International Journal of GEOMATE, Feb., 2024 Vol.26, Issue 114, pp.9-16
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2024.114.4002
Geotechnique, Construction Materials and Environment

UNIFORMITY OF RECONSTITUTION OF LIQUEFIABLE SAND SPECIMEN USING A RAINER BOX SYSTEM

Aisyah Salimah[1], Widjojo Adi Prakoso[1]*, Dandung Sri Harninto[1], Muhammad Zaky Alvaro[2], Yelvi[2], Fathiyah Hakim Sagitaningrum[1], Wiwik Rahayu[1],

[1]Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia, Depok, Indonesia.
[2]Departement of Civil Engineering, Politeknik Negeri Jakarta, Depok, Indonesia.

*Corresponding Author, Received: 01 July 2023, Revised: 28 Jan 2024, Accepted: 30 Jan 2024

ABSTRACT: Experimental laboratory-scale liquefaction models aim to investigate the behavior of soils, particularly non-cohesive soils with liquefaction potential. Achieving the desired density in reconstituted soil beds is vital for conducting geotechnical modeling tests. The first stage is that the soil samples must be reconstructed to approach their original state. It assesses parameters such as the densities, moisture content, and uniformity of the sand specimens obtained from each setup. The dry density of soil samples is an important parameter used in geotechnical engineering for designing structures in liquefiable sands. This paper describes the efforts to create a sand Rainer box that facilitates specimen reconstitution using the air pluviation method. The Rainer system used in this laboratory was designed to control the velocity of sand rain using a perforated plate. The diameter of the perforated plate is 0.6 mm, and liquefiable sand samples with 0.15 to 0.5 mm particle size were used. The procedure entailed combining sand and water in a container, allowing the sand to settle, and eliminating excess water. To control the uniformity of relative density, use a mold with three positions in a box plan. It is placed in the middle and the corners in a box plan. The Sand Rainer Box produced the reconstituted specimen with less than 8% error for horizontal and 5% for vertical uniformity. This dependable accurately estimates relative density when preparing sand samples for repeated laboratory testing. The research illustrates the effectiveness of the Rainer system in producing sand specimens with consistent characteristics.

Keywords: Sand specimen, Uniformity, Loose sand, Rainer box

1. INTRODUCTION

Soil liquefaction during earthquakes is deemed to be responsible for the failure of many infrastructures. An experimental study of liquefaction has been done in several studies at the laboratory [1-6]. This provides valuable insights into the behavior of sandy soils during liquefaction, contributes to understanding the geotechnical phenomenon, and helps improve understanding as well as develop effective mitigation strategies. The reconstitution model of specimen sand soil significantly affects the test results. Soil reconstitution that is not measured will affect the accuracy of subsequent tests. Achieving the desired density of reconstituted soil samples in laboratory settings is crucial for investigating various geotechnical issues. This process serves various purposes, including calibrating field instruments, analyzing model foundations' behavior, retaining structures, examining soil response under dynamic or seismic loads, validating numerical models, etc. [7-13].

The significance of soil behavior in geotechnical investigations lies in the relative density, which measures the proportion between the void ratios of a cohesionless soil when it is in its loosest state compared to its existing natural state and the difference between its void ratio in the loosest and densest states. Thus, achieving a specific density in large soil samples is crucial for proper analysis. To illustrate, in one instance, researchers [14] examined the interaction between geosynthetics and soil through pull-out tests conducted in a soil bed measuring 1.5 meters by 0.6 meters.

In a study, the reconstitution of dry sand samples involves various methods such as tamping [15-18], vibration [19, 20], and pluviation, which has been extensively explored in the literature. These methods have demonstrated their efficacy in achieving different relative densities, with values typically ranging from 40% to 100% [21-23]. It is important to note that these methods can be broadly classified into two main categories based on the stage at which the density modification occurs. The first group comprises tamping and vibration techniques, where the density of the sample is modified after it has been deposited in the testing apparatus. Conversely, the second group, known as pluviation, focuses on determining the density of the sample during the deposition process itself [24]. The choice of method depends on several factors, including the desired relative density, the specific experimental objectives, and the available resources. By exploring and understanding the characteristics and distinctions of these reconstitution methods, researchers can make informed decisions and select the most suitable technique for their particular study, ultimately enhancing the accuracy and reliability of their experimental findings.

The relative density is influenced by several factors, including the height from which the particles are dropped, the intensity of deposition, and the mesh size of the grid used for particle deposition [25, 26]. Higher drop heights increase drop velocity, leading to greater packing density. However, this densification effect is limited to drop heights below a certain maximum, as particle velocity reaches a plateau at higher drop heights due to air drag [27]. Higher deposition intensities for a given drop height lead to decreased deposition density [28-30], as the simultaneous drop of multiple particles increases inter-particle interference [24]. Increasing the grid mesh size can achieve higher deposition intensities [28].

One of the air pluviation methods is the rain system. It is widely used to prepare sand samples in the laboratory. However, for liquefaction research, water saturation is required after soil reconstitution. This is a challenge in itself; the sand saturation process must be careful not to change the relative density that has been formed. The presence of water flow in the saturation process can make the relative density in each sand layer non-uniform. Sand layers directly exposed to the water flow may become denser due to the water slipping or may become looser due to being pushed upwards.

The researchers in this study have designed and implemented a Rainer system with water in the shaking box. The water demand and drop height in the shaking box were calculated. This method is essential in laboratory modeling to create particular specimens with desired characteristics and relative densities under water-saturated conditions. A set of laboratory experiments was carried out to assess the effectiveness of the developed system.

By reconstituting liquefiable sand specimens using a Rainer box system, researchers can investigate the behavior and susceptibility of sandy soils to liquefaction under controlled laboratory conditions.

2. RESEARCH SIGNIFICANCE

The significance of this study lies in the reconstitution of a model of a liquefiable sand layer for conducting liquefaction experiments. The research is expected to demonstrate the effectiveness of the Rainer system in producing sand specimens with consistent characteristics. Therefore, this method can be consistently employed for repeated liquefaction testing. The significance of this study lies in the reconstitution of a model of a liquefiable sand layer for conducting liquefaction experiments, which plays a crucial role in advancing our understanding of this natural hazard. This is achieved through the creation of a sand Rainer box that facilitates specimen reconstitution using the air pluviation method, a technique that allows for precise control and uniform distribution of sand particles within the box. By implementing this innovative approach, the research aims to demonstrate the effectiveness of the Rainer system in producing sand specimens with consistent characteristics, including grain size distribution, density, and moisture content. The consistency of these characteristics is of paramount importance as it ensures reliable and reproducible results in subsequent liquefaction testing. By establishing a method that can be consistently employed for repeated liquefaction testing, this study not only enhances the reliability of experimental results but also enables researchers to investigate various factors contributing to liquefaction susceptibility and develop effective mitigation strategies. Overall, the development and validation of this reconstitution method provide a valuable contribution to the field of geotechnical engineering and earthquake studies, aiding in the better understanding and management of liquefaction-induced hazards.

3. EXPERIMENTAL PROGRAM

The experiments of this study were conducted in the Geotechnical Laboratory, Civil Engineering, Politeknik Negeri Jakarta, Indonesia. The experiments consisted of three stages. The first was soil sample preparation, which included the physical and engineering properties of soil. The second stage was preparation for a Rainer box with mesh 0.6 mm in size. It was conducted on how to make a sand drop uniformly. The third was deposit preparation. In this test, the drop height varied from 474 to 494 mm and was used to reconstitute the samples. The drop height was maintained during this test by pulling up the chain block slowly at a certain speed to keep the drop height constant.

3.1 Soil Properties

Seed defines liquefaction as the process wherein water-saturated sandy soil transitions into a liquid state due to increased pore pressure that equals the total soil stress from dynamic loads generated by tectonic earthquakes. This increase in pore pressure causes the effective stress of the soil to become zero [31]. Liquefaction primarily occurs in loose sand near the groundwater table. Tsuchida conducted observations and studies on gradation curves related to pre-earthquake soil behavior in Japan and found a similar response in laboratory experiments. The distribution of soil particle sizes in the gradation curve can differentiate soils with liquefaction potential from those without.

The soil used throughout this testing program was processed uniform sand, referred to as filter sand. Fig. 1 shows the results of the grain size analysis.

It can be concluded from Fig that the silica sand used has a size of 0.15 mm to 0.5 mm with uniform grain gradation, which means poor grading. Based on the results of the specific gravity test, relative density test, and sieving analysis of the sample, the silica sand property index was obtained, as shown in Table 1.

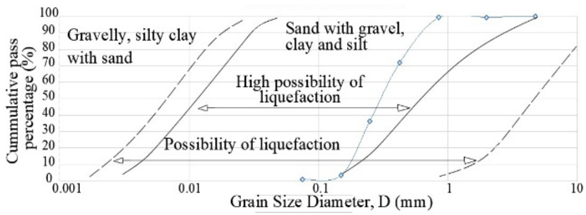

Fig. 1 Grain size distribution

Table 1 Soil Properties of Silica Sand

	Notation	Test result	Unit
Av. of Maximum Index Unit Weight	γd_{max}	14.47	kg/m^3
Av. of Minimum Index Unit Weight	γd_{min}	13.33	kg/m^3
Specific gravity	Gs	2.64	
Maximum Index Void Ratio	e_{max}	0.950	
Minimum Index Void Ratio	e_{min}	0.796	
Coefficient Uniformity	C_{u}	2.056	
Coefficient Gradation	C_{c}	0.794	
Cohesion Value	c	0.017	
Internal Friction	°	29.2793	

3.2 Rainer Box System

All the tests were carried out using filter sand deposits prepared within the Rainer box, as depicted in Fig. 2. This box was constructed using steel plates with a thickness of 2 mm, reinforced with steel angles along the edges and sides to enhance its rigidity.

The internal dimensions of the boxes measured 480 mm in length, 480 mm in width, and 650 mm in depth. Additionally, a 56° funnel was incorporated to complement the setup. These boxes were fitted with chain blocks to make them manoeuvrable by a single person. A chain block is a mechanism composed of several parts and operated by two chain loops, a lifting chain, and a hand chain. The way the chain block works is that the chain is wrapped around a wheel or wheel, which is the core of this mechanism. When the hand chain is pulled, the lifting chain will lift or lower the load so that it can be easily moved from one place to another along with the trolley.

This experiment uses a Sand Rainer box to drop sand into the sandbox. This tool has a sand filter with a diameter of 0.6 mm. The Sand Rainer Box has a pulley to control the height of the sand drop into the box, which will affect the relative density of the soil when it is tested.

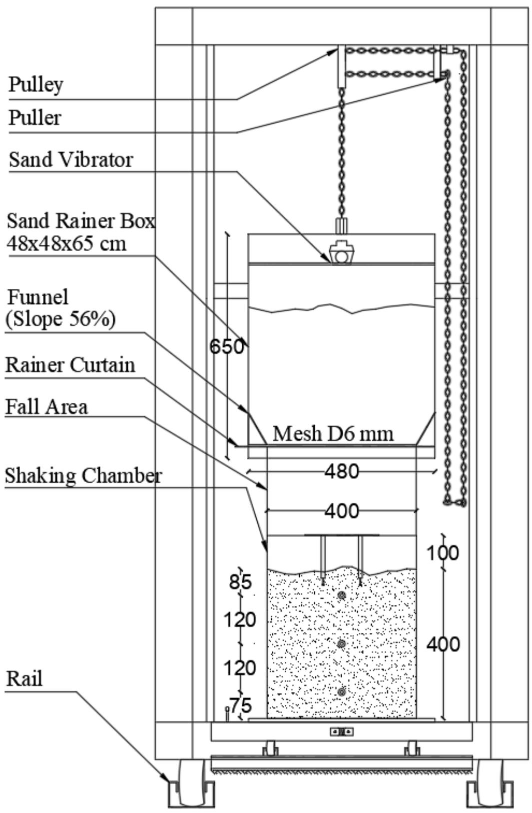

Fig. 2 Systematic of the Sand Rainer Box

Preparing the deposit began by placing an empty box directly underneath the suspended full box, as illustrated in Fig. 2. The height of the upper box and its position concerning the testing box on the floor was carefully regulated using a chain block connected to a trolley. Fig. 3 shows the details of the sand rainer box.

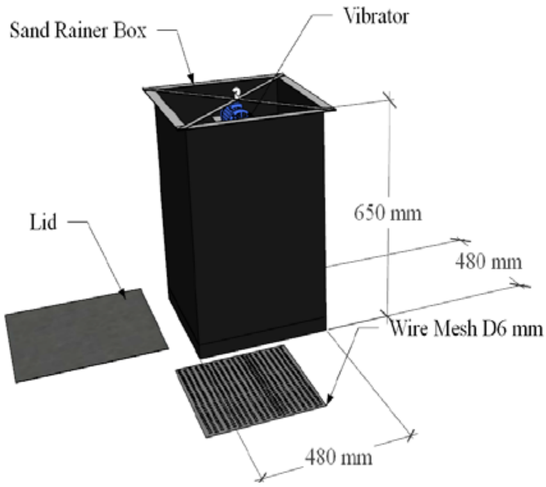

Fig. 3 Detail of Sand Rainer Box

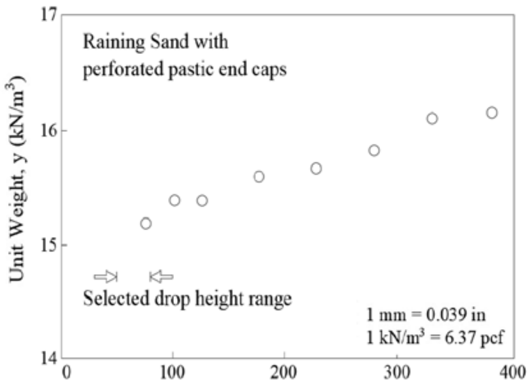

Fig. 4 Correlation of Drop Height to Specific Gravity of Soil [31]

As seen in Fig. 4, falling objects with large masses and high speeds can affect the specific gravity of the surrounding soil. This is caused by the object's kinetic energy, which causes a large force on the surrounding soil, changes the arrangement of the soil grains, and increases the soil density in the area affected by the falling object. However, the effect of drop height on the specific gravity of the soil depends on the characteristics of the soil. Conversely, sandy, or gravelly soils with a low water content may have a more significant effect because the soil is denser and more challenging to deform [2, 25, 31].

Filter wire mesh allows the sand to fall evenly on each side. The drop height has been correlated with the specific gravity of the soil, as shown in Fig. 4. A large specific gravity requires a greater drop height, and vice versa. The drop height is between 474 mm and 494 mm for medium specific gravity. However, it is necessary to do the test yourself first due to the difference in the use of soil types and sieve diameters. Therefore, this study focused on uniformity.

3.3 Deposit Preparation

To ensure efficiency, the test deposit preparation was designed to be performed by a single person. Two boxes were used interchangeably as both sand hoppers and testing boxes. It is important to highlight that the sand Rainer system, including the drop height, remained consistent for each test. In order to determine the relative density in each test, three to five sampling molds with a diameter of 50 mm were positioned in the bottom plate of the box.

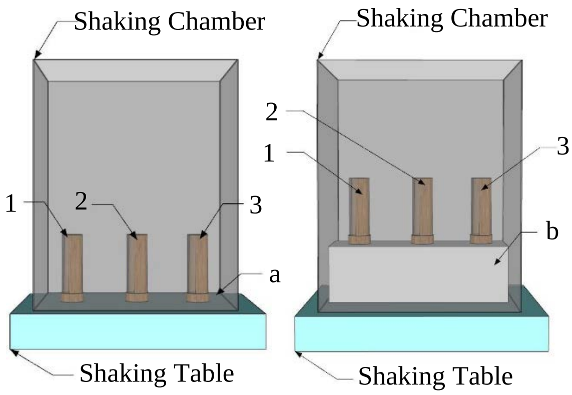

Fig. 5 Position of molds for uniformity tests in the vertical direction (a) elevation 1st; (b) elevation 2nd

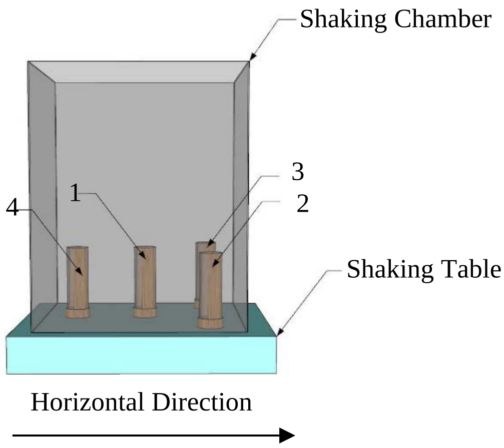

Fig. 6 Position of molds for uniformity tests in the horizontal direction

It is important to mention that the drop height of the sand during pluviation was kept constant in every test. To assess the relative density in each test, a set of three sampling molds (for vertical) and five sampling molds (for horizontal) were employed. The configuration of the sampling molds is depicted in Fig. 5 and 6. In each trial, these molds were utilized to determine the relative density of the reconstituted samples. The method of calculating relative density is presented in ASTM D 4253-16 and ASTM 4254-16 (e_{min} and e_{max}, respectively).

$$\mathbf{Dr}(\%) = \frac{emax - e}{emax - emin}\ x\ \mathbf{100} \qquad (1)$$

$$\mathbf{e} = \frac{Gs\ x\ \gamma w}{\gamma d} - \mathbf{1} \qquad (2)$$

4. EXPERIMENTAL RESULT

3.1 Relative Density Measurement

With this method, the sand unit weight depends primarily on the velocity and intensity of the sand particle drop [31]. As mentioned earlier, loose sediment was obtained by raining sand through a 480 x 480 mm Rainer box with a 0.6 mm diameter of wire mesh. A drop height of 474 to 494 mm was maintained through the raining procedure to obtain the loose sand deposits. The test was conducted in two methods: dry and wet conditions. This dry method results from the sand's relative density depending primarily on the velocity and intensity of the sand particle drop, similar result to [31].

Furthermore, the wet method has the same trend. The relative density increases with increasing velocity, which can be obtained by increasing the drop height in both of two methods. However, as shown in Fig. 7, the wet method has a smaller relative density than the dry method by almost 35%. This condition happens because the water in the mold reduces the velocity of the sand when the sand begins to fall in the water, thus reducing the relative density value; with the same volume of water in each test, the density value that occurs in each test will also be different.

The implemented procedures for obtaining sand deposits aimed to achieve a uniform and consistent unit weight throughout the testing program. The final determination of unit weight for each deposit was conducted by dividing the net weight of sand in the testing box by the volume of the box. To calculate the relative density of each mold, specific formulas, referred to as Eq. (1) and Eq. (2) were employed.

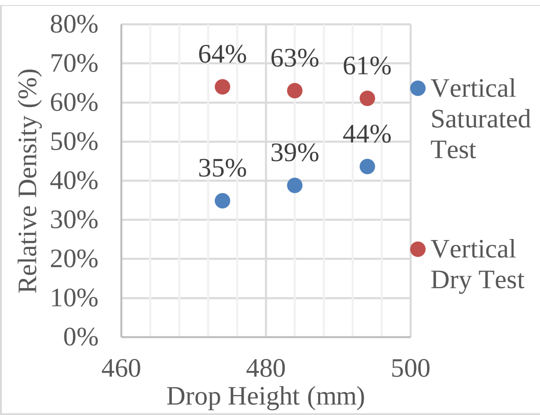

Fig. 7 Effect of drop height on relative density

3.2 Uniformity Analysis of the Relative Density of the Reconstituted Specimen in Vertical Direction

This section is dedicated to discussing the uniformity tests conducted on vertically oriented models after the reconstitution of the samples. The results of vertical uniformity analysis for reconstituted specimens under wet conditions are visually represented in Fig. 8, which provides valuable insights into the experimental outcomes. In this particular experiment, the box was equipped with three sampling molds positioned at each level to ensure comprehensive data collection.

Analyzing the data presented in Fig. 8 becomes evident that the drop height during the test significantly influences the relative density values obtained. As the drop height increases, the relative density value tends to increase as well. Specifically, the data from the first saturated vertical test (vertical saturated test 1) with a drop height of 474 mm yielded an average relative density value of 35%. On the other hand, the data from the second saturated vertical test (vertical saturated test 2) with a slightly higher drop height of 484 mm resulted in an average relative density value of 39%. It is worth noting that there was a noticeable difference in relative density values at a height difference of 10 mm, amounting to a 4% variation.

Furthermore, the largest disparity in relative density values for each position was found to range from 2% to 4%. These findings underscore the sensitivity of the relative density values to the drop height and highlight the importance of maintaining consistency in the testing conditions to ensure accurate and reliable results. By carefully analyzing and interpreting the data obtained from the vertical uniformity tests, researchers gain a deeper understanding of the behavior and characteristics of the reconstituted samples under different drop heights. The relative densities at both elevations were significantly affected based on the position of specimens.

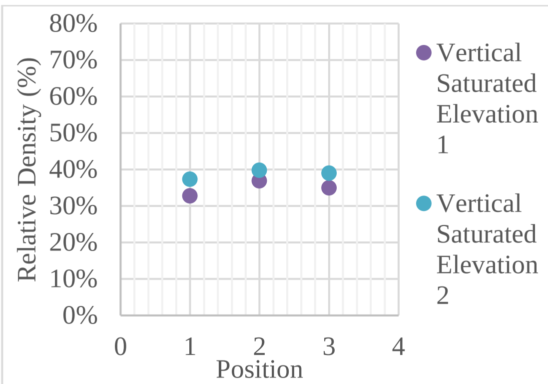

Fig. 8 Relationships between relative density and position of specimens with different elevation

3.3 Uniformity Analysis of the Relative Density of the Reconstituted Specimen in Horizontal Direction

This section focuses on the uniformity tests conducted horizontally after reconstituting the specimen in a wet condition, aiming to evaluate the study objectives. To ensure comprehensive analysis, five strategically placed sampling molds were utilized within the test box. The dry and wet tests were performed using a sand pluviation device equipped with a Rainer wire mesh measuring 0.6 mm in diameter. It is worth noting that a consistent sand pluviation height of 494 mm was maintained throughout all experiments.

The results obtained from the analysis of horizontal uniformity for reconstituted specimens under wet conditions are illustrated in Fig. 9. To assess the reproducibility of the proposed device and its capability to achieve horizontal uniformity, the horizontal uniformity test, described in the previous paragraph, was repeated three times. The test results indicated a percentage difference in relative density ranging from 3% to 7% for each position. The average relative density percentage was found to be 41%, with an error percentage of less than 8%. These findings highlight the reliability and consistency of the sand pluviation method, as well as its ability to produce reconstituted specimens with a satisfactory level of horizontal uniformity. By ensuring such uniformity, researchers can enhance the accuracy and validity of subsequent analyses and interpretations based on the reconstituted specimens, ultimately contributing to the advancement of knowledge in the field of geotechnical engineering and soil testing.

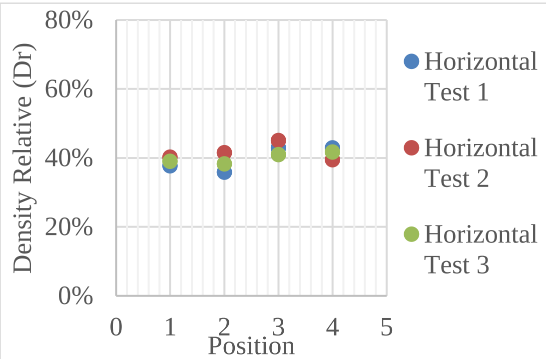

Fig. 9 The results of horizontal uniformity analysis for reconstituted specimens' wet condition

5. CONCLUSIONS

Utilizing a Rainer box system to reconstitute liquefiable sand specimens makes it more accessible to investigate the behavior and susceptibility of sandy soils to liquefaction under controlled laboratory conditions. This is achieved using a novel air pluviation device for the reconstruction of sand specimens. The device was designed to reconstitute specimens with uniform loose density both vertically and horizontally. The device comprises a Rainer box with a diameter of 0.6mm. Two reconstitution methods were employed. The first method involved dry sand pluviation tests, and the second was the saturation sand pluviation test, where the relative density was found to increase with higher velocities, controlled by the drop height.

Four sampling molds were employed within the test box to evaluate the horizontal uniformity. This process was repeated three times, and the results obtained were compared with those from the main tests. The outcome of this analysis revealed that the proposed sand pluviation device exhibited the ability to consistently generate samples with the desired conditions, thus demonstrating its reproducibility. Test results showed the percentage of Relative Density Difference in each position is 3% - 7%, with an average percentage of relative density of 41%. That value of relative density exhibited acceptable levels of horizontal uniformity. The saturated vertical test 1 data with a drop height of 474 mm obtained an average relative density value of 35%, and the saturated vertical test 2 data with a drop height of 484 mm obtained an average relative density value of 39% with a difference in relative density values at a height difference of 10 mm by 4%. The difference in each position's largest relative density value is 2% - 4%. The sand rainer box was designed with unique features that distinguish it from other similar models. These features include achieving horizontal and vertical uniformity in the reconstituted specimens, with an error percentage of less than 8% for horizontal uniformity and less than 5% for vertical uniformity. Furthermore, the air pluviation device has the added advantage of efficiently producing specimens within a short timeframe, giving it a competitive edge over similar models.

6. ACKNOWLEDGMENT

The author would like to thank the Laboratory of Civil Engineering, Politeknik Negeri Jakarta and Universitas Indonesia for their support. This research was funded by the Unit of Students, Research, and Community Service Engineering Faculty Universitas Indonesia, under Seed Funding Professor FTUI 2023/2024 (Grant No. PENG-2588/UN2.F4.D/PPM.00.00/2023).

7. REFERENCES

[1] Elzamel A., Altahrany A., and Elmeligy M., Using Cement and Fibers as Additives for

Liquefaction Mitigation of Sandy Soils, International Journal of GEOMATE, Vol. 23, Issue 96, Aug. 2022, pp. 129-36.

[2] Hakam A., Ismail F.A., and Fauzan. Liquefaction Potential Assessment Based on Laboratory Test, International Journal of GEOMATE, Vol. 11, Issue 26, Oct. 2017, pp. 2553-2557.

[3] Unni K.G., Beena K.S., and Mahesh C., Development of 1-D Shake Table Testing Facility for Liquefaction Studies, Journal of the Institution of Engineers, 2018, Series A, Vol. 99, Issue 3, pp. 423-432.

[4] Lee C.J, Hung W.Y., Tsai C.H., Tu Y.C., Huang C.C., Wu Y.C., and Hsieh M.H., Seismic Responses of Short Grouped-Piles Embedded in Liquefiable Sandy Soils During Earthquakes, International Journal of GEOMATE, Vol. 8, No. 16, June 2016, pp. 1218-1225.

[5] Otsubo M., Towhata I., Hayashida T., Shimura M., Uchimura T., Liu B., Taeseri D., Cauvin B., Rattez H., Shaking Table Tests on Liquefaction Mitigation of Embedded Lifelines by Backfilling With Recycled Materials, International Journal of Soils and Foundations, Vol. 56, 2016, pp. 365-378.

[6] Banerjee R. Konai S., Sengupta A., and Deb K., Shake Table Tests and Numerical Modelling of Liquefaction of Kasai River Sand, Geotechnical and Geological Engineering, Vol. 35, Issue 4, 2017, pp. 1327-1340.

[7] Tabaroei A., Abrishami S., Hosseininia E. S., Comparison Between Two Different Pluviation Setups of Sand Specimens, Journal of Materials in Civil Engineering, Vo. 29, Issue 10, 2017, pp. 04017157.

[8] Al-Yasir A.T. and Al-Taie A.J., A New Sand Raining Technique to Reconstitute Large Sand Specimens, Journal of the Mechanical Behaviour of Materials, Vol. 32, Issue 1, 2023, pp. 20220228.

[9] Hariprasad C., Rajashekhar M. and Umashankar B., Preparation of Uniform Sand Specimens Using Stationary Pluviation and Vibratory Methods, Geotechnical and Geological Engineering, Vol. 34, 2016, pp. 1909–1922.

[10] Raghunandan M. E., Juneja A., and Hsiung B.C.B., Preparation of Reconstituted Sand Samples in the Laboratory, International Journal of Geotechnical Engineering, Vol. 6, 2012, pp. 125-131

[11] Hossain M.Z. and Ansary M.A., Development of a Portable Traveling Pluviator Device and its Performance to Prepare Uniform Sand Specimens. Innovative Infrastructure Solutions, Vol. 3, Issue 1, 2018, pp. 53.

[12] Oliveira F., Freitas A., Morais P., Mendes B., Carvalho A.T., Serra J.B., A Travelling Sand Pluviator to Reconstruct Large Soil Specimens, 15th International Conference on Experimental Mechanics, Portugal, 2012, paper ref./pp. 3761

[13] Abdollahi M. and Bazaz J.B., Reconstitution of Sand Specimens Using a Rainer System, International Journal of Engineering, Vol. 30, Issue 10, Oktober 2017, pp. 1451-1463.

[14] Meyer N. and Nernheim A., Interaction Behaviour Of Geosynthetics And Soil Under Static And Cyclic Loadings Using The Pull-Out Test, Proceedings of the 8th International Conference on Geosynthetics (8ICG), Yokohama, Japan, Vol. 1-4, 2006, pp.1451-1454.

[15] Zhu Z., Zhang F, Dupla J. C., Canou J., Foerster E., Peng Q., Assessment of Tamping-Based Specimen Preparation Methods on Static Liquefaction of Loose Silty Sand, Soil Dynamics, and Earthquake Engineering, Vol. 143, 2021, paper ref./pp.106592.

[16] Sawwaf M.E. and Nazir A.K., Behaviour of Repeatedly Loaded Rectangular Footings Resting on Reinforced Sand, Alexandria Engineering Journal, Vol. 49, Issue 4, 2010, pp. 349–356.

[17] Raghunandan M., Juneja A., Hsiung B., Preparation of Reconstituted Sand Samples in The Laboratory, International Journal of Geotechnical Engineering, Vol. 6, Issue 1, 2012, pp. 125–131.

[18] Chen C., Quan Q., Deng Z., Jiang S., Vibratory Compaction Method for Preparing Lunar Regolith Drilling Simulant, Advances in Space Research, Vol. 58, Issue 1, 2016, pp. 145–154.

[19] White D., Barefoot A., and Bolton M., Centrifuge Modelling of Upheaval Buckling in Sand, International Journal of Physical Modelling in Geotechnics, Vo. 1, Issue 2, 2001, pp. 19– 28.

[20] Fattah M.Y., Al-Mosawi M.J., and Al-Ameri A.F.I., Vibration Response of Saturated Sand-Foundation System, Earthquakes and Structures, Vol. 11, Issue 1, July 2016, pp. 83–107.

[21] Li Y., Yang Y., Yu H.S., Roberts G., Effect of Sample Reconstitution Methods on the Behaviours of Granular Materials under Shearing, Journal of Testing and Evaluation, Vol. 46, 2018, pp. 6.

[22] Dave T. N. and Dasaka S., Assessment of Portable Travelling Pluviator to Prepare Reconstituted Sand Specimens, Geomechanics and Engineering, Vol. 4, Issue 2, 2012, pp. 79–90.

[23] Srinivasan V., Srivastava S., Ghosh P., Optimization and Parametrical Investigation to Assess The Reconstitution of Different Types of Indian Sand Using Portable Travelling Pluviator, Geotech Geol Eng., Vol. 34, Issue 1,

2016, pp. 59–73
[24] Hariprasad C., Rajashekhar M., and Umashankar B., Preparation of Uniform Sand Specimens Using Stationary Pluviation nd Vibratory Methods, Geotechnical and Geological Engineering, Vol. 34, No. 6, 2016, pp. 1909–1922.
[25] Maillot B., A Sedimentation Device to Produce Uniform Sand Packs, Tectonophysics, Vol. 593, 2013, pp. 85–94.
[26] Lagioia R., Sanzeni A., and Colleselli F., Air, Water, and Vacuum Pluviation of Sand Specimens for The Triaxial Apparatus, Soils Foundation, Vol. 46, No. 1, 2006, pp. 61–67.
[27] Kazemi, Majid, and Bolouri J.B., A Curtain Traveling Pluviator to Reconstitute Large Scale Sand Specimens, Geomechanics and Engineering, Vol. 14, No. 2, February 2018, pp. 131–39.
[28] Zhang S., Gong W., Wu Q., Li T., Zhao X., Experimental Studies on Dynamic nd Static Properties of Sand During Repeated Liquefaction Events, Acta Geotech, Apr. 2023.
[29] Vaid, Yoginder P., and Dawit Negussey. Preparation of Reconstituted Sand Specimens, ASTM special technical publications, 1988, pp. 405–417.
[30] Choi S.K., Lee M.J., Choo H., Tumay M., Lee W., Geotechnical Testing Journal, Preparation of a Large Size Granular Specimen Using a Rainer System with a Porous Plate, Vol 33, Issue 1, 2010, doi 10.1520/GTJ101634.
[31] Vidic S, Kulhawy F.H., Trautmann C.H., Experimental Study of Drained Behaviour of Drilled Shafts During Cyclic Inclined Loading, Electric Power Research Institute, Cornell University, Ithaca, New York, 1992, pp. 1.1–9.7.