BRITISH STANDARD

BS EN
13286-4:2003

Unbound and hydraulically bound mixtures —

Part 4: Test methods for laboratory reference density and water content — Vibrating hammer

The European Standard EN 13286-4:2003 has the status of a British Standard

ICS 93.080.20

National foreword

This British Standard is the official English language version of EN 13286-4:2003.

The UK participation in its preparation was entrusted by Technical Committee B/510, Road materials, to Subcommittee B/510/4, Cementitious bound materials, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled "International Standards Correspondence Index", or by using the "Search" facility of the *BSI Electronic Catalogue* or of British Standards Online.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 18 March 2003

Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 20, an inside back cover and a back cover.

The BSI copyright date displayed in this document indicates when the document was last issued.

Amendments issued since publication

Amd. No.	Date	Comments

ISBN 0 580 41410 8

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 13286-4

March 2003

ICS 93.080.20

English version

Unbound and hydraulically bound mixtures - Part 4: Test methods for laboratory reference density and water content - Vibrating hammer

Mélanges traités et mélanges non traités aux liants hydrauliques - Partie 4: Méthodes d'essai pour la masse volumique de référence et la teneur en eau en laboratoire - Marteau vibrant

Ungebundene und hydraulisch gebundene Gemische - Teil 4: Laborprüfverfahren für die Trockendichte und den Wassergehalt - Vibrationshammer

This European Standard was approved by CEN on 12 December 2002.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN 13286-4:2003 E

Contents

Foreword

This document (EN 13286-4:2003) has been prepared by Technical Committee CEN/TC 227 "Road Materials", the secretariat of which is held by DIN.

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 September 2003, and conflicting national standards shall be withdrawn at the latest by December 2003.

This European Standard is one of a series of standards as follows:

EN 13286-1, *Unbound and hydraulically bound mixtures – Part 1: Test methods for laboratory reference density and water content – Introduction, general requirements and sampling.*

prEN 13286-2, *Unbound and hydraulically bound mixtures – Part 2: Test methods for laboratory reference density and water content – Proctor compaction.*

EN 13286-3, *Unbound and hydraulically bound mixtures – Part 3: Test methods for laboratory reference density and water content – Vibrocompression with controlled parameters.*

EN 13286-4, *Unbound and hydraulically bound mixtures – Part 4: Test methods for laboratory reference density and water content – Vibrating hammer.*

EN 13286-5, *Unbound and hydraulically bound mixtures – Part 5: Test methods for laboratory reference density and water content – Vibrating table.*

prEN 13286-7, *Unbound and hydraulically bound mixtures — Part 7: Cyclic load triaxial test for unbound mixtures.*

EN 13286-40, *Unbound and hydraulically bound mixtures — Part 40: Test method for the determination of the direct tensile strength of hydraulically bound mixtures.*

EN 13286-41, *Unbound and hydraulically bound mixtures — Part 41: Test method for the determination of the compressive of strength of hydraulically bound mixtures.*

EN 13286-42, *Unbound and hydraulically bound mixtures — Part 42: Test method for the determination of the indirect tensile strength of hydraulically bound mixtures.*

EN 13286-43, *Unbound and hydraulically bound mixtures — Part 43: Test method for the determination of the modulus of elasticity of hydraulically bound mixtures.*

prEN 13286-44, *Unbound and hydraulically bound mixtures — Part 44: Test method for the determination of the alpha coefficient of vitrified blastfurnace slag.*

prEN 13286-45, *Unbound and hydraulically bound mixtures — Part 45: Test method for the determination of the workability period of hydraulically bound mixtures.*

EN 13286-46, *Unbound and hydraulically bound mixtures — Part 46: Test method for the determination of the moisture condition value.*

prEN 13286-47, *Unbound and hydraulically bound mixtures — Part 47: Test method for the determination of California bearing ratio, immediate bearing index and linear swelling.*

prEN 13286-48, *Unbound and hydraulically bound mixtures — Part 48: Test method for the determination of the degree of pulverisation.*

prEN 13286-49, *Unbound and hydraulically bound mixtures — Part 49: Test method for the determination of the accelerated swelling of soil treated by lime and/or hydraulic binder.*

prEN 13286-50, *Unbound and hydraulically bound mixtures — Part 50: Method for the manufacture of test specimens of hydraulically bound mixtures using Proctor equipment or vibrating table compaction.*

prEN 13286-51, *Unbound and hydraulically bound mixtures — Part 51: Method for the manufacture of test specimens of hydraulically bound mixtures using vibrating hammer compaction.*

prEN 13286-52, *Unbound and hydraulically bound mixtures — Part 52: Method for the manufacture of test specimens of hydraulically bound mixtures using vibrocompression.*

prEN 13286-53, *Unbound and hydraulically bound mixtures — Part 53: Method for the manufacture of test specimens of hydraulically bound mixtures using axial compression.*

Annexes A and B are normative.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard specifies a method for the determination of the relationship between the dry density and water content of a mixture when compacted using a vibrating hammer.

This European Standard applies to mixtures used in road construction which contain not more than 30 % by mass retained on the 20 mm test sieve. It is not applicable to mixtures with more than 10 % by mass of the mixture retained on the 40 mm test sieve.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 932-2, *Tests for general properties of aggregates – Part 2: Methods for reducing laboratory samples.*

EN 933-1, *Tests for geometrical properties of aggregates – Part 1: Determination of particle size distribution – Sieving method.*

EN 1097-5, *Tests for mechanical and physical properties of aggregates – Part 5: Determination of the water content by drying in a ventilated oven.*

EN 13286-1:2003, *Unbound and hydraulically bound mixtures – Part 1: Test methods for laboratory reference density and water content – Introduction, general requirements and sampling.*

3 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in EN 13286-1:2003 apply.

4 Principle

The mixture is compacted into a CBR-type cylindrical metal mould using an electrically powered vibrating hammer over a range of water contents. The range includes the optimum water content at which the maximum dry density for the specified degree of compaction is obtained. The relationship between dry density and water content is described in EN 13286-1.

5 Apparatus

5.1 Cylindrical, corrosion resistant, metal mould, with an internal diameter of (152,0 ± 0,5) mm, an internal depth (127,0 1,0) mm and a minimum wall thickness of 5,0 mm. The internal faces shall be smooth, clean and dry before use.

NOTE Cylindrical mould and collar extension is shown in Figure 1.

5.2 Detachable baseplate and removable extension piece, to fit mould.

5.3 Electrically powered vibrating hammer, conforming to the performance check in annex A.

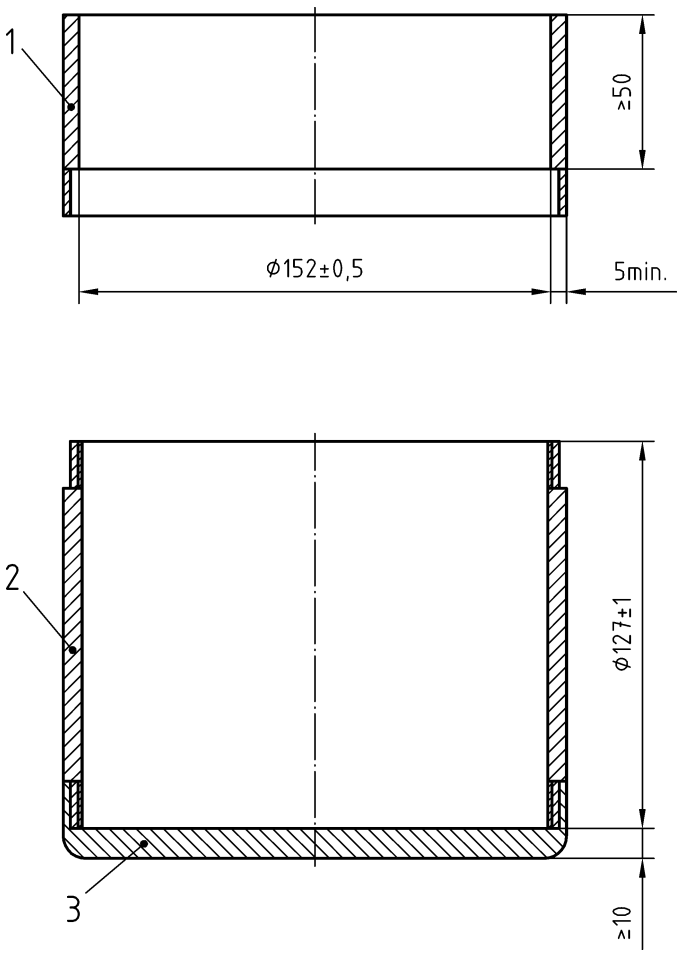
NOTE A vibrating hammer with a power consumption of at least 600 W, an operating frequency between 25 Hz and 60 Hz, and fitted with a suitable safety circuit breaker may be suitable.

5.4 Steel tamper attachment, for the vibrating hammer with a flat bottom face of diameter (145,0 2,0) mm, a base thickness of at least 10,0 mm and a total mass of not more than 3,0 kg.

5.5 Supporting guide frame for the hammer (optional).

5.6 Depth gauge or steel rule, readable to 0,5 mm.

Dimensions in millimetres



Key

1 Wall, min. 5 mm
2 Good finish on bore
3 Detachable baseplate

Figure 1 — Cylindrical mould and collar extension

5.7 Balance, of suitable capacity to weigh the mould, test specimen and baseplate, and readable to 5 g.

5.8 Steel straightedge, at least 200 mm long.

5.9 Test sieves, aperture sizes 40 mm and 20 mm, and a suitable receiver, for use in preparation of the test portion.

5.10 Metal or plastic trays.

5.11 Suitable scoop.

5.12 Stopclock or similar timer, readable to 1 s.

5.13 Apparatus for extracting the sample from the mould.

6 Preparation of test portions

6.1 Evaluation of the submitted sample

Weigh and record the mass of the submitted sample. The sample submitted to the laboratory shall have a mass of at least 40 kg.

Determine the particle size distribution of the laboratory sample, using the procedures described in EN 933-1, including the 40 mm and 20 mm sieves.

NOTE This test method is suitable for use if the particle size distribution conforms to the grading envelope in Table 1.

Table 1 — Particle size distribution

Test sieve	Percentage passing
40 mm	90 to 100
20 mm	70 to 100

Determine the water content of a test portion taken from the laboratory sample using the procedures described in EN 932-2 and EN 1097-5.

6.2 Preparation of the test portion

Remove all of the particles retained on the 40 mm test sieve from the remainder of the laboratory sample. Use the sieving procedures described in EN 933-1, without first washing and drying the sample. If necessary, sieve in parts to ensure that the test sieve is not overloaded.

Weigh and record the mass of the particles retained on the 40 mm sieve.

If the laboratory sample contains 5 % or less, by mass, of particles retained on the 40 mm test sieve, the resulting modified sample shall be considered as the test portion.

If the laboratory sample contains more than 5 % but less than 10 %, by mass, of particles retained on the 40 mm test sieve, further modify the sample by adding an equal mass of similar material which passes the 40 mm test sieve but is retained on the 20 mm test sieve. The resulting modified sample shall be considered as the test portion.

6.3 Preparation of the test specimens

Subdivide the test portion into five or more test specimens, each of about 6 kg, using the procedures described in EN 932-2. Weigh and record the mass of each test specimen.

Using the water content of laboratory sample, calculate the required amount of water which needs to be added to, or lost from, each test specimen to give a suitable range of nominal water contents.

The range of nominal water contents selected shall be such that at least two values lie either side of the value at which the laboratory dry density is expected to occur.

NOTE Increments of 1 % to 2 % are suitable.

If a test specimen initially contains more water than is required for compaction at a selected nominal water content, allow the test specimen to dry to the desired nominal water content, and mix thoroughly.

7 Procedure

7.1 Compaction

Weigh the mould with the baseplate and extension attached. Record the mass m_1 to the nearest 5 g. Measure and record the height H of the extended mould, to nearest 0,5 mm.

Place the assembly on a heavy solid base with a mass of not less than 50 kg.

NOTE 1 A concrete floor or concrete plinth are suitable.

Place some of the first test specimen into the mould such that, when compacted, it occupies about one third of the height of the mould body. Place the foot of the tamper attachment on the specimen and compact with the vibrating hammer for (60 ± 2) s.

During compaction, apply a steady downward force on the hammer so that the tamper attachment does not bounce on the compacted specimen and the total downward force on the test specimen, including the mass of the hammer, is between 300 N and 400 N.

NOTE 2 The application of the necessary pressure to achieve the required downward force should be checked by the operator before the test starts. Push the hammer – without vibration – against the load pan of a suitable platform balance until a mass of 30 kg to 40 kg is indicated.

Place a second similar volume of the first test specimen into the mould and repeat the compaction stage. Add a third volume of the test specimen so as to give an expected compacted volume which will conform to the requirements for height set out in 7.2, and compact again.

7.2 Measurement

Remove any loose material lying on the surface of the test specimen around the side of the mould. Lay the straightedge across the top of the extended mould. Measure down from the straightedge to the compacted surface of the test specimen, to the nearest 0,5 mm.

Take readings at four points spaced evenly over the surface of the test specimen, at least 15 mm from the side of the mould. Using the previously measured internal height of the extended mould H calculate the mean height h of the test specimen, to the nearest millimetre.

If the mean height of the test specimen h is less than 127 mm or more than 133 mm, reject the compacted test specimen and repeat 7.1 and 7.2 using the remainder of the test specimen. Make suitable adjustments to the amount used, until a compacted specimen of the required height is obtained.

Weigh the mould, compacted test specimen, extension collar and base plate. Record the mass m_2 to the nearest 5 g.

Remove the compacted test specimen from the mould and determine its water content using the procedures described in EN 1097-5. Discard any of the test portion which remains.

7.3 Further test specimens

Repeat the procedures described in 7.1 and 7.2 for the remainder of the test specimens.

8 Calculation and expression of results

8.1 Calculate the bulk density

Calculate the bulk density, , of each compacted specimen from the equation

$$= 1\,000 \quad (m_2 \quad m_1)/(a \quad h) \tag{1}$$

where

is the bulk density, in megagrams per cubic metre (Mg/m^3);

m_1 is the mass of mould and baseplate and extension, in grams (g);

m_2 is the mass of mould, baseplate and compacted mixture, in grams (g);

h is the height of the compacted sample, in millimetres (mm);

a is the cross-sectional area of the mould, in square millimetres (mm^2).

8.2 Calculation of dry density

Calculate the dry density $_d$ of each compacted specimen from the equation:

$$_d = (100 \quad)/(100 + w) \tag{2}$$

where

is the bulk density, in megagrams per cubic metre (Mg/m^3);

$_d$ is the dry density, in megagrams per cubic metre (Mg/m^3);

w is the water content of the mixture, in percentage (%).

8.3 Plotting of densities

Plot the dry densities obtained from a series of determinations as ordinates against the corresponding water contents as abscissae. Draw a curve of best fit to the plotted points and identify the position of the maximum on this curve. Read off the values of dry density and water content corresponding to that point (see EN 13286-1).

NOTE The maximum can lie between two observed points but, when drawing the curve, care should be taken not to exaggerate its peak.

8.4 Plotting of voids ratios

On the same graph, plot the curves corresponding to 0 %, 5 % and 10 % air voids, calculated from the equation

$$_d = (1 \quad V_a/100)/(1/ \ _s + w/100 \quad _w) \tag{3}$$

where

$_d$ is the dry density, in megagrams per cubic metre (Mg/m^3);

$_s$ is the particle density, in megagrams per cubic metre (Mg/m^3), determined in accordance with EN 1097-6;

$_w$ is the density of water, in megagrams per cubic metre (Mg/m^3), assumed equal to 1;

V_a is the volume of air voids in the mixture, expressed as a percentage of the total volume of the mixture (equal to 0 %, 5 %, 10 % for the purpose of this plot);

w is the water content of the mixture, in percentage (%), (see Figure 1).

9 Test report

The test report shall include at least the following information:

a) reference to this European Standard;

b) identification of the sample;

c) identification of the laboratory;

d) date;

e) maximum dry density $_{d,max}$ in megagrams per cubic metre (Mg/m^3) to the nearest 0,01 Mg/m^3;

f) optimum water content to the nearest 0,5 %;

g) the amount of particles retained on the 40 mm test sieve reported to the nearest 1 % by dry mass;

h) the particle density used in the calculation. If measured, state the method used.

If required, the test report shall also include the following optional information.

i) name and location of the sample source;

j) description of the material.

k) the experimental points and the smooth curve drawn through them showing the relationship between water content and dry density.

Annex A
(normative)

Performance check of vibrating hammer

A.1 Materials

Clean, dry sand, with a silica content of at least 95 %. The grading shall be such that at least 75 % passes the 0,600 mm sieve and is retained on the 0,425 mm test sieve and 100 % passes the 0,850 mm test sieve and is retained on the 0,300 mm test sieve. Dry and not previously used sand shall be used. This sand shall be sieved through a 0,600 mm test sieve and the coarse fraction shall be discarded.

A.2 Procedure

Take (5,0 ± 0,1) kg sample of the sand specified in A.1 and mix it with water in order to raise its water content to (2,5 ± 0,5 %).

Carry out a total of three tests, all on the same sample of sand, and determine the mean dry density.

Determine the dry density values to the nearest 0,002 Mg/m^3.

If the range of values in the three tests exceeds 0,01 Mg/m^3, repeat the procedure. Consider the vibrating hammer suitable for use in the vibrating compaction test if the mean dry density of the sand exceeds 1,74 Mg/m^3.

A.3 Pressure check

Apply pressure combined with vibration to ensure the required degree of compaction. A downward force on the sample surface of 300 N to 400 N shall be applied, this being greater than the force needed to prevent the hammer bouncing on the mixture.

The required pressure shall be assessed by applying the vibrating hammer, without vibration, to a platform scale. The required force shall be applied when a mass of 30 kg to 40 kg is indicated.

Annex B
(normative)

Compatibility test for graded aggregates

B.1 Introduction

This Annex describes a variation to the method set out in the main text. It is suitable for graded mixtures which mostly pass the 40 mm, but which may not conform to the 20 mm sieve requirement in clause 6.

NOTE 1 This method is used in the UK to determine the optimum water content for the compaction of granular mixtures used in capping layers. It is assumed that the mixture contains some particles which are susceptible to crushing under the action of the vibrating hammer; a different test portion is used for each value of water content.

This test gives a measure of the bulk density of aggregate subjected to a high level of vibratory compaction. The test may be carried out at any particular specified water content or over a range of water contents. In the case of continuously-graded aggregates when the test is carried out over a range of water contents it can provide information of the effects of water content upon bulk density levels. In such circumstances it may be possible to identify optimum water conditions.

NOTE 2 The procedure involves the removal of particles larger than 37,5 mm in size and the amount that is removed of such material should be borne in mind in the interpretation of the results.

B.2 Apparatus

B.2.1 Standard compaction mould and anvil, comprising a body, a base and a filter assembly. The standard mould and anvil shall conform to Figure B.1.

The cross-sectional area of the mould, calculated to the nearest 10 mm^2, shall be stamped on the side of the mould body. The cylinder bore and external diameter of the anvil shall be parallel. The difference in diameter of the internal wall of the mould and the external surface of the anvil shall be greater than 0,3 mm and less than 0,9 mm. The depth of the mould shall be sufficient to contain the uncompacted test portion and the whole of the anvil above it. A seal ring shall be provided between the cylinder and base.

NOTE 1 The filter assembly should consist of a suitable geotextile between two perforated steel plates.

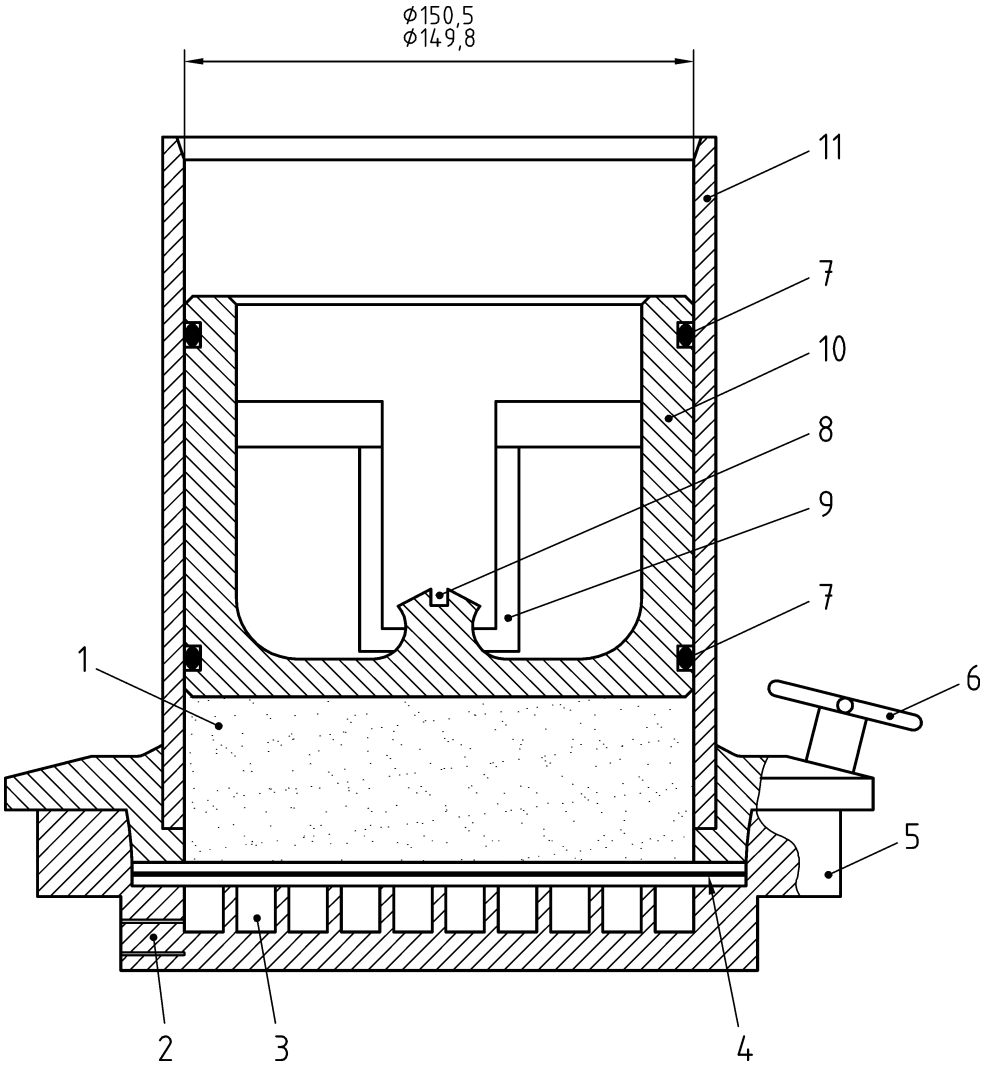
NOTE 2 The anvil is fitted with a pair of rubber O-rings, which will suffer wear. In time this will allow fines to be forced past the O-rings during compaction. Replacement O-rings should therefore be kept and fitted after 50 uses or earlier if necessary.

B.2.2 Electric vibrating hammer, having a nominal power consumption of 900 W and capable of delivering about 2 000 blows per minute to the anvil. It shall be equipped with a suitable shank which makes contact with the anvil (see Figures B.1 and B.2). The vibrating hammer shall also conform to the performance check in annex A.

B.2.3 Loading frame, to permit the hammer to be brought into contact with the anvil in the mould (see Figure B.2). The surcharge mass and the length of the lever arm shall be such that when the lever arm is in a horizontal position the total dead-weight force under the anvil is (640 ± 10) N when the mould is not in position, but the rest of the apparatus is assembled.

NOTE The loading frame can be placed on a rubber mat to prevent movement during vibration.

Dimensions in millimetres



Key

1 Test portion
2 Vent
3 Supporting ribs for filter assembly
4 Filter assembly
5 Base
6 Clamp (at least 3)
7 Rubber 'O' ring
8 Small hole to locate depth gauge
9 Shank guide
10 Anvil EN 24Z steel
11 Cylinder: stainless steel

Figure B.1 — Compaction mould apparatus

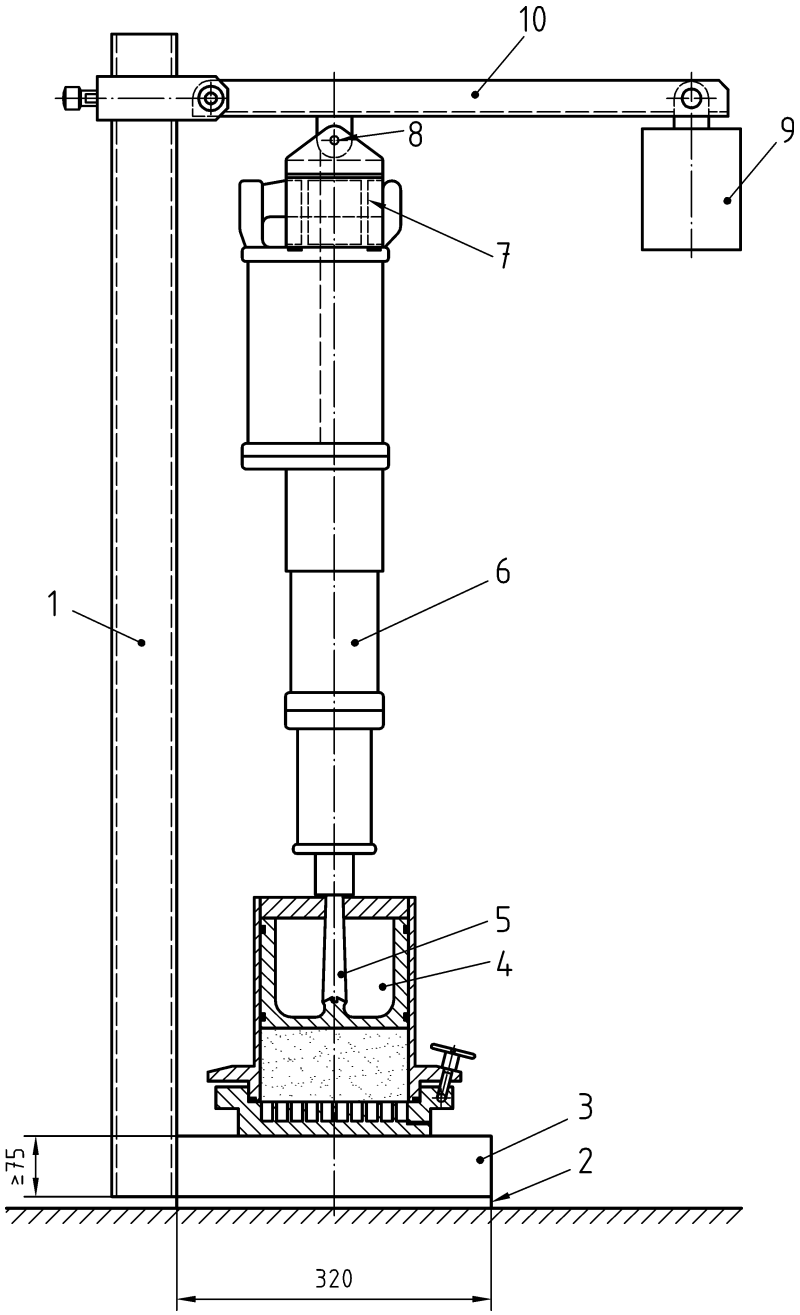
B.2.4 **Depth gauge,** to measure the distance between the top of the mould and the upper surface of the anvil to an accuracy of 0,1 mm or better.

B.2.5 **Stop-watch, stop-clock or an automatic timer**, to control the period of vibration.

B.2.6 **Filter papers**, 150 mm in diameter.

B.2.7 **A square-holed perforated plate test sieve**, 40 mm size.

Dimensions in millimetres



Key

1	Support frame	6	Vibrating hammer
2	Rubber mat	7	Hammer grip assembly
3	Steel base, minimum area 0,1 m^2	8	Securing pin to allow hammer to hang vertically
4	Compaction mould and anvil	9	Surcharge mass
5	Shank	10	Lever arm

Figure B.2 — Compaction rig assembly

B.2.8 **Balance**, of suitable capacity to weigh the mould and test specimen, and readable to 5 g.

B.2.9 **Containers**, at least 16, for storage, water tight, sealable and large enough to hold a test portion.

B.3 Preparation of test specimens

B.3.1 Take the test portion, prepared as described in 6.2 and use oven-dried material (see NOTE) passing the 37,5 mm test sieve, so that after removal of the oversize material it has a dry mass of (2,5 ± 0,1) kg. Record and report the percentage of oversize material.

NOTE If more than 15 % of material is removed the aggregate is too coarse to be tested.

B.3.2 If the test is to be carried out only at one specified water content W prepare two test portions at the required water content according to the procedure given in 6.2.

B.3.3 When compaction tests are to be carried out over a range of water contents to define the relation between water content and dry density mix the dry test portions with different amounts of water following the procedure given in B.3.4 to give a suitable range of water contents W_1, W_2 to W_n.

NOTE The choice of the range of water content to use requires trial and error. Although 12 test portions can be sufficient, it is usually necessary to produce a larger number than this. As a guide to the choice of water contents Table B.1 gives some typical ranges of optimum values for various types of aggregate.

Table B.1 — Typical values of optimum water content for various aggregates

Description of material	Range of optimum water content
Crushed granite subbase	4 % to 6 %
Crushed carboniferous limestone subbase	3 % to 5 %
Sand and gravel subbase	6 % to 8 %

B.3.4 Where a water condition other than oven-dried or saturated and surface-dried is required, mix water with the test portion to raise its water content to within ± 0,1 % of the required value, W. Store the wetted portion in the soaked water-tight container (see B.2.9) for at least 12 h to promote thorough wetting before testing.

B.3.5 Initially, carry out tests at water contents 2 % apart to find the approximate location of the optimum water content, if this is now known. Determine the precise location of the optimum water content from tests carried out at water contents 0,5 % apart.

Select these so that results are obtained at about the optimum and at two water contents each side of the optimum at this spacing. Test two test specimens at each water content.

NOTE For example initial test with duplicate test portions at water contents of 2 %, 4 %, 6 % and 8 % suggests that optimum water content is about 6,5 %. Further tests are then conducted at water contents of 5,5 %, 6,5 %, 7,0 % and 7,5 % to obtain a good definition of the optimum value. The initial test requires eight test portions and the supplementary test requires another eight test portions.

B.4 Procedure

B.4.1 Before each compaction test check the compaction mould to ensure that it is thoroughly clean and dry. Assemble the mould body, base, filter plates and fibre filter, taking care to ensure that the parts fit together properly. Tighten the clamps to full tightness.

B.4.2 Lay three filter papers flat on the bottom of the mould and insert the anvil into the mould so that it touches the upper filter paper. Apply the vibrating hammer to the anvil for about 5 s to ensure that it is properly bedded. Measure carefully the distance e between the bottom of the small hole within the half-ball in the anvil and the top of the mould. Record this distance to an accuracy of 0,1 mm. Remove the anvil and filter papers. Replace two of the filter papers flat on the bottom of the mould.

B.4.3 Remix thoroughly the appropriate test portion in its container. Record the mass of the container and test portion, and that of the empty container. From these results calculate the initial mass of the test portion m_1 to an accuracy of 0,1 %.

Place the whole of the test portion in the mould in such a way as to form a single layer with minimum segregation. Roughly level off the top of the test portion, being careful not to remove any material from the mould, and cover it with the remaining filter paper.

Locate the filled compaction mould assembly in the loading frame. Insert the anvil into the mould so that it rests on the upper filter paper and place the vibrating hammer in position. Apply the surcharge load and operate the vibrating hammer for (180 ± 5) s to compact the test portion. After compaction has ceased remove the vibrating hammer from the frame and from the mould.

B.4.4 With the depth gauge measure carefully and record to an accuracy of 0,1 mm the distance f between the bottom of the small hole in the anvil and the top of the mould. Calculate the height of the compacted portion.

$$h = e - f \qquad \text{(B.1)}$$

where

h is the of the compacted sample, in millimetres (mm);

e is the depth gauge reading in empty mould, in millimetres (mm);

f is the depth gauge reading in filled mould, in millimetres (mm).

NOTE Care should be taken not to disturb the anvil after compaction has ceased and before the depth measurement is made.

B.4.5 Extract the compacted test portion in its entirety from the mould, remove the filter papers and transfer the test portion to an appropriate container of known mass. Determine its water content by oven-drying the whole contents of the container following the procedure described in EN 1097-5. The water content obtained in this way is the residual water content W, i.e. the water content after the compaction process has been completed.

NOTE The value of the residual water content usually differs from the initial water content because some water is squeezed out during compaction. If the value of the residual water content differs from the initial water content by more than two units ignore this particular result when estimating the optimum water content (see B.6).

B.4.6 Repeat the processes described in B.4.1 to B.4.5 inclusive until all the remaining test portions have been compacted.

B.5 Calculation

NOTE A model test form for one determination is shown in Table B.2. This sets out the stages of the calculations, and gives an example.

B.5.1 Calculate the dry mass m_2 of each test portion from the equation:

$$m_2 = (100 \quad m_1)/(w + 100) \qquad \text{(B.2)}$$

where

m_2 is the initial mass of the test portion (solid particles and any contained water) placed in the mould, in grams (g);

W is the initial water content of the test portion when mixed (see B.4.3) i. e. a value in the range W_1, W_2 to W_n in percentage (%).

Table B.2 — Suitable test sheet with worked example for the determination if vibrated bulk density and corresponding residual water content

Sample reference:	Oven-dried particle density = 2,530 Mg/m^3 (Weighted for grading used)				
Specimen only	Water absorption value = 1,9 % (Weighted for grading used)				
Calculations	Observations	Precision	Test results		Mean value
w	Initial water content, in percent (%)	nearest 0,1	6,0	6,0	6,0
x	Mass of storage container and sample, in grams (g)	nearest 1	2 996	2 998	–
y	Mass of storage container empty, in grams (g)	nearest 1	303	301	–
$m_1 = x - y$	Initial wet mass of test portion, in grams (g)	nearest 1	2 693	2 697	–
m_2 = 100 $m_1/(w$ + 100)	Initial dry mass of test portion, in grams (g)	nearest 1	2 541	2 544	–
a	Cross sectional area of mould, in square millimetres (mm^2)	nearest 10	17 680	17 680	–
b	Mass of portion at residual water content, in grams (g)	nearest 1	2 664	2 673	–
c	Mass of oven-dry portion, in grams (g)	nearest 1	2 538	2 540	–
$d = b - c$	Mass of residual water, in grams (g)	nearest 1	126	133	–
e	Depth gauge reading on empty mould, in millimetres (mm)	nearest 0,1	278,7	278,7	–
f	Depth gauge reading on compacted portion, in millimetres (mm)	nearest 0,1	211,1	210,3	–
$h = e - f$	Height of compacted portion, in millimetres (mm)	nearest 0,1	67,6	68,4	–
$= m_2$ (100 + W_R)/(a h)	Vibrated bulk density, in megagrams per cubic metre (Mg/m^3)	nearest 10	2,230	2,210	2,220
$_d = m_2/(a$ $h)$	Vibrated dry density, in megagrams per cubic metre (Mg/m^3)	nearest 10	2,130	2,100	2,120
W_R = 100 d/c	Residual water content, in percent (%)	nearest 0,1	5,0	5,2	5,1

B.5.2 Calculate the vibrated bulk density, , of each portion from the formula:

$$= 100 \quad m_2 \quad (100 + W_R)/(a \quad h) \tag{B.3}$$

where

is the vibrated bulk density, in megagrams per cubic metre (Mg/m^3);

m is the mass of dry aggregate, in grams (g);

W_R is the residual water content of each test portion, in percentage;

a is the cross-sectional area of the mould, in square millimetres (mm^2);

h is the height of compacted portion, $e - f$, in millimetres (mm).

B.5.3 Calculate the vibrated dry density $_d$ of each test portion from the formula:

$$_d = 1\,000 \quad m_2/(a \quad h) \tag{B.4}$$

where

$_d$ is the vibrated dry density, in megagrams per cubic metre (Mg/m^3);

m is the mass of dry aggregate, in grams (g);

a is the cross-sectional area of the mould, in square millimetres (mm^2);

h is the height of compacted portion, $(e - f)$, in millimetres (mm).

e is the depth gauge reading in empty mould, in millimetres (mm);

f is the depth gauge reading in filled mould, in millimetres (mm).

B.6 Expression of results

B.6.1 Where the vibrated bulk and/or dry density at one specified water content is required, report the mean value to the nearest 0,010 Mg/m^3.

If the individual values differ by more than 0,050 Mg/m^3 repeat the test procedure with two further test portions.

B.6.2 Where the vibrated dry density is being determined over a range of water contents follow the procedure given in B.7.

B.7 Estimation of the optimum water content and maximum dry density

B.7.1 From the results obtained as described in B.6 plot the vibrated dry density values against the corresponding residual water content values. Use the values obtained for the individual test portions with water content as the x axis of the graph and dry density as the y axis.

Plot the three lines representing 0 %, 5 % and 10 % air voids. Appropriate values of dry density for given contents of water and air voids are obtained from the equation.

$$_d = (1 \quad V_a/100) / (1/ \ _s + w/100 \quad _w) \qquad \text{(B.5)}$$

where

$_d$ is the dry density, in megagrams per cubic metre (Mg/m^3);

V is the air void content, i.e. 0 %, 5 % or 10 % by value, in percent (%);

is the particle density on an oven-dried basis, in megagrams per cubic metre (Mg/m^3);

W_R is the residual water content, in percent (%);

W_A is the water absorption value, in percent (%).

B.7.2 Compaction curves for aggregates take three forms depending on the grading and the porosity of the aggregate under test. These forms are shown in Figure B.3.

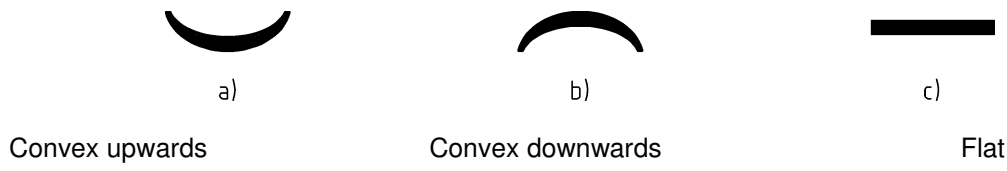


Figure B.3 — Forms of compaction curve

B.7.3 Where the curve approximates to the convex upwards from the plot of dry density against water content for a well-graded aggregate might give a curve with the crest near the 0 % air voids but other aggregates, particularly if they contain less than about 35 % of material finer than 5 mm (if the nominal maximum size is 37,5 mm) exhibit peak values of density at air void contents higher than about 5 %.

B.7.3.1 When the curve has been drawn and it has been identified as being convex upwards the peak dry density, and the corresponding optimum water content shall be read from the curve and recorded to the nearest 10 kg/m^3 and 0,5 % respectively.

B.7.3.2 Where the curve is convex downwards determine the values for laboratory dry density and optimum water content as the terminal values and record to the nearest 10 kg/m^3 and 0,5 % respectively.

B.7.3.3 Where no curve can be drawn and the best line through the points is approximately horizontal it shall be reported that no value for optimum water content exists and the value for density shall be quoted for any water content required.

B.8 Expression of results

B.8.1 Report the values of vibrated dry density, including peak values to the nearest 10 kg/m^3 and when optimum water contents can be measured report them to the nearest 0,5 %.

B.8.2 The graphical plot of dry density against water content shall also be included with the results.

B.9 Test report

B.9.1 Where the aggregate was tested at one specified water content, the test report shall state that the vibrated bulk density at the water content that was specified was determined in accordance with this European Standard and whether or not a certificate of sampling is available. If available, a copy of the certificate shall be provided.

The test report shall contain the following additional information:

a) sample identification and sample description;

b) the value of the initial water content at which the determination was made;

c) the value of the vibrated bulk density and the residual water content after compaction;

d) the proportion of any material coarser than 37,5 mm in particle size that was discarded.

B.9.2 Where the aggregate was tested over a range of water contents, the test report shall state that the maximum vibrated dry density and optimum water content were determined in accordance with this European Standard and if these values could not be estimated from the results this fact shall be stated. The test report shall also state whether or not a certificate of sampling is available and, if so, a copy of the certificate shall be provided.

The test report shall also contain the following additional information:

a) sample identification and sampling description;

b) the individual values of vibrated dry density and the corresponding residual water contents;

c) an estimate of the peak value of the vibrated dry density and (if possible) an estimate of the optimum water content at which the peak value occurs;

d) the graphical plot of density against residual water content;

e) the proportion of any material coarser than 37,5 mm in particle size that was discarded.

B.10 Precision

A precision experiment was carried out in 1988 under the control of BSI. 12 laboratories took part. The results are given in Tables B.3 and B.4.

Table B.3 — Precision data

Laboratory dry density Mg/m^3	r	R
Carboniferous limestone subbase	0,029	0,122
Gravel subbase	0,033	0,054

Table B.4 — Precision data

Optimum water content (%)	r	R
Carboniferous limestone subbase	0,4	1,3
Gravel subbase	0,6	1,2

blank

BSI — British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover. Tel: +44 (0)20 8996 9000. Fax: +44 (0)20 8996 7400.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to Customer Services. Tel: +44 (0)20 8996 9001. Fax: +44 (0)20 8996 7001. Email: orders@bsi-global.com. Standards are also available from the BSI website at http://www.bsi-global.com.

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library and its Technical Help to Exporters Service. Various BSI electronic information services are also available which give details on all its products and services. Contact the Information Centre. Tel: +44 (0)20 8996 7111. Fax: +44 (0)20 8996 7048. Email: info@bsi-global.com.

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration. Tel: +44 (0)20 8996 7002. Fax: +44 (0)20 8996 7001. Email: membership@bsi-global.com.

Information regarding online access to British Standards via British Standards Online can be found at http://www.bsi-global.com/bsonline.

Further information about BSI is available on the BSI website at http://www.bsi-global.com.

Copyright

BSI
389 Chiswick High Road
London
W4 4AL