Designation: C1699 – 09 (Reapproved 2023)

Standard Test Method for
Moisture Retention Curves of Porous Building Materials Using Pressure Plates[1]

This standard is issued under the fixed designation C1699; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method specifies a laboratory procedure for the determination of the water retention curve (or moisture storage capacity) of porous building materials at very high relative humidity (RH) levels (≈ 95 to 100% RH) corresponding to the capillary moisture region of the sorption isotherm. This is achieved by using the pressure plate test apparatus. This technique was originally developed to study soil moisture content and eventually had been adapted to building construction materials.

1.2 At higher RH levels (≈ 95 to 100% RH) of the sorption isotherm (see Test Method C1498), use of climatic chamber is not an option. This technique uses overpressure to extract water out of the pore structure of porous materials until equilibrium between the moisture content in the specimens and the corresponding overpressure is achieved. Using the pressure plate extractors, equilibrium can only be reached by desorption.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C1498 Test Method for Hygroscopic Sorption Isotherms of Building Materials

D2325 Test Method for Capillary-Moisture Relationships for Coarse- and Medium-Textured Soils by Porous-Plate Apparatus (Withdrawn 2007)[3]

D3152 Test Method for Capillary-Moisture Relationships for Fine-Textured Soils by Pressure-Membrane Apparatus (Withdrawn 2007)[3]

E337 Test Method for Measuring Humidity with a Psychrometer (the Measurement of Wet- and Dry-Bulb Temperatures)

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *desorption isotherm*—the sorption isotherm measured exclusively during the hygroscopic desorption process started from the condition of full water saturation of the material.

3.1.2 *sorption isotherm*—relationship between the relative humidity (see Test Method E337) and the equilibrium moisture content of the material, at a specified temperature.

3.1.3 *pressure-plate facility*—Heavy steel vessel capable of holding different pressure levels.

3.1.4 *moisture content, by mass*—mass of water retained in the specimen divided by the dry mass of the specimen.

4. Significance and Use

4.1 The purpose of this test is to obtain, by means of a specified laboratory procedure, the values of the equilibrium moisture content at higher RH levels ((≈ 95 to 100%). These values are used either as means to characterize the material or as material characteristics needed as input to appropriate computer models that can simulate wetting or drying potential

---

---

of individual building materials or material assemblies under specified environmental conditions.

5. Apparatus

5.1 *Pressure vessel*—Heavy-duty steel vessels of approximately 305 mm in diameter and about 75 mm or 250 mm high with heavy top lid tightly-held against O-ring gasket by clamping bolts (see Fig. 1).

5.2 *Porous ceramic plates*—This is the plate upon which the specimens sit and is composed of microscopic pores allowing only water to flow through it. The plate assembly is exposed to an overpressure that can be adjusted, while the other side of the plate is always at atmospheric pressure resulting in a pressure difference over the plate and the specimens.

5.3 *Balance*—An analytical balance capable of weighing within 1 mg shall be used. The accuracy of the balance shall be at least ± 0.1 percent of the total specimen weight.

5.4 *Drying oven*—A ventilated drying oven, capable of maintaining the required drying temperature within ±2K for temperatures less than 75°C and ±4K for temperatures above 75°C , and a relative humidity of less than 10%, shall be used. In warm-humid laboratory environment or at low drying temperatures, it will be necessary to provide a supply of dried air to achieve the less than 10 % relative humidity specification in the drying oven.

5.5 *Desiccator equipped with outflow knob*—Used as a vacuum chamber to remove air (that is, evacuate) from the water and evacuate specimens.

5.6 *Kaolin paste and acetate fabric*—This clay paste ensures good hydraulic contact between plate/specimen. The acetate fabric prevents contamination of the specimens by the clay.

5.7 *Pressure source*—Compressed air or nitrogen in cylinders, or high-pressure air compressor.

5.8 *Pressure manifold*—Assembly of conduits and valves regulating the air supplied to the extractors.

6. Test Specimens

6.1 A test specimen shall be cut to approximately 15 cm^2 and have a thickness as minimal as possible ($\approx$ 5mm, depending on the structure of the material) to reduce the time to reach equilibrium.

6.2 A minimum of five specimens shall be tested in each pressure environment. The test procedure, as specified below, and the precision of weighing shall be applied to each specimen.

7. Preparations of Test Specimens

7.1 Dry specimens in oven to constant weight (see Note 1).

7.2 Measure and record dry specimen dimensions.

7.3 For vacuum saturation (see Note 2), follow steps 7.3.1 to 7.3.3

7.3.1 Place them in a vacuum chamber (that is, desiccator equipped with outflow knob and connected to vacuum pump) and evacuate for 24 hours. This ensures that no air remains in the pores when specimens are being saturated.

7.3.2 Evacuate distilled water by pumping air out for 1 to 2 hours.

7.3.3 Use this water to saturate the specimens under vacuum. The assembly remains under vacuum for at least 3 days or until no air bubbles are observed. Keep the specimens fully submerged in the vacuum chamber until ready for measurement. This minimizes the amount of drying that can occur.

7.4 For capillary saturation (see Note 3), specimens shall be immersed completely in distilled water (kept at room temperature) until a constant weight is attained.

7.5 Soak the porous ceramic plate(s) in distilled water for a minimum of 8 hours.

7.6 Prepare the kaolin paste (see Note 4) by mixing 125g of kaolin powder with 150g distilled water and apply it directly onto the saturated plate.
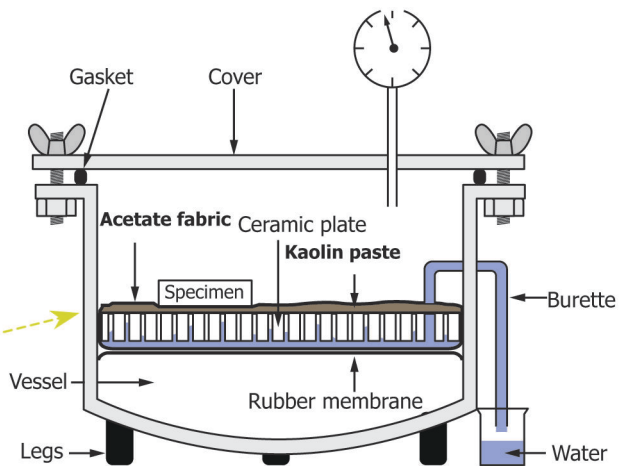
(a) Test assembly   **(b)** Pressure chamber

FIG. 1 Pressure Plate Test Apparatus

7.7 Cover the paste with a layer of acetate cloth to prevent the kaolin from sticking to the specimens.

7.8 Remove excess water off specimen surfaces by patting on a damp sponge and record specimen masses.

7.9 Press each specimen firmly on the acetate cloth ensuring good contact and also removal of any air bubbles underneath.

7.10 Close the pressure plate extractor lid after ensuring good connection of the outflow tube to the ceramic plate.

NOTE 1—Typically, the following temperatures are used for drying the test specimens: *(a)* for materials which do not change either structure or dimensions at 105°C, (221°F), for example, some mineral materials, use 105 ± 4°C (221 ± 8°F), *(b)* for materials, in which structural or dimensional changes occur between 70°C (158°F) and 105°C (221°F), for example, some cellular plastics, use 70 ± 2°C (158 ± 4°F), *(c)* for materials, in which elevated temperatures bring about chemical or physical changes, for example, crystalline water in gypsum or blowing agent solubility in some cellular plastics, use 40 ± 2°C (104 ± 4°F), and *(d)* when drying at the specified aforementioned temperatures adversely affects the building material, dry specimen to moisture free weight (that is dry weight, see 7.1) in a desiccator at room temperature or inside an airtight chamber flushed with dry air having a dew point less than ≅ − 40°C.

NOTE 2—Vacuum saturation leads to the maximum possible equilibrium moisture content in a material and is relevant to underwater and below-grade construction.

NOTE 3—Capillary saturation is relevant to above-grade construction.

NOTE 4—Kaolin from a previous test may be reused so long as there is no visible contamination. The entire amount of damp kaolin should be scraped of the plate and weighed. Distilled water should be added to the mixture to return the original weight of 275 g (125 g kaolin and 150 g of water) and the mixture should be well mixed.

8. Procedure

8.1 The room temperature shall remain constant at 22 ± 1°C (73°± 2°F) for the duration of the test. If the lid or the body of the extractor cools down then condensation will occur inside the pressure vessel and it will give erroneous results.

8.2 Check the initial pressure transducer voltage reading and make adjustment, if necessary.

8.3 Connect the external outflow tube to a flexible plastic tube and place it into a burette's opening so it can be noted when moisture equilibrium is obtained.

8.4 Open air-control valves to admit compressed air or gas. Adjust the pressure regulator (see Note 5) until the desired pressure is reached in order to extract moisture from specimens. Record the pressure.

8.5 Bring test specimens to equilibrium state of moisture content, first at one of the lower suction pressure, given in Table 1, and consecutively at other user-determined pressure levels. Equilibrium is achieved when the water outflow (in the burette) is less than 0.05mL in 48 hours (see Note 6).

8.6 Clamp off flexible plastic tube. Release the air pressure from the pressure plate extractor, open the lid and remove specimens to immediately determine their masses gravimetrically.

8.7 Rewet Kaolin paste with excess of distilled water. Place specimens back on a ceramic plate and repeat from step 8.3 until all user-determined suction pressures are covered. Depending on the pressure ranges, a combination of several

different pressure plates/extractors will be required. When moving from one extractor to another, a new saturated ceramic plate is used along with fresh clay paste. Above 15 bar pressure, the use of higher-pressure systems with cellulose membranes instead of ceramic plates is necessary.

8.8 After all pressure plate measurements are completed, place specimens in oven and dry to constant weight. This final dry mass (m_0) is used to calculate moisture contents.

NOTE 5— In order to avoid hysteresis effect it is important to manage the regulator so that the desired pressure is approached from a lower pressure. That is, do not overpressure the chamber and then reduce the pressure to the desired level.

NOTE 6—Depending on the nature of the material, this can take several days, weeks and even months.

9. Calculation

9.1 Calculate the moisture content, u (kg·kg^{-1}), for each specimen at each suction pressure (that is, gauge pressure) as follows:

$$u = \frac{(m - m_o)}{m_o} \tag{1}$$

m = the mass of the specimen at equilibrium, and
m_o = that of the dry specimen.

9.2 Calculate the average moisture content, U (kg·kg^{-1}), of specimens at each suction pressure levels.

9.3 The relative humidity (RH) can be calculated either from Eq 2 or obtained from Table 1. The equilibrium suction pressure (P_h) can be converted to the RH (φ) using:

$$1n\varphi = -\frac{M}{\rho RT} P_h \tag{2}$$

M = the molar mass of water
R = the ideal gas constant
T = the thermodynamic temperature and
ρ = the density of water

10. Report

10.1 The test report shall include the following:

10.1.1 Reference to this ASTM Standard.

10.1.2 *Product identification:*

10.1.2.1 Name, manufacturer or supplier,

10.1.2.2 Type, as in manufacturer's specification,

10.1.2.3 Production code number, if any,

10.1.2.4 Packaging,

TABLE 1 Suction Pressure Set-Points and Corresponding Relative Humidity

Suction Pressure Pa	Equivalent Pressure bar	RH %
50000	0.50	99.96
75000	0.75	99.94
100000	1.0	99.93
350000	3.5	99.74
500000	5.0	99.63
750000	7.5	99.45
1000000	10.0	99.27
1500000	15.0	98.90
3000000	30.0	97.81