Comparison between Two Different Pluviation Setups of Sand Specimens

Abdolah Tabaroei1; Saeed Abrishami2; and Ehsan Seyed Hosseini, M.ASCE3

Abstract: Sand pluviation is a method used to prepare a model sand specimen to carry out some particular laboratory tests such as static and dynamic tests on footings, retaining walls, piles, as well as calibration of static and dynamic penetrometers. Preparation of uniform reconstituted sand specimens of required density is a prerequisite for obtaining reliable results. In this paper, two rainer systems, which are capable to prepare homogeneous sand specimens, are introduced. The first is a rainer system with a perforated plate and the second is a portable curtain rainer system. The portable curtain rainer system essentially consisting of a sand storage, flexible hose, a hopper, rigid tubes, and curtain with different opening widths. This study aims to reach a better understanding of the effects of deposition intensity (DI) and height of fall (HF) on the relative density (RD) of reconstituted sand specimens. The uniformity of the sand bed is verified by measuring the relative densities of 20 samples at different locations of the tank. By using a portable curtain rainer system, large uniform sand specimens with a wide range of RD = 23–96% can be achieved. The results demonstrate that at a lower value of HF, the variation of RD is significant, while it has an insignificant effect on RD for values of HF ≥ 600 mm. Furthermore, in order to achieve a dense to very dense sand bed, the DI should be controlled. It was also observed that both systems significantly improve the horizontal and vertical homogeneities of the sand specimens. With an increase in the RD of reconstituted sand specimens, higher repeatability of uniform pluviation was achieved. DOI: 10.1061/(ASCE)MT.1943-5533.0001985. © 2017 American Society of Civil Engineers.

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Introduction

To study the parameters and the behavior of cohesionless soils, the use of laboratory specimens seems to be necessary. For this purpose, the soil specimen should be reconstituted to its natural state. Sample preparation techniques can be affected on fabric and stress-strain response of the soil particles. There are three methods for preparation of reconstituted sand specimens, tamping, vibration, and pluviation (Lo Presti et al. 1992; ASTM 2006). Among these methods, pluviation has been widely used due to its ability to achieve a wide range of relative densities for sand bed (Rad and Tumay 1987; Fretti et al. 1995; Choi et al. 2010; Dave and Dasaka 2012; Gade and Dasaka 2015). Additionally, this method is mainly advantageous when it is needed to reconstitute large specimens for model tests or calibration chamber tests within a short time (Fretti et al. 1995). Kuerbis and Vaid (1987) reported that the method used to prepare a reconstituted sand bed should be able to produce a very loose to very dense bed, a uniform void ratio throughout the specimen, no segregation of soil particles (regardless of particle size or fines content), and replicable natural soil deposits. Other advantages of the sand pluviation technique can be noted as follows: no particle crushing, ease in preparation, more consistent specimens, ease in interruption for placing instrumentation, or placing a large of geosynthetic material, and repeatability of relative density results (Rad and Tumay 1987; Lo Presti et al. 1992, 1993; Dave and Dasaka 2012).

According to the type of implementation, pluviation can be divided into three types; air-pluviation, water-pluviation, and vacuum-pluviation. In order to prepare a small or large specimen for laboratory testing, researchers prefer to implement air-pluviation. In the air-pluviation method, from a certain raining height and with a constant velocity, dry sand particles are poured through the air into the specimen container. Air-pluviation may be further divided into three groups depending on the type of opening under the sand storage or hopper. The first type is a single nozzle in which the soil is poured through the nozzle moving in a regular pattern (Fretti et al. 1995). The second type is a curtain rainer in which the sand from the hopper is poured through a narrow slot in a thin sand curtain (Butterfield and Andrawes 1970; Gemperline and Ko 1984; Garnier and Cottineau 1988; Stuit 1995). The third type is a sieve rainer where the soil is poured by one or multiple sieves over an area equal to or slightly larger than the specimen container (Miura and Toki 1982; Cresswell et al. 1999; Abbreddy 2008).

The relative density (RD) of sand reconstituted by air-pluviation depends on the height of fall (HF), the deposition intensity (DI), uniformity of raining sand, the porosity of the diffuser sieve, the opening width of the curtain in curtain technique, particle characteristics, and other parameters (Kolbuszewski 1948; Kolbuszewski and Jones 1961; Butterfield and Andrawes 1970; Rad and Tumay 1987; Vaid and Negussey 1988; Lo Presti et al. 1992, 1993; Fretti et al. 1995; Lagioia et al. 2006; Choi et al. 2010; Dave and Dasaka 2012; Gade and Dasaka 2015).

Height of fall (HF) is the distance between the lowest diffuser sieve/hopper bottoms to the surface of the sand in the specimen
Experimental results of Miura and Toki (1982) showed that the effect of HF on RD of the specimen is insignificant in the pluviation method. Theoretical studies by Vaid and Negussey (1984, 1988) on individual particles demonstrated a significant effect of HF on RD values. The impact velocity of sand particles increases nonlinearity with an increase in HF until critical velocity is reached, while further increase in HF certainly would not affect the RD of the specimen. Furthermore, with an increase in particle size, there is also an almost linear increase in the magnitude of critical velocity. Kolbuszewski (1948) and Vaid and Negussey (1984, 1988) found that if the HF is smaller than critical HF, the effect of HF on RD values of specimen is significant. Also, they showed that an increase in HF beyond the critical HF causes an insignificant change in RD of the specimen.

Deposition intensity (DI) is the mass of soil falling in the container/chamber per unit of area per unit of time and it is controlled by the effective area of the opening provided at the bottom of the sand hopper through which soil flows into the rigid tubes or directly falls into the container being used for the preparation of the specimen (Lo Presti et al. 1993; Dave and Dasaka 2012; Gade and Dasaka 2015). The opening area can include single or multiple circular or rectangular holes. Vaid and Negussey (1984) showed that the void ratio-HF graph consists of two zones; in the first zone, the HF significantly affected the RD and in the second zone the DI plays a major role in controlling the RD of the specimen. For a certain HF, an increase in DI augments the porosity of deposition (Kolbuszewski 1948; Walker and Whitaker 1967), an increase in void ratio (Rad and Tumay 1987), and a decrease in RD of the sand specimen (Miura and Toki 1982; Lo Presti et al. 1992, 1993; Fretti et al. 1995). At higher values of DI, the volume of sand that leaves the sand hopper is much higher, increasing the chances that the soil particles collide with each other before falling into the container (Gade and Dasaka 2015). Conversely, at a lower value of DI, individual particles freely fall into the container with minimum interference and could achieve critical velocity and much higher densities (Vaid and Negussey 1988; Cresswell et al. 1999). Cresswell et al. (1999) used a flow divider to divert the flow from the hopper and found that RD increases with a decrease in DI up to a limiting value corresponding to a 3–4-grain-thick energy layer causing compaction to take place. Rad and Tumay (1987) observed that for a certain DI, the use of a diffuser sieve with smaller openings results in higher values of RD. Stuit (1995) reported that with

![Photograph of complete setup test and rainer system with a perforated plate (RSPP)](image-url)
the increase in the hopper velocity, RD of granular specimens reconstituted decreases by a curtain rainer system.

One of the main goals of this paper is the preparation of large-size reconstituted specimens using the air-pluviation method. A thorough search in previous studies showed that few studies focused on preparation of large size specimens (Walker and Whitaker 1967; Fretti et al. 1995; Choi et al. 2010; Dave and Dasaka 2012; Gade and Dasaka 2015). Also, to the best knowledge of the authors, a comprehensive comparison on performance of curtain rainer and other systems has not been addressed so far. In order to prepare a sand specimen in a short time and for a wide range of RD with higher homogeneity, the present study suggests two different setups are designed based on the simultaneous control of HF and DI. The performance of the two systems was investigated and tested by more than 193 experimental tests. The paper consists of three parts: The first part describes all components of a rainer system with a perforated plate, material used in the tests, and the results that obtained by this system; the second part describes the portable curtain system and the results obtained by this system; and the third part describes the comparison of the performance of both rainer systems.

Rainer System with a Perforated Plate

Experimental Program

In order to prepare sand specimens, the first setup used in this study is a rainer system with a perforated plate (RSPP). This setup works on the basis of a pouring method. Fig. 1 shows the setup test of RSPP. As shown, the system consists of four parts: the support, lifting system, the movable hopper of sand, and the sliding valve and perforated plate.

The support system including steel plate, pedestal, and rotating column holds the hopper at the desired pluviation height and transfers the weight of the hopper to the loading frame and provides the rotation of the system in any direction. The lifting system includes the picket (horizontal arm), pulley, toggle, and cable that are connected to the rotating column, which provides the possibility of height adjustment with increments of 6 mm. The hopper can move in a vertical direction using the cable and pulley system. Also, the hopper can be held constant at a desired height with the help of the toggle and pulley. Moreover, the flexibility of the cable and rotation of the horizontal arm, which is connected to the rotating column, allows the hopper to move in a horizontal direction. The movable hopper is a rigid box that can store 62 kg of sand. The hopper consists of upper and lower parts. The upper part is in the form of a rectangular cube with dimensions of 300 (L) × 300 (W) × 450 (H) mm, and the lower part is in the form of an inclined funnel and has dimensions of 100 (L) × 100 (W) mm. At the end of the hopper, a simple sliding plate has been made to control the pouring rate of sand particles. The hopper and location of the perforated plate are shown in Fig. 2. The size and number of holes of the perforated plate control the pouring rate. Different perforated plates and HF could be used to change DI values and obtain various values of RD. In the present study, the hole diameters of perforated plates are 8.5 (PP1), 10 (PP2), and 12 mm (PP3). Perforated plates have 49 holes and therefore, PP1, PP2, and PP3 have a porosity of 27.8, 38.5, and 55.4%, respectively. Fig. 3 shows the perforated plates used in the rainer system. During the pouring by using the perforated plate, the sand starts to fall from the hopper to the specimen container or soil surface, depending on the value of DI.

Material for Preparation of the Specimens

The soil used for preparation of the specimens in the present study was a dry and relative uniform silica sand with grain sizes between 0.075 and 1.18 mm. The grain-size distribution curve of the sand is presented in Fig. 4. The specific gravity (Gs) of the soil particles is 2.71. The sand is classified as poorly graded sand (SP) according to the Unified Soil Classification System, USCS [ASTM D2487-11 (ASTM 2011)]. The sand has a coefficient of uniformity (Cu) of 1.5, a coefficient of curvature (Cc) of 1.07, an effective grain size (D10) of 0.48 mm, and mean grain size (D60) of 0.68 mm. For determining RD of the sand specimens, it is important to measure the maximum and minimum void ratio of sand precisely. The minimum void ratio is 0.69, according to the pluviation method (Miura and Toki 1982) to avoid particle crushing (Lo Presti et al. 1992), and the maximum void ratio is 1.085, according to the standard procedure [ASTM D4254 (ASTM 2006)].

Investigation Tests

A total of 60 preliminary raining tests were performed to investigate the effects of HF and DI (different values of diameter of holes in perforated plates) on the RD of pluviated specimens. Each test was performed two or three times to verify the repeatability of the test data. DI of the PP1, PP2, and PP3 are 1.89, 3.55, and
6.05 g/cm$^3$/s, respectively. The pouring was performed with the rates of 52.6, 136.6, and 335.3 g/s. The HF varied from 100 to 1,000 mm. In the previous studies, Lee and Manjunath (2000) and El sawwaf and Nazir (2012) deposited sand in 50-mm-thick layers to prepare specimens. In order to evaluate the effect of soil layer thickness, sand particles were poured into 25- and 50-mm-thick layers to prepare specimens. Fig. 5 shows the effects of HF on RD for different values of DI and soil layers thickness.

According to Fig. 5, it can be seen that for a given DI, RD of the reconstituted specimen increases with an increase in HF. The reconstituted specimen that was prepared with PP1 achieves a higher RD than those prepared with PP2 and PP3. Also, the effect of HF on RD of the reconstituted specimen was negligible beyond 600 mm. When using RSPP, the air-pluviation at a higher HF appears to be within the DI control zone. It was observed that reconstituted specimens prepared with a thickness of 25 and 50 mm achieved RD in the range of 35.1–73.7% and 32.9–72.6%, respectively. The values of RD obtained from a soil layer with a thickness of 25 mm are greater than those from a soil layer with a thickness of 50 mm. The difference in values of RD for a soil layer with a thickness of 25 and 50 mm decreases with an increase in HF.

**Uniformity Tests**

In previous studies, four methods have been used in order to evaluate the uniformity of sand specimens in the laboratory: miniature cone penetration testing (Walker and Whitaker 1967; Fretti et al. 1995; Hsu and Huang 1999; Choi et al. 2010; Dave and Dasaka 2012; Gade and Dasaka 2015), shear wave velocity method (Choi et al. 2010), RD evaluation with depth using small containers placed at various locations throughout the pluviated depth (Lo Presti et al. 1993; Choi et al. 2010; Hariprasad et al. 2016), and chemical impregnation (Schneider et al. 1989; Sutterer et al. 1996; Clayton et al. 1994). Additionally, heat propagation within the specimen was assessed by measuring thermal conductivity/resistivity to understand the uniformity of the sand specimens indirectly (Singh et al. 1979; Bellotti et al. 1991).

From these four methods mentioned earlier, the third method (using small containers), is more common to control the horizontal and vertical uniformity of large-scale reconstituted specimens. As presented in Fig. 6, the variation of the RD of reconstituted specimens was evaluated by measuring the local densities in cylindrical molds installed at 20 different locations within the specimen. The circular testing tank of 1,400 mm in diameter and 900 mm in height was divided into three parts of 250 mm and a part of 150 mm and then five molds were installed at the bottom of the tank. The diameter, height, and volume of each cylindrical mold were 100, 100, and 785.4 × 10$^3$ mm$^3$, respectively. In order to fill the testing tank, the hopper is manually moved back and forth in two directions perpendicular to each other over the area of 1,400 mm, to cover the all areas of the tank. Sand particles were poured into the tank in 25-mm-thick layers with the help of RSPP. This process is repeated until the 900-mm height of the tank was filled with sand with a total of 20 molds installed. As presented in Fig. 6, the horizontal and vertical spacing of molds from each other was 450 and 150 mm, respectively.

To evaluate the uniformity and repeatability of the sand bed in RSPP, seven full-scale tests were performed. In the full-scale tests, the PP1, PP2, and PP3 were used and the values of HF were 100, 600, and 1,000 mm, respectively. After completion of the raining process and filling tank, the molds were removed and RD was calculated. RDs of the sand specimens were in the range of loose to dense. RD of the reconstituted specimen increases with an increase in HF. Fig. 7 shows the vertical distribution of RD for the PP1, PP2, PP3, and HF in RSPP. From Fig. 7, it can be seen that the value of RD tended to increase slightly as the depth increased. The reason of achieving higher values of RD with depth is the surcharge caused by the weight of the upper layers. The weight of the molds was not so high that it influences the RD of the specimen and sand weight is a major factor on the RD specimen. It is noted that the average density of each layer is 175.2 g. As presented in Fig. 8, the density differences in the vertical direction for medium-dense sand specimens that produce with RSPP were 13, 10.8, 10.8, 8.9, and 7.8%, respectively. Also, with an increase in RD, a better vertical homogeneity is achieved regardless of the DI. Rad and Tumay (1987) reported that the difference in RD in a vertical direction for a sand specimen was 2–5%. Puppala et al. (1995), using a thin-wall sleeve showed a 5–7% difference in RD of medium-dense to dense sand specimens. Choi et al. (2010) reported that the conventional rainer system generates a 6.5–10% relative density difference. Comparing the results obtained from RSPP with results of Choi et al. (2010), it can be concluded that the density difference of this method is not very high. Moreover, it can be said that the density differences in the vertical direction for the medium-dense sand specimens are in good agreement with the results that were presented by previous studies.

Fig. 8 shows the horizontal distribution of RD for the PP1, PP2, PP3, and HF in RSPP. In this figure, the left side of the tank is

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**Fig. 4.** Grain size distribution of sand used in experimental tests

**Fig. 5.** Effect of HF on RD for different values of DI and soil layer thickness

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considered as the origin. The results showed that the horizontal homogeneity improves as RD increases, irrespective of DI. The density differences in the horizontal direction for medium-to-dense specimens that produce with RSPP were 5, 4, 3, 3.3, and 2.3%, respectively. The results obtained from the density of specimens in horizontal and vertical direction showed that RSPP can produce homogenous reconstituted specimens.

**Portable Curtain Rainer System**

**Experimental Program**

The second setup used in this study is a portable curtain rainer system (PCRS) that works on the basis of the air-pluviation method. P CRS consists of five main parts: a stationary sand storage, the flexible hose with various lengths, a hopper that can move at the top of the soil tank, the rigid tube, and the curtain rainer with different opening widths. Drawing detail of the PCRS assembly is depicted schematically in Fig. 9. A photograph showing the complete setup test, detail of the hopper and tank, rigid tubes, and curtain rainers with different opening widths are shown in Fig. 10. It should be noted that the sand pluviation used in the previous studies consists of a curtain rainer to form thin layers throughout the depth or large diffuser sieves of size equal to the model specimen container.

The sand storage is a rigid steel box that has inside dimensions of 1,100 × 1,100 mm in plan view and 1,100 mm in depth. The capacity of the sand storage is 2,000 kg. The sand storage is supported by four steel columns where two steel columns are firmly fixed to the horizontal steel beam (frame) and other columns are fixed to the plates, which are firmly clamped to the lab ground using two pins (rigid base). The flexible hose is connected to the sand storage bottom on one side with the help of hose clamps and is free on the other side to fill the hopper. The length of the flexible hose is considered variable, depending on the position of the hopper. The diameter of the flexible hose is chosen because first, the speed of movement of sand particles within the hose can be performed easily and second, it does not create any clogging within the flexible hose (in this case the rate of filling the hopper is reduced). Several tests
with different diameters of flexible hose are carried out to investigate the speed of movement of sand particles within the flexible hose. Finally a flexible hose with a diameter of 45 mm is selected.

The hopper is a rigid box with dimensions of $300 \times 200 \times 300$ mm and can accommodate approximately 30 kg of sand. The hopper used in this study is located on a steel frame and that frame can move on a steel beam (split) with the help of four wheels. A steel beam is located on another steel beam that can move with the help of four wheels and finally, two beams are fixed to the four columns, which are firmly clamped to the lab ground. In using this system, the hopper can be moved in two directions over a length of 2,000 mm to cover the entire diameter of the testing tank.

A rigid tube is connected to the curtain rainer that can manually move back and forth over the area of interest. The length of the rigid tube used in this study is variable depending on the HF. It is evident that, with increases in HF, the length of the rigid tube decreases. A rigid tube is connected to the hopper bottom on one side, and the curtain rainer on the other side. As shown in Fig. 10(d), the lengths of the rigid tubes used in this study are 100, 200, 300, 400, 500, 600, and 700 mm. To study the effect of DI on RD values, the opening width of the curtain is considered variable. In the present study, the length of the curtain rainer is 200 mm; this length is chosen due to the wider length of sand flow poured into the testing tank per unit time. Also, as shown in Fig. 10(e), the opening widths of the curtain are 2, 2.5, 3, 3.5, 4, and 4.5 mm.

During air-pluviation by using a flexible hose, the sand particles move from the sand storage to the hopper. Then, the sand particles start to fall from the hopper to the curtain rainer. Finally, the sand particles exit from the curtain rainer to the specimen container or soil surface, depending on the value of DI (by different opening widths of the curtain rainer). By using the suggested PCRS, it is possible to achieve a wide range of RD under conditions of HF and DI control.

Prior to carrying out the full-scale experimental program, a total of 120 preliminary raining tests are carried out in order to evaluate the effects of HF (100–1,000 mm) and DI (different values of opening width of the curtain) on RD of the pluviated specimen. The effect of the opening width of the curtain on the DI is presented in Fig. 11.

In order to evaluate the effect of soil layer thickness, the sand is poured in 25- and 50-mm-thick layers. Similar to the tests performed by RSPP, five samples are used to control the values of RD sand specimens. RD for each test is obtained by averaging the respective values obtained from five identical specimens. The experimental tests are performed with different values of DI and HF. The values of the opening width of the curtain and HF are 2–4.5 and 100–1,000 mm, respectively.

**Investigation Tests**

To evaluate the performance of PCRS in preparation of reconstituted uniform specimens, 120 tests were carried out with...
controlling DI and HF. Similar to the RSPP tests, each test was performed two or three times to verify the repeatability of the test data. The value of DI varied from 6.8 g/cm²/s in a curtain with an opening width of 2 mm to 16.6 g/cm²/s in a curtain with an opening width of 4.5 mm. The HF varied from 100 to 1,000 mm. Fig. 12 presents the effect of HF on RD for different values of DI (for soil layers with thickness of 25 and 50 mm).

As shown in Fig. 12, for a given DI, the RD of the reconstituted specimen increases with an increase in HF. For most cases, the value of RD of the reconstituted specimen increases linearly with an increase in HF to 600 mm, beyond which a further increase in HF does not show a significant increase in RD of the specimen. Therefore, the air-pluviation of the sand particles through a curtain rainer system at a HF of 100–600 mm is likely to be within the zone of HF control, which significantly affects the impact velocity of sand particles and at higher values of HF appears to be within the DI control zone. These observations are in good agreement with the observations of previous studies (Vaid and Negussey 1988; Stuit 1995; Choi et al. 2010; Dave and Dasaka 2012; Srinivasan et al. 2016). Choi et al. (2010) showed that by using a porous plate the variation in RD for HF = 100–400 mm is relatively high, and after that the DI changes the RD values. The curtain rainer made by Stuit (1995) produced specimens in a range of RD = 28–93%.

Considering the PCRS with an opening width of 2–4.5 mm and a soil layer with thicknesses of 25 and 50 mm, RD of pluviated sand specimens in the range of 27.6–95.8% and 23.2–94.8% were achieved. The variation of RD with HF for different values of opening width and soil thickness is shown in Fig. 13. The results clearly indicate that the values of RD obtained from a soil layer with a thickness of 25 mm are greater than those from a soil layer with thickness of 50 mm. The difference in values of RD for a soil layer with thickness of 25 and 50 mm decreases with an increase in HF. The greatest difference in values of RD is 12%, corresponding to the curtain rainer with an opening width of 2 mm and HF = 100 mm.

Fig. 14 shows the effect of DI and HF on RD separately (for soil layer with a thickness of 25 and 50 mm). The opening width of the curtain in PCRS has been known as one of the major factors affecting DI. As presented in Fig. 14, for a given HF, the RD
of a reconstituted specimen decreases with an increase in DI and a smaller density is obtained with larger value of DI (16.6 g/cm²/s). DI decreases with a reduction in opening width of the curtain, which could have resulted in the increase of RD. This may be due to the allowance of sufficient time for sand grain hammering (Cresswell et al. 1999). The sand specimens prepared with opening widths of 2–2.5 mm, 3–3.5 mm, and 4–4.5 mm have dense-to-very dense, medium-to-dense, and loose-to-dense RD, respectively. Figs. 15(a–f) show the sand flow during the specimen preparation for HF of 500 mm. By increasing the opening width of the curtain, the sand flow, which exists from the curtain rainer, increases per unit time and by increasing the DI, the RD of the specimens decreases (see sand flow of opening width of 4.5 mm in comparison with opening width of 2 mm).

**Uniformity Tests**

To control the vertical and horizontal uniformity of a pluviated sand bed in PCRS, a total of six full-scale tests was performed. The uniformity tests performed similar to RSPP tests. In the full-scale tests, the opening widths of the curtain and HF were 2.5, 3.5, 4, and 4.5 mm and 100, 200, 300, and 400 mm, respectively. RDs of the sand specimens were in the range of loose to dense. Fig. 16 shows the vertical distribution of RD for different values of opening width of the curtain and HF. Similar to the RSPP, it can be seen that the value of RD tended to increase slightly as the depth increased (except for dense specimen). Also, an improved vertical uniformity is obtained from Fig. 16. These results are in good agreement with those reported by Rad and Tumay (1987), Puppala et al. (1995), and Choi et al. (2010). As presented in Fig. 16, the density difference in the vertical direction for medium-to-dense sand specimens that produce with PCRS were 12.4, 9.2, 7.2, and 5%, respectively. Also, with an increase in RD, a better vertical homogeneity is achieved irrespective of the DI. The density difference in a
vertical direction for the medium-to-dense sand specimens are in good agreement with the results presented by Choi et al. (2010). They reported that a rainer system with a porous plate produced a 5–8% density difference in a vertical direction for RD = 36–70% and the conventional rainer system generated a 6.5–10% density difference for RD = 54–80%.

Fig. 17 shows the horizontal distribution of RD for different values of opening widths of the curtain. The results showed that the horizontal homogeneity improves as RD increases, irrespective of the DI. The density differences in the horizontal direction for medium-to-dense specimens produced with PCRS were 4.1, 3.5, 3.2, and 3.1%, respectively. The results obtained from the density of specimens in horizontal and vertical directions showed that the PCRS suggested in this study can produce homogenous reconstituted specimens.

Comparison of Two Rainer Systems

In previous sections, the component and performance of a rainer system with a perforated plate (RSPP) and portable curtain rainer system (PCRS) were explained separately. In this section, a comparison between two rainer systems is presented. The comparison of RSPP and PCRS are tabulated in Table 1.

The advantages of two rainer systems can be noted as:

- Ease in implementation and cost effective: The suggested systems are simple and inexpensive to use and do not require skilled workers;
- Ease in placing layers of geosynthetic material in soil reinforced technique and placing instrumentation;
- Both rainer systems can prepare layers with different values of RD or different materials (in dry conditions);
- Efficiency and performance of suggested systems to prepare specimens with high uniformity (in horizontal and vertical directions); and
- High repeatability of specimens that can be prepared by suggested systems.

Summary and Conclusions

In this paper, the results of two different setups of sand specimen preparations are presented. The first is a rainer system with a perforated plate (RSPP), and the second is a portable curtain rainer system (PCRS). Both systems were capable of preparing uniform
granular specimens, but only the PCRS system is capable of preparing a wide range of RDs. The performance of both systems was investigated by evaluating the effects of perforated plates and openings of the curtain and soil thickness on the relationship between the RD and HF. Based on the results from this study, the following conclusions can be drawn:

- By using a rainer system with a perforated plate (RSPP), a limited range of RD can be achieved in the range of 35.1–73.7% and 32.9–72.6% for raining soil with thicknesses of 25 and 50 mm, respectively;
- By using a portable curtain rainer system (PCRS) with different values of opening widths of the curtain (2–4.5 mm), it is possible to produce a specimen with RD in the range of 27.6–95.8% and 23.2–94.8% for raining soil with thicknesses of 25 and 50 mm, respectively;
- In both suggested rainer systems, RD of reconstituted specimens increases with an increase in HF, but the effect of HF on RD was significant at a lower HF and it is insignificant for greater values of HF. For values of HF ≥ 600 mm, HF had no significant effect on RD;
- RD of reconstituted specimens decreases with an increase in DI for a given HF. In both rainer systems, a smaller RD was obtained with large DI. Although achieving a lower DI is time consuming, RD obtained from these DIs were high. Therefore, dense and very dense sand specimens could be achieved by controlling DI;
- The uniformity and repeatability of pluviated sand specimens using RSPP and PCRS were investigated directly by measuring the RDs of 20 cylindrical molds at different locations within the reconstituted specimen. Both rainer systems improve the homogeneity of reconstituted specimens at any level of RD in horizontal and vertical directions. With increase in RD of specimens, a better homogeneity was achieved (in vertical and horizontal directions), irrespective of DI; and
- The advantages of PCRS can be pointed out: ease in implementation, no need for skilled workers, nonclogging of sand particles in curtain rainer, achieving higher values of raining in comparison with RSPP. Preparation of a medium-to-large size specimen for a wide range of RDs, high uniformity of specimens in horizontal and vertical directions, and repeatability of pluviated sand bed.

References


