BRITISH STANDARD

BS EN 15803:2009

Conservation of cultural property — Test methods — Determination of water vapour permeability (δp)

ICS 97.195

National foreword

This British Standard is the UK implementation of EN 15803:2009.

The UK participation in its preparation was entrusted to Technical Committee B/560, Conservation of tangible cultural heritage.

A list of organizations represented on this committee can be obtained on request to its secretary.

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 28 February 2010.

ISBN 978 0 580 61877 2

Amendments/corrigenda issued since publication

Date	Comments

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 15803

December 2009

ICS 97.195

English Version

Conservation of cultural property - Test methods - Determination of water vapour permeability (δ_p)

Conservation des biens culturels - Méthodes d'essai - Détermination de la perméabilité à la vapeur d'eau (δ_p)

Erhaltung des kulturellen Erbes - Prüfverfahren - Bestimmung des Wasserdampfleitkoeffizienten (δ_p)

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Ref. No. EN 15803:2009: E

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Foreword

This document (EN 15803:2009) has been prepared by Technical Committee CEN/TC 346 “Conservation of cultural property”, the secretariat of which is held by UNI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2010 and conflicting national standards shall be withdrawn at the latest by June 2010.

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Introduction

This test method can be applied if it does not change the value of the cultural property and follows relevant ethical codes of conservation practice.

1 Scope

This European Standard specifies a method for determining the water vapour permeability (WVP) of porous inorganic materials used for and constituting cultural property. The method may be applied to porous inorganic materials either untreated or subjected to any treatment or ageing.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

prEN 15898:2009, *Conservation of cultural property — Main general terms and definitions concerning conservation of cultural property*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in prEN 15898:2009 and the following apply.

3.1
porous inorganic materials
materials including natural stones, e.g. sandstone, limestone, marble, as well as artificial materials, such as mortar, plaster, brick and others

3.2
water vapour flow rate
G
mass of water vapour transferred through the specimen per time

3.3
density of water vapour flow rate
vapour transmission rate
g
mass of water vapour transferred through the specimen per time and per unit area

3.4
water vapour permeance
W_p
value of the mass of water vapour diffused through a specimen, induced by a partial vapour pressure gradient through the specimen, per unit area, time and partial vapour pressure difference

3.5
water vapour permeability
δ_p
product of the water vapour permeance and the thickness of a homogeneous specimen

3.6
water vapour permeability of air
δ_a
water vapour permeability of air δ_a is defined by the Schirmer equation:

$$\delta_a = 0{,}000\ 023\ 1\ (p_o/(p \times R \times T)) \times (T/273\ K)^{1{,}81}\ kg/(m \cdot s \cdot Pa) \quad (1)$$

where

p_o is the standard barometric pressure (= 1 013,25 hPa);

p is the barometric pressure (hPa);

T is the temperature (K);

R is the gas constant for water vapour (= 462 Nm/(kg·K))

3.7
water vapour diffusion resistance coefficient
μ
water vapour permeability of air divided by that of the material concerned

3.8
water vapour diffusion-equivalent air layer thickness
s_d
value of a specimen which indicates the thickness of a motionless air layer that has the same water vapour resistance as the specimen of thickness D.

The s_d value can be obtained in two ways:

i) by multiplication of the μ-value with the thickness D of the specimen;

ii) from the water vapour permeability of air δ_a divided by the water vapour permeance of the specimen Wp

4 Principle

Determination of the water vapour flow through the specimen subjected to different partial water vapour pressures.

5 Symbols and abbreviations

For the purposes of this document, the following symbols and abbreviations apply:

m mass of specimen and cup assembly, in kg

D mean thickness of specimen, in m

A test surface area, in m²

t time, in s

G water vapour flow rate through specimen, in kg/s

g density of water vapour flow rate, in kg/(m²·s)

Δp_v water vapour pressure difference across the specimen, in Pa

W_p water vapour permeance with respect to partial vapour pressure, in kg/(m²·s·Pa)

δ_p water vapour permeability with respect to partial vapour pressure, in kg/(m·s·Pa)

δ_a water vapour permeability of air, in kg/(m·s·Pa)

μ water vapour diffusion resistance coefficient (-)

s_d water vapour diffusion-equivalent air layer thickness, in m

6 Test equipment

6.1 Test set-ups: two types of cup systems are possible as presented in Figure 1 and Figure 2.

The cup's weight should be compatible with the measurement method which needs the use of an analytical balance.

Test cups shall be resistant to corrosion from the desiccant or salt solutions. Typically cups are made of glass, metal or PVC.

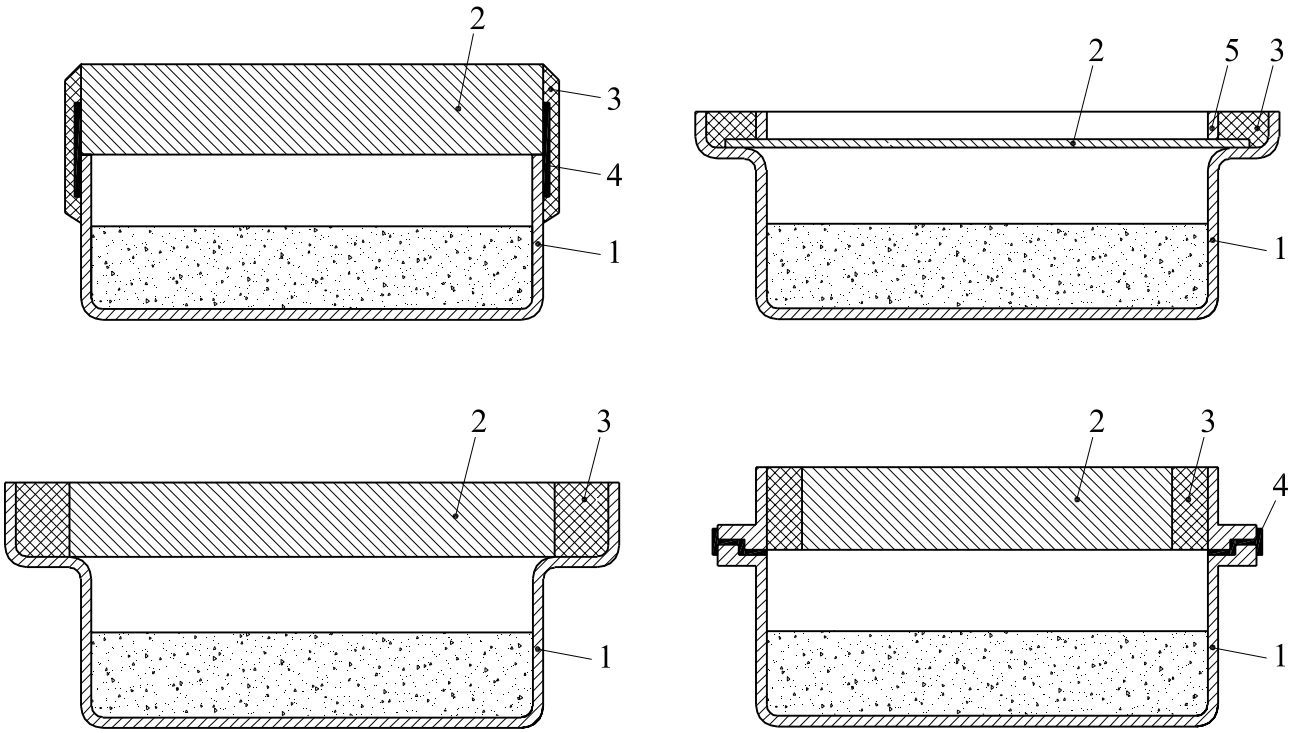
For certain cups and sealing methods, a template, with shape and size corresponding to that of the test cup, is used when applying the sealant to give a sharply defined, reproducible test area. The template shall have an area of at least 90 % of the specimen to limit non-linear vapour flow. The sealant, which is impermeable to water vapour, should neither undergo changes during the test nor bring about changes to the test surface of the specimen.

NOTE Circular cups can be easier to seal. Transparent cups enable observing the test in progress; thus, the saturated state of the salt solutions can be monitored.

Examples of suitable sealants:

— a mixture of 90 % microcrystalline wax and 10 % plasticizer;

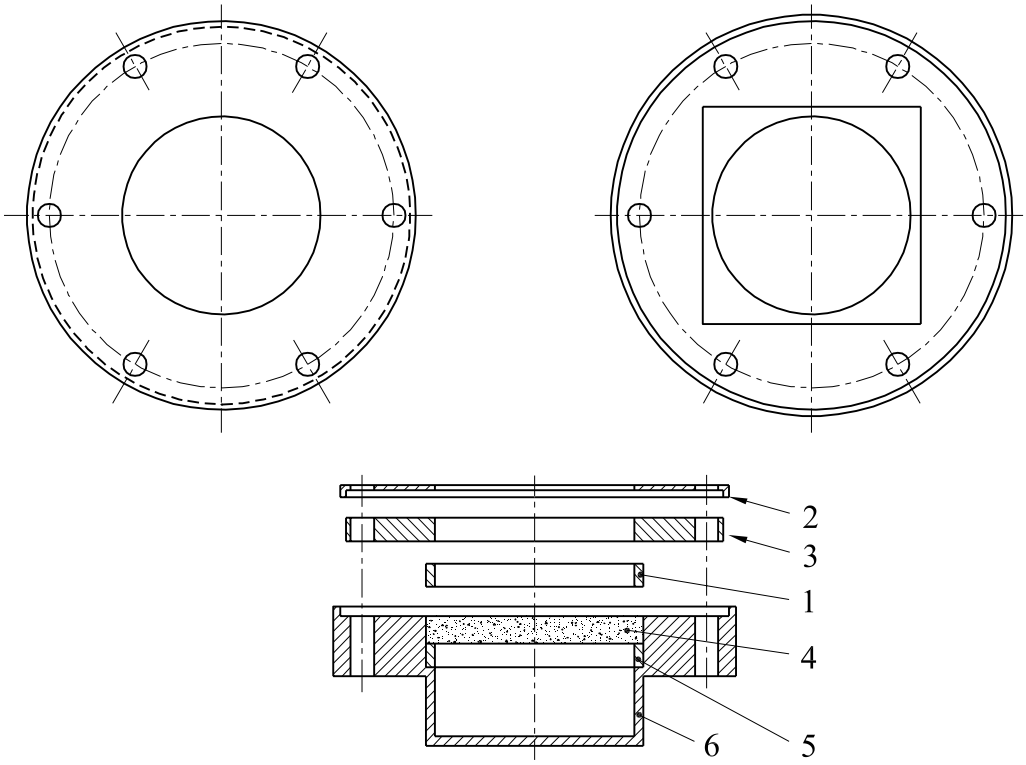
— a mixture of 60 % microcrystalline wax and 40 % refined crystalline paraffin.



Key

1 vessel with sorbent
2 specimen
3 sealing
4 adhesive tape
5 stop ring

Figure 1 — Examples of schematic cup system type 1



Key

1 joint rubber

2 aluminium disc

3 higher trimming

4 specimen

5 lower trimming

6 PVC cup

Figure 2 — Example of a schematic cup system type 2

6.2 An analytical balance with an accuracy of 0,001 g, capable of weighing the test assembly. In the case of material with a porosity < 1 %, an analytical balance with higher resolution (0,000 1 g) is recommended.

6.3 A test chamber to achieve controlled experimental conditions of temperature and relative humidity. The temperature is set at (23 ± 1) °C. For the relative humidity, a maximum variation of 3 % of the set point 50 % is allowed. The air velocity above the specimens shall not exceed 0,3 m/s and shall not fall short of 0,02 m/s.

6.4 Suitable sensors to continuously record the temperature, relative humidity and, if necessary, the barometric pressure in the test chamber. The sensors shall be calibrated at regular intervals.

6.5 A barometer with an accuracy of 0,1 kPa.

6.6 A linear measuring device (calliper) with an accuracy of 0,1 mm.

7 Preparation of test specimens

7.1 Number and dimensions of test specimens

The number of specimens is related to the heterogeneity of the material. At least 3 specimens are recommended for the test. In case of anisotropy, each series shall be tested according to the same orientation.

The specimens shall be prepared in a way that the parallel test faces are perpendicular to the direction of water vapour flow. Specimens shall be cut as to correspond with the dimensions of the chosen test assembly (see 6.1).

The thickness of the specimens will influence the time to reach the equilibrium as well as the precision of the test method. For compact and homogeneous materials it is recommended to use specimens of a thickness D of maximum 20 mm. In the case of heterogeneous materials, such as mortars containing coarse aggregates, the thickness of the specimens shall be at least two times the largest particle size.

The diameter of the test area (A) shall be at least two times the specimen's thickness. In the case of heterogeneous materials, such as mortars containing coarse aggregates, the diameter of the test area shall be at least five times the largest grain size. The test area shall be the arithmetic mean between the free lower tested surface and its opposite face area. The test area of the two opposite faces shall not deviate more than 10 %.

The number and dimension of the specimens can be different in cases when there could be difficulties in sampling the required amount of material.

7.2 Pre-conditioning of test specimens

Before testing, the specimen shall be stored at (23 ± 1) °C and (50 ± 3) % relative humidity for a period long enough for their weight to stabilize with the test climatic conditions.

Constant mass is reached when the difference between two successive weighings at an interval of 24 h is not greater than 0,1 % of the mass of the specimen.

8 Test procedure

8.1 General

The test specimen shall be mounted in the cup with the test face up and sealed to the open side of a test cup containing either a desiccant (dry cup) or an aqueous saturated salt solution (wet cup). The assembly shall then be placed in the pre-conditioned test chamber. Because of the different partial water vapour pressure between the inside of the test cup and the test chamber, a water vapour flow through the specimen occurs. In order to measure the water vapour permeability in the steady state, the mass of the cup system is periodically determined by means of weighing.

8.2 Test environmental conditions

The procedure is based on the "dry cup" or the "wet cup" system and can use the cups shown in Figure 1 or Figure 2. One of the cup systems presented in Table 1 shall be selected. Only results obtained from tests using the same cup system can be compared.

Table 1 — Test conditions

Cup system	Boundary condition for temperature (internal and external) (°C)	Internal relative humidity RH (%)	External relative humidity RH (%)
Dry cup	23 ± 1	0 to 3	50 ± 3
Wet cup	23 ± 1	93 ± 3	50 ± 3

Dry cup tests give information about the performance of materials at low humidities when moisture transfer is dominated by vapour diffusion. Wet cup tests give guidance about the performance of materials under high humidity conditions. At high humidity (93 %), the specimen pores start to fill with water which increases transport of liquid water and reduces vapour transport. Consequently, test results obtained under these conditions give some information about liquid water transport properties in porous materials.

Adequate saturated salt solutions or gels are examples of suitable sorbents. The following desiccants and saturated aqueous solutions produce the specified relative air humidity at 23 °C:

— Silica gel: 0 to 3 %;

— Magnesium nitrate $Mg(NO_3)_2$: 53 %;

— Calcium nitrate $Ca(NO_3)_2$: 50 %;

— Ammonium dihydrogen phosphate $NH_4H_2PO_4$: 93 %;

— Potassium nitrate KNO_3: 93 %.

NOTE Ammonium phosphate is not compatible with metal.

8.3 Procedure

Prepare the test specimens as specified in 6.1 for the selected test assembly. The thickness of the specimens is measured with an accuracy of 0,1 mm at four positions equally spaced around the circumference. Calculate the mean thickness D. Place the desiccant or aqueous solution with minimum of 15 mm in the bottom of each cup so that the air space between the desiccant or saturated solution and the specimen shall be at least 15 mm. Seal the specimen in the cup, which is then placed in the climate-controlled test chamber set at 23 °C and 50 % RH. The climatic test conditions shall be monitored continuously.

The cups shall be weighed at specific time intervals, and the masses recorded. Weighings shall be carried out at (23 ± 3) °C. The determination of the mass shall be repeated until the mass change per unit time is no longer subject to variations within the uncertainty of measurement. Drawing a diagram, in which the cumulative mass change per unit area is plotted versus time, enables the determination of the steady state water vapour diffusion flow through the specimen.

9 Expression of results

9.1 Cumulative mass change and density of water vapour flow rate

For each set of successive weighings of the specimens, calculate the cumulative mass change Δm_i using:

$$\left|\Delta m_i\right| = m_i - m_0 \qquad (2)$$

where

m_i and m_0 is the mass of the test assembly respectively at time t_i and t_0, in kg.

The slope of the linear section of the curve (G, in kg/s), presenting the mass change (Δm_i) versus time (t), shall be calculated by linear regression, using at least 5 successive aligned points.

Calculate the density of water vapour flow rate using the following equation:

$$g = \frac{G}{A} \tag{3}$$

where G = Δm/Δt in kg/s.

9.2 Water vapour permeance

Calculate the water vapour permeance $W_p = \frac{G}{A \cdot \Delta p_v}$ (4)

The value of Δp_v is calculated from the mean of the temperature and relative humidity measured over the course of the test.

9.3 Water vapour permeability

Calculate the water vapour permeability $\delta_p = W_p \times D$ (5)

9.4 Water vapour diffusion resistance coefficient

Calculate the water vapour diffusion resistance coefficient μ:

$$\mu = \frac{\delta_a}{\delta_p} \tag{6}$$

9.5 Water vapour diffusion-equivalent air layer thickness

Calculate the water vapour diffusion-equivalent air layer thickness s_d which is given by:

$$s_d = \mu D \tag{7}$$

The values (δ_p, μ) are not applicable to layered samples.

10 Test report

The test report shall include the following information:

a) reference to this European Standard;

b) name and address of the test laboratory in which the test was carried out;

c) date of testing (yy-mm-dd);

d) type, name, provenance, description of the porous inorganic material including chemical, petrographical, mineralogical and physical characteristics (if available) in accordance with existing standards;

e) number, shape, dimensions and orientation of anisotropy present, if any;

f) description of pre-conditioning;

g) description and dimension of the surface area subjected to the test, the date when the specimens were prepare, type and date of treatment applied, if any;

h) for each specimen the following data shall be reported:

   1) test environmental conditions (T, RH) and the chosen cup system;

   2) graph of the Δm_i values as a function of the time t_i completed with the temperature and relative humidity recorded in the test chamber;

   3) the water vapour flow rate G;

   4) coefficient of correlation for each regression line;

   5) water vapour permeance W_p (kg/(m²·s·Pa) and water vapour diffusion-equivalent air layer thickness s_d (m);

   6) for non-layered specimens only, water vapour permeability δ_p (kg/(m·s·Pa) and water vapour resistance factor μ (-);

i) arithmetic mean and standard deviation for the test series;

j) all deviations from this European Standard and their justification;

l) in case of treated samples the position of the treated face and the value of relative humidity of the environment directly in contact with the treated surface;

k) any additional remarks.

Bibliography

[1] EN 1936, *Natural stone test methods — Determination of real density and apparent density, and of total and open porosity*

[2] EN 12440, *Natural stone — Denomination criteria*

[3] EN 12670, *Natural stones — Terminology*

[4] EN ISO 12572, *Hygrothermal performance of building materials and products — Determination of water vapour transmission properties (ISO 12572:2001)*

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