)	0	0	0	0
Sand (%)	100	100	100	100
Fine grain (%)	0	0	0	0
Uniform coefficient, C_u	1.55	1.69	2.01	6.79
Curvature coefficient, C_c	0.91	0.88	1.07	1.73

5.2 Effective Stress

Vertical stress that is effective When a one-way vibrating table is tested, the soil decreases while the pores enlarge. All of the surface magnitude can be determined from the position of the pipe measuring the rise of the water pores, which is placed at half the sand's ground thickness. When the soil loses its strength, the value of the effective vertical voltage is equal to zero, and under extreme conditions, the value of the effective vertical pressure is negative.

Fine sand has the lowest effective vertical tension value. Effective vertical voltage values reach $-1,58 \text{ gr/cm}^2$ at the 93rd cycle for 0.25g acceleration and -5.91 gr/cm^2 at the 324th cycle for 0.32g acceleration. According to Hakam, Yuliet, and Donal (2010), when cyclic pressures such as earthquakes occurred, sand discharge tended to decrease in volume, resulting in increased porous water pressure and lower ground efficient sliding strength. The time it took for the increase in porous pressure to be transferred into an effective tension form between soil particles was quite brief (Nugroho, Putra, and Yusa 2018).

Figure 4. p'_O at acceleration $a=0.25\text{g m/s}^2$

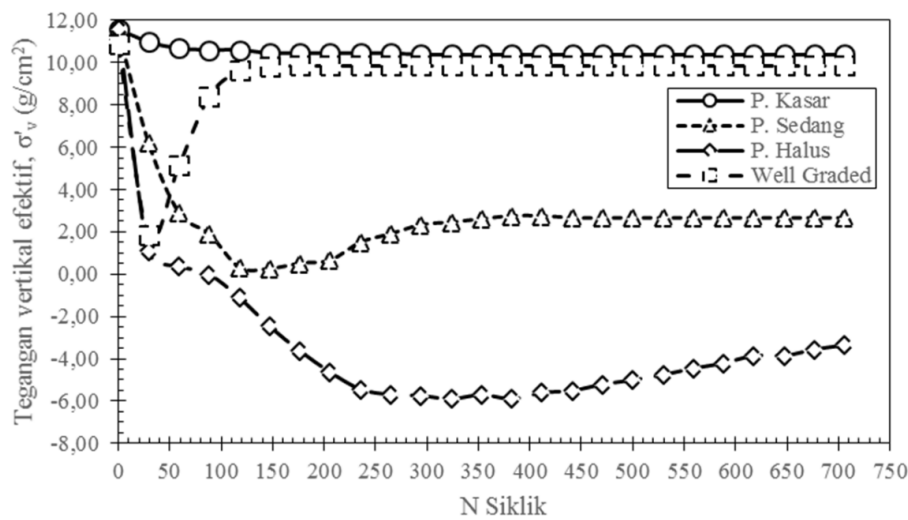


Figure 5. p'_O at acceleration $a=0.32g\ m/s^2$

5.3 Excess Pore Water Pressure Ratio

Increased porous water pressure ratio R_u values are calculated by comparing the tension of the porous water with the overall voltage. Fine sand has the greatest R_u values at accelerations of 0.25g and 0.32g. This is because fine sands have the greatest increase in pores and the greatest decrease in soil. In fine sand, acceleration 0.25g has a R_u value of 1.1 at the 93rd cycle, while acceleration 0.32g has a R_u value of 1.51 in the 382nd cycle.

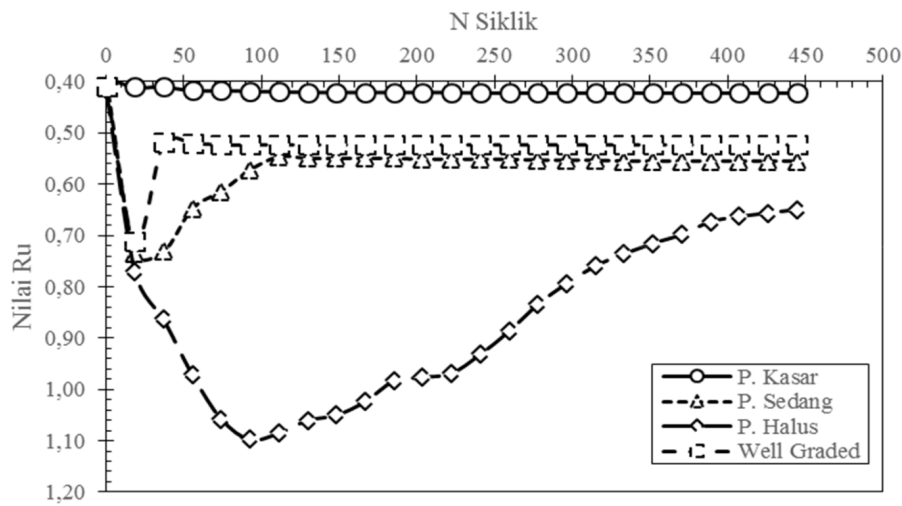


Figure 6. Value of R_u at acceleration $a=0.25g\ m/s^2$

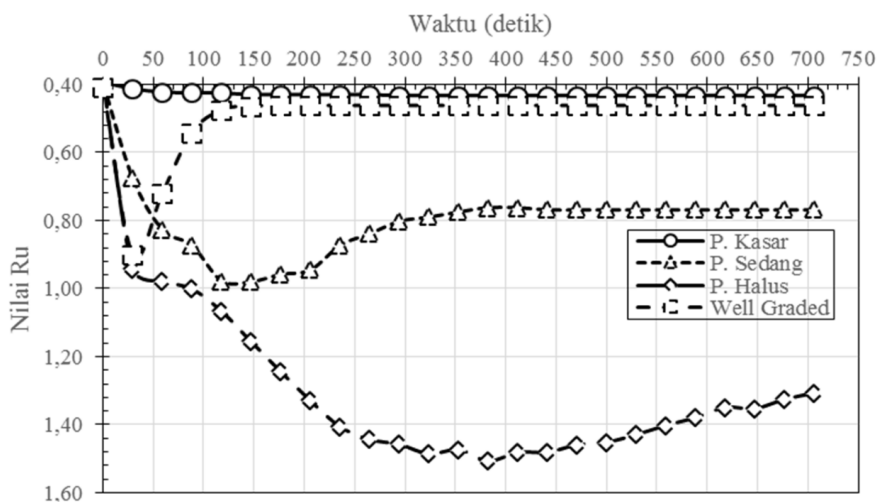


Figure 7. Value of RU at acceleration $a = 0.32g \text{ m/s}^2$

6. Conclusion

The results of the soil's effective vertical voltage calculation show that poor gradation sand has a high liquefaction potential. The smaller the value of effective vertical voltage, the greater the acceleration. The effective vertical voltage value of the soil is less than zero on fine sand. This shows that the sand is inadequately graded and that fine sand is liquefying. Good gradation sand is more stable, but when subjected to cyclic pressures, the soil will experience high effective vertical tension.

References

- Aldi, M. 2011. Variasi beban dan percepatan getar untuk potensi likuifaksi pada pasir dengan uji model laboratorium. *Pekanbaru: Universitas Riau*.
- ASTM. 2007. *Astm volume 04.08 soil and rock (i): d420-d5611*. Annual Book of ASTM Standards. ASTM. ISBN: 9780803143388.
- Gupta, Ashok K. 2009. Effect of particle size and confining pressure on breakage and strength parameters of rockfill materials. *Electron. J. Geotech. Eng* 14:1–12.
- Gupta, MK. 1977. Liquefaction of sands during earthquakes. PhD thesis, Department of Earthquake Engineering, University of Roorkee, India.
- Hakam, Abdul, Rina Yulier, and Rahmat Donal. 2010. Studi pengaruh penambahan tanah lempung pada tanah pasir pantai terhadap kekuatan geser tanah. *Jurnal Rekayasa Sipil* 6, no. 1 (February): 11–22. <https://doi.org/10.25077/jrs.6.1.11-22.2010>.
- Mase, Lindung Zalbuin, Teuku Faisal Fathani, and Agus Darmawan Adi. 2013. Studi eksperimental potensi likuifaksi di kali opak imogiri provinsi daerah istimewa yogyakarta. In *Pit hatti xvii*, 199–204. Jakarta, Indonesia, November.
- Mase, Lindung Zalbuin, Suched Likitlersuang, and Tetsuo Tobita. 2022. Verification of liquefaction potential during the strong earthquake at the border of thailand-myanmar. *Journal of Earthquake Engineering* 26 (4): 2023–2050. <https://doi.org/10.1080/13632469.2020.1751346>.
- Muksin, Umar, Klaus Bauer, Muzli Muzli, Trond Ryberg, Irwandi Nurdin, Masturiyono Masturiyono, and Michael Weber. 2019. Acehseis project provides insights into the detailed seismicity distribution and relation to fault structures in central aceh, northern sumatra. *Journal of Asian Earth Sciences* 171:20–27. ISSN: 1367-9120. <https://doi.org/10.1016/j.jseas.2018.11.002>.
- Mustafa, Badrul. 2010. Analisis gempa nias dan gempa sumatera barat dan kesamaannya yang tidak menimbulkan tsunami. *Jurnal Ilmu Fisika | Universitas Andalas* 2, no. 1 (March): 44–50. <https://doi.org/10.25077/jif.2.1.44-50.2010>.

- Nugroho, Soewignjo Agus, Agus Ika Putra, and Muhamad Yusa. 2018. Study gradation and moisture content of sand embankment on peat subjected vibration potential liquefaction. In *Iop conference series: materials science and engineering*, 316:012033. 1. IOP Publishing.
- Nugroho, Soewignjo Agus, Agus Ika Putra, Muhamad Yusa, and Syawal Satibi. 2019. Liquefaction potential of sandfill with various grain size distribution on peat with shaking table. *AIP Conference Proceedings* 2094, no. 1 (April): 020014. issn: 0094-243X. <https://doi.org/10.1063/1.5097483>.
- Vesariany, R. 2012. Potensi likuifaksi pada pasir ditinjau dari gradasi, ukuran butiran, dan kandungan air dengan uji kandungan air dengan uji model laboratorium. *Tugas Akhir*.
- Yusfania, Meiriska, Ira Mutiara Anjasmara, and I Dewa Amertha Sanjiwani. 2016. Pemodelan mekanisme gempa bumi padang 2009 berdasarkan data sugar. *Geoid* 12 (1). issn: 2442-3998.