

LABORATORY METHODS FOR EVALUATION OF PUTTING GREEN ROOT ZONE MIXES

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The following laboratory procedures were put together by Dr. Norman W. Hummel, Jr., and were reviewed by members of the Advisory Committee and by personnel at soil testing laboratories currently testing materials for USGA-standard greens. Although few readers will be interested in the details of these procedures, they are published here to provide a widely distributed, readily available reference for future use.

Standard Test Methods for Saturated Hydraulic Conductivity, Water Retention, Porosity, and Bulk Density on Putting Green Root Zone Mixes

1. Scope

1.1 These test methods cover the measurements of saturated hydraulic conductivity, water retention, porosity (including distribution of capillary and air-filled porosity at 40 cm tension), and particle and bulk density on root zone mixes to be used for construction and topdressing of USGA recommendation greens or other highly trafficked turfgrass areas.

1.2 Water retention as described in this standard is a gravimetric expression of capillary porosity and is not a required measurement for USGA recommendation greens. Its inclusion in this standard is for the benefit of those who wish to continue to report it. Likewise, bulk density is no longer a specified measurement, but must

be determined for calculation of total and capillary porosity.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to its use.*

2. Referenced Documents

2.1 Methods of Soil Analysis, Part 1: Physical and Mineralogical Methods. American Society of Agronomy Monograph No. 9, Part 1, Second Edition.

2.2 ASTM Standard D 854-83, Standard Test Method for Specific Gravity of Soils.

3. Summary of Methods

3.1 *Method A* — Saturated hydraulic conductivity is determined on compacted, saturated soil cores. Water flow through the core is maintained at a constant hydraulic head for four hours, or the point equilibrium is reached, at which time aliquots are collected.

3.2 *Method B* — Water retention at 40 cm tension is obtained by extracting the water from a prepared core by means of a tension table or other water extraction apparatus. When the weight reaches equilibrium, the weight is recorded. The core is oven dried at 105° C, until a constant weight is obtained. Water retention is calculated on an oven dried basis. Bulk density is calculated from the soil weight and volume.

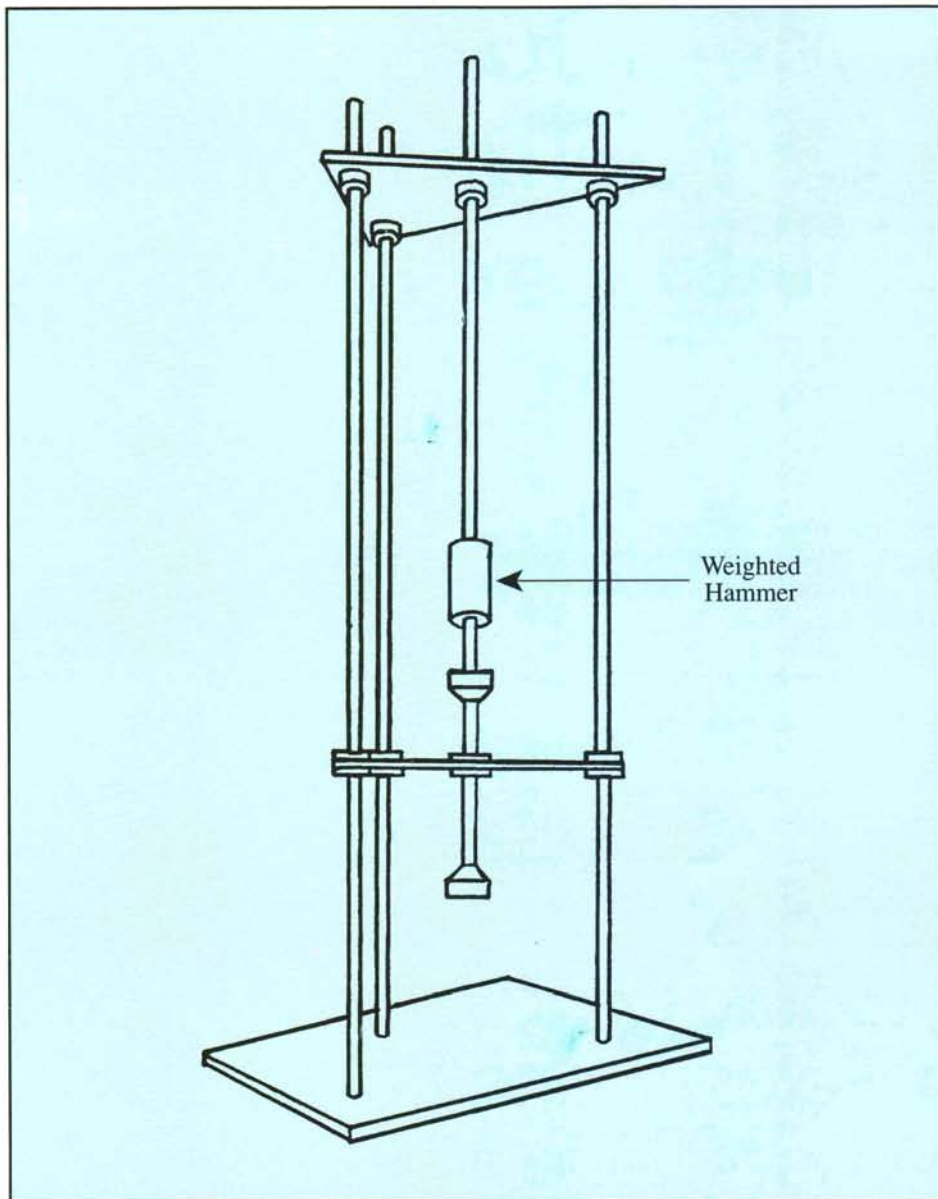


Figure 1. A suggested impact-type compactor to produce a total dynamic energy of 3.03 J/cm^2 across the surface cross-sectional area of the core. It has been found that 15 drops of the hammer from a height of 12 inches (as measured from the bottom of the weight to the top of the anvil) will produce a degree of compaction comparable to a severely compacted putting green, provided the soil contains moisture approximating field capacity.

3.3 *Method C* — Particle density is an average for all components of a rootzone mix and is used for calculating total porosity.

3.4 *Method D* — Total porosity is calculated from the bulk density and particle density.

3.5 *Method E* — Capillary porosity is calculated from the bulk density and water retention information. Air-filled or aeration porosity is calculated from the difference of total and capillary porosity.

4. Apparatus

4.1 *Cylinders*, made of metal, PVC, or similar durable materials shall have an inside

diameter of 51 to 76 mm, and a minimum height of 76 mm.

4.2 *Compactor*, shall be such as to exert a total dynamic energy of 3.03 J/cm^2 (14.3 ft lbs/in^2) across the surface cross sectional area of the core. Figure 1 shows an example of such a device where a 3 lb weighted hammer is dropped 15 times from a height of 305 mm (12 inches).

4.3 *Permeameter*, capable of maintaining a constant hydraulic head for several hours.

4.4 *Tension or porous plate apparatus*, capable of extracting water out of the cores at a matric potential of - 40 mbars (40 cm tension). Figure 2 shows an example of a tension table.

4.5 *Oven*, capable of maintaining a constant temperature of 105°C .

4.6 *Pycnometer* — a small flask with a capacity of 50mL. The pycnometer should have a ground glass stopper with a small hole in it to allow the escape of air. A volumetric flask with a 100 mL capacity may also be used, but a larger sample size will have to be used to compensate for the decrease in precision of measuring the fluid volume.

4.7 *Balance* — A balance sensitive to 1 mg (0.001g) should be used with pycnometers. A balance with sensitivity to 10 mg may be used with volumetric flasks.

4.8 *Thermometer* — accurate to 0.5°C .

5. Preparation of Sample

5.1 Premixed samples

5.1.1 The cylinders should be prepared by attaching a double layer of cheesecloth or other suitable material with a rubber band onto the bottom of each cylinder. Weigh and record the weight of each cylinder.

5.1.2 Attach another cylinder of the same diameter to the top, securing with a 1" piece of bicycle inner tube or a water proof tape.

5.1.3 Screen the root zone mixture through a No. 4 sieve to remove peat clods and other debris. Peat clods should be broken up and returned to the sample.

5.1.4 Place moistened root zone mix into the cylinder, tapping gently on a firm surface as mix is added. Add sufficient quantities of mix to the cylinder so that the final level is 2-4mm above the top of the lower cylinder. The intent here is to have the surface of the soil as close as possible to the top, but not above the lip of the lower cylinder after compaction.

5.1.5 Place the cylinder in a pan of water and allow it to saturate from the bottom up. Be careful not to splash any water onto the soil surface. Allow the core to saturate for 30 to 60 minutes.

5.1.6 Place the cylinders on a tension table or other water extracting device, set to remove water at 40 cm of tension (see figure 2 for proper measurement). Leave sample cores on the table for at least 16 hours.

5.1.7 Place the cylinder onto the base of the compactor, and drop the weight 15 times from a height of 305 mm (12 inches).

5.1.8 Remove the upper cylinder. If the level of the mix is above the top of the lower cylinder, remove the mix, repack the cylinder, and recompact the sample. **Do not shave off the top of the soil.** If the level of the mix is

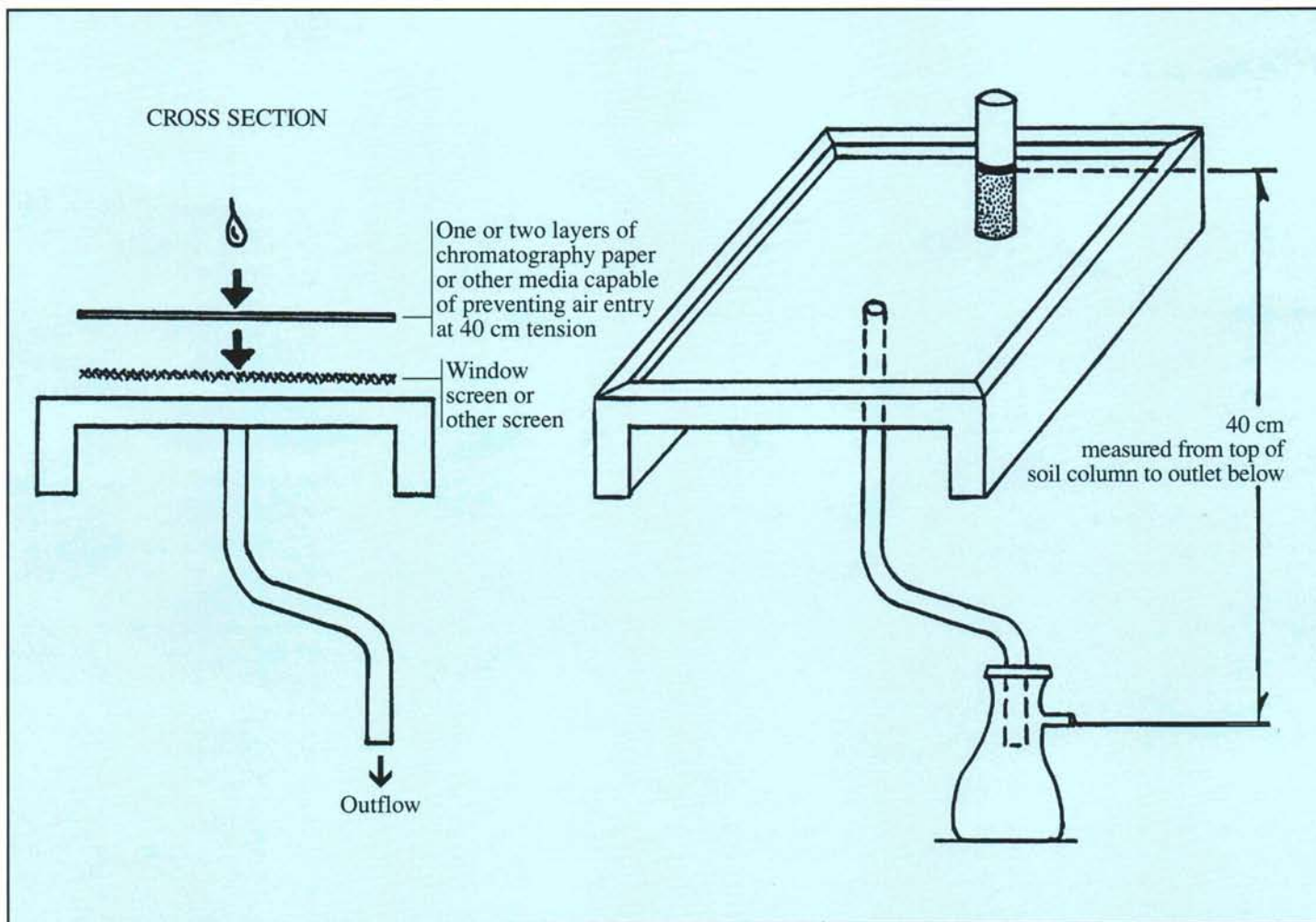


Figure 2. Suggested tension apparatus capable of extracting water out of the cores at 40 cm tension.

below the edge of the cylinder, measure the length of this depression to the nearest 0.1 cm (mm). Subtract this value from the height of the cylinder to determine length of the soil column (L). Record this number (cm).

5.1.9 Calculate the volume of the soil column as follows: $V = L \times A$, where: L = length of the soil column (to the nearest 0.1 cm), and A = cross sectional area of the column ($A = \pi r^2$).

5.2 Laboratory mixed samples

5.2.1 Root zone mixes are nearly always mixed on a volume basis. Use a measuring device such as a graduated cylinder or small beaker for measuring sand and soil volumes.

5.2.2 Peat volumes should be measured in a compressed state.

5.2.3 Thoroughly mix the sand, peat and/or soil to the desired volume ratios.

5.2.4 Determine percent organic matter by the Walkley-Black potassium dichromate

oxidation technique or loss on ignition method to quantify organic matter content on a weight basis. This value and the method used should be reported so that field checks of mixes can assure that the mix corresponds to that developed in the laboratory.

5.2.5 Follow steps 5.1.1 through 5.1.9 for sample preparation.

6. Quality Assurance/Quality Control

6.1 A minimum of two, and preferably three replicates of each sample should be included for all measurements.

6.2 A well-characterized standard root zone sample should also be included in each and every run of all physical parameters.

Saturated Hydraulic Conductivity

7. Method A

7.1 Place the compacted sample into a pan of water and saturate from the bottom up.

7.2 Place the cylinder with mix onto the permeameter and begin running water through the sample. Tap water may be used. Set the permeameter to a known hydraulic head. For setups where the water flows from the top down, the hydraulic head (h) is measured from the bottom of the soil column to the water level above the soil (Figure 3). Record this value (to the nearest 0.1 cm).

7.3 Measure and record the water temperature ($^{\circ}\text{C}$).

7.4 After four hours, place a collection bottle, flask, or beaker at the outflow for the cylinders and begin collecting the outflow. Collect effluent for a specific period of time, the time based on the rate of flow. Collection of one or more samples over a 30-minute period is suggested.

7.5 Measure the effluent and record in cm^3 collected over time period t .

8. Method A Calculation

8.1 Calculate the saturated hydraulic conductivity as follows: $K_{sat} = QL/hAt$, where:

K_{sat} = saturated hydraulic conductivity (cm hr⁻¹)

Q = quantity of effluent collected (cm³) in period of time (t)

L = length of soil column (cm)

h = hydraulic head (cm)

A = cross sectional area of the soil core (cm²)

t = time required to collect Q (hr).

8.2 Correct the saturated hydraulic conductivity for the viscosity of water to that for 20°C (68°F) by multiplying K_{sat} by the ratio of the viscosity of water at the test temperature to the viscosity of water at 20°C.

8.3 Divide K_{sat} by 2.54 to convert cm/hr to in/hr, if desired.

Bulk Density and Water Retention

9. Method B

9.1 Remove the sample from the permeameter and place on the soil water extractor or tension table set at 40 cm tension for at least 16 hours.

9.2 Allow the sample to reach equilibrium weight, then weigh and record weight (0.1g).

9.3 Place the sample in a drying oven set at 105° C and dry for 24 hours. Weigh and record weight (0.1g).

10. Calculation of Bulk Density

10.1 Calculate the bulk density of the soil core as follows:

$$p_d = \frac{M_1 - M_2}{V}$$

where:

p_d = dry soil bulk density (g cm⁻³)

M_1 = mass of oven-dried soil and cylinder (g)

M_2 = mass of cylinder (g)

V = volume of the soil core (cm³)

11. Calculation of Water Retention

11.1 Calculate the 40 cm water retention as follows:

$$\Theta_{dw} = \left(\frac{M_w}{M_d} - 1 \right) \times 100$$

where:

Θ_{dw} = water retention on dry weight basis (%)

M_w = net 40 cm weight, ((mass 40 cm soil and cylinder) - cylinder mass)

M_d = net dry weight mass, ((mass oven dry soil and cylinder) - cylinder mass)

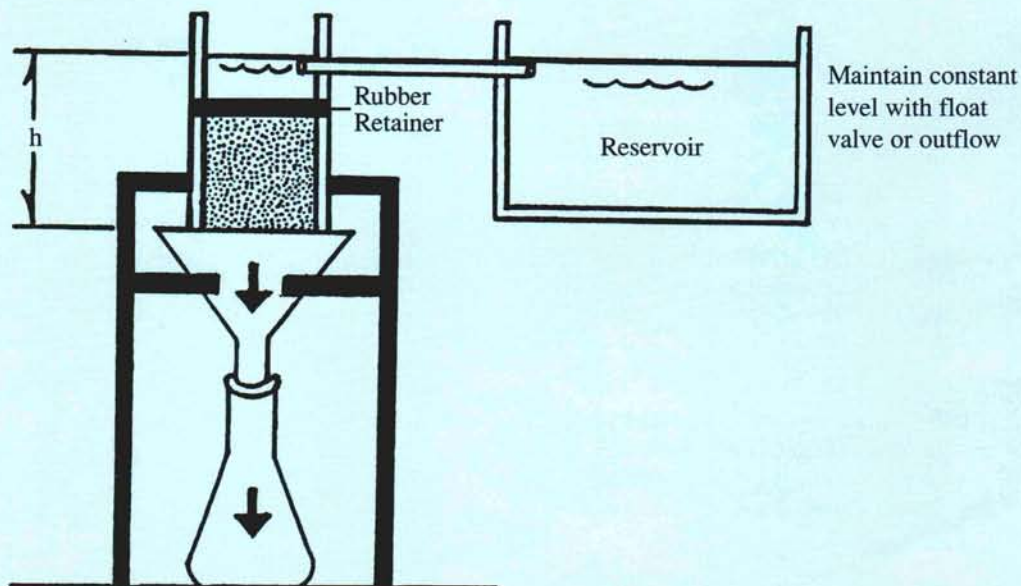
Particle Density

12. Method

12.1 Calibration of Pycnometers (taken from ASTM D 854 - 83)

12.1.1 The pycnometer shall be cleaned, dried, weighed, and the weight recorded. The pycnometer shall be filled with distilled water at room temperature. The weight of the pycnometer and water W_o shall be determined and recorded. A thermometer shall be inserted in the water and its temperature T_i determined to the nearest whole degree.

Figure 3. Suggested permeameter setup to calculate saturated hydraulic conductivity. The hydraulic head (h) is measured from the bottom of the soil column to the water level above the soil.



12.1.2 From the weight W_a at the observed temperature T_i , a table of values of weight W_a shall be prepared for a series of temperatures that are likely to prevail when the weights W_b are determined later (see note 1). These values of W_a shall be calculated as follows:

$$W_a(at T_x) = \frac{\text{density of water at } T_x}{\text{density of water at } T_i} \times (W_a(at T_i) - W_f) + W_f$$

where:

W_a = weight of pycnometer and water, g

W_f = weight of clean, dry pycnometer, g

T_i = observed temperature of water, °C, and

T_x = any other desired temperature, °C

Note 1 — This method provides a procedure that is most convenient for laboratories making many determinations with the same pycnometer. It is equally applicable to a single determination. Bringing the pycnometer and contents to some designated temperature when weights W_a and W_b are taken requires considerable time. It is much more convenient to prepare a table of weights W_a for various temperatures likely to prevail when weights W_b are taken. It is important that weights W_a and W_b be based on water at the same temperature. Values for the relative density of water at temperatures from 18 to 30°C are given in Table 1.

Table 1

RELATIVE DENSITY OF WATER AND CONVERSION FACTOR K FOR VARIOUS TEMPERATURES

Temperature, °C	Relative Density of Water	Correction Factor K
18	0.9986244	1.0004
19	0.9984347	1.0002
20	0.9982343	1.0000
21	0.9980233	0.9998
22	0.9978019	0.9996
23	0.9975702	0.9993
24	0.9973286	0.9991
25	0.9970770	0.9989
26	0.9968156	0.9986
27	0.9965451	0.9983
28	0.9962652	0.9980
29	0.9959761	0.9977
30	0.9956780	0.9974

12.2. Procedure

12.2.1 Place a 10 gram air dried sample into the weighed pycnometer, taking care not to spill any of the mix. Reweigh to obtain the exact soil weight to 0.001g. If a volumetric flask is used, use a 50 gram sample. Determine the water content of a duplicate soil sample by drying it at 105°C.

12.2.2 Add distilled water to fill the pycnometer one half full, or the volumetric flask three-quarters full.

12.2.3 Remove entrapped air by either of the following methods: 1) subject the contents to a partial vacuum (air pressure not exceeding 100 mm Hg), or 2) Boil gently for at least 10 minutes while occasionally rolling the pycnometer to assist in the removal of air. Subject the contents to reduced air pressure either by connecting the pycnometer to an aspirator or vacuum pump, or by the use of a bell jar.

12.2.4 Cool the heated samples to room temperature.

12.2.5 Fill the pycnometer with distilled water, and clean the outside with a clean, dry cloth. Determine the weight of the pycnometer and its contents, W_b , and the temperature in degrees Celsius, T_x , of the contents as described in Section 12.1.

12.3 Calculation and Report

12.3.1 Calculate the particle density (p_p), based on water temperature T_x , as follows:

$$p_p = \frac{W_o}{W_o + (W_a - W_b)}$$

where:

W_o = weight of sample, corrected to oven dry water content.

W_a = weight of pycnometer filled with water at temperature T_i (g), may be taken from the Table described in Section 12.1.

W_b = weight of pycnometer filled with soil and water at temperature T_x (g).

12.3.2 Unless otherwise required, particle density values reported shall be based on water at 20°C. The value based on water at 20°C shall be calculated from the value based on water at the observed temperature, T_x as follows:

$$p_p \text{ at } 20^\circ\text{C} = K \times p_p \text{ at } T_x$$

where K = the values given in Table 1.

Total Porosity

13. Method D Calculation of Total Porosity

13.1 Calculate the total porosity of the sample as follows:

$$S_t = \left(1 - \frac{P_b}{P_p}\right) \times 100$$

where:

S_t = total porosity (%)

P_b = dry soil bulk density (g cm⁻³)

P_p = particle density of root zone mix (g cm⁻³)

Pore Distribution

14. Method D Calculation

14.1 Calculate the capillary porosity as follows:

$$\Theta_{vb} = p_b \times \Theta_{dw}$$

where:

Θ_{vb} = volumetric water content at 40 cm tension (capillary porosity)

p_b = dry soil bulk density

Θ_{dw} = water retention

14.2 Calculate the air-filled porosity as follows:

$$S_a = S_t - \Theta_{vb}$$

where:

S_a = air filled porosity

S_t = total porosity

Θ_{vb} = capillary porosity

15. Report

15.1 The report should include the following:

15.1.1 Volume ratio of mixes tested (if laboratory mixed).

15.1.2 Percent organic matter (on weight basis) to the nearest 0.1%

15.1.3 Saturated hydraulic conductivity to the nearest 0.1 in/hr.

15.1.4 Porosity, including distribution of capillary and air-filled to the nearest 1%.

15.1.5 Particle density of the mix(es).

15.1.6 Bulk density of the compacted mix(es).

15.1.7 pH of each mix tested.