

# Methods of testing cement —

## Part 1: Determination of strength

The European Standard EN 196-1:2005 has the status of a  
British Standard

ICS 91.100.10

# National foreword

This British Standard is the official English language version of EN 196-1:2005. It supersedes BS EN 196-1:1995 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee B/516, Cement and lime, to Subcommittee B/516/12, Sampling and testing, 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.**

## Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 33 and a back cover.

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

## Amendments issued since publication

Amd. No.	Date	Comments

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 22 March 2005

© BSI 22 March 2005

ISBN 0 580 45670 6

English version

## Methods of testing cement - Part 1: Determination of strength

Méthodes d'essais des ciments - Partie 1: Détermination  
des résistances mécaniques

Prüfverfahren für Zement - Teil 1: Bestimmung der  
Festigkeit

This European Standard was approved by CEN on 29 December 2004.

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 Central Secretariat 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 Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, 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

# Contents

Page

Foreword .....	3
1 Scope .....	5
2 Normative references .....	5
3 Principle .....	5
4 Laboratory and equipment .....	6
4.1 Laboratory .....	6
4.2 General requirements for the equipment .....	6
4.3 Test sieves .....	6
4.4 Mixer .....	7
4.5 Moulds .....	8
4.6 Jolting apparatus .....	12
4.7 Flexural strength testing apparatus .....	13
4.8 Compressive strength testing machine .....	14
4.9 Jig for compressive strength testing machine .....	15
4.10 Balance .....	16
4.11 Timer .....	16
5 Mortar constituents .....	17
5.1 Sand .....	17
5.2 Cement .....	18
5.3 Water .....	18
6 Preparation of mortar .....	18
6.1 Composition of mortar .....	18
6.2 Mixing of mortar .....	18
7 Preparation of test specimens .....	19
7.1 Size of specimens .....	19
7.2 Moulding of test specimens .....	19
8 Conditioning of test specimens .....	19
8.1 Handling and storage before demoulding .....	19
8.2 Demoulding of specimens .....	19
8.3 Curing of specimens in water .....	20
8.4 Age of specimens for strength tests .....	20
9 Testing procedures .....	20
9.1 Flexural strength .....	20
9.2 Compressive strength .....	21
10 Results .....	21
10.1 Flexural strength .....	21
10.2 Compressive strength .....	22
11 Validation testing of CEN Standard sand and of alternative compaction equipment .....	23
11.1 General .....	23
11.2 Validation testing of CEN Standard sand .....	23
11.3 Validation testing of alternative compaction equipment .....	27
Annex A (normative) Alternative vibration compaction equipment and procedures validated as equivalent to the reference jolting compaction equipment and procedure .....	29

## Foreword

This document (EN 196-1:2005) has been prepared by Technical Committee CEN/TC 51 '*Cement and building limes*', the secretariat of which is held by IBN/BIN.

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 August 2005, and conflicting national standards shall be withdrawn at the latest by August 2005.

This document supersedes EN 196-1:1994.

This European Standard on the methods of testing cement comprises the following Parts:

EN 196-1, *Methods of testing cement — Part 1: Determination of strength*

EN 196-2, *Methods of testing cement — Part 2: Chemical analysis of cement*

EN 196-3, *Methods of testing cement — Part 3: Determination of setting time and soundness*

EN 196-5, *Methods of testing cement — Part 5: Pozzolanicity test for pozzolanic cements*

EN 196-6, *Methods of testing cement — Part 6: Determination of fineness*

EN 196-7, *Methods of testing cement — Part 7: Methods of taking and preparing samples of cement*

EN 196-8, *Methods of testing cement — Part 8: Heat of hydration — Solution method*

EN 196-9, *Methods of testing cement — Part 9: Heat of hydration — Semi-adiabatic method*

NOTE A previous Part, EN 196-21: *Methods of testing cement — Part 21: Determination of the chloride, carbon dioxide and alkali content of cement*, has been revised and incorporated into EN 196-2

Another document, ENV 196-4 *Methods of testing cement — Part 4: Quantitative determination of constituents*, has been drafted and will be published as a CEN Technical Report.

This edition introduces the following technical changes based on comments received by the secretariat.

- a) The testing procedure has been revised with respect to hardness and surface texture of moulds (4.5) and compression strength testing machine platens (4.8) as supplied; suitability of mould oil (4.5); frequency of operation of jolting apparatus (4.6); the inclusion and accuracy of a balance (4.10); deionised water is now permitted (5.3); procedures for mixing mortar (6.2) and the moulding (7) and conditioning (8) of test specimens have been revised to reflect current best practice.
- b) Test results (10) are now reported in megapascals replacing newtons per square millimetre. (One megapascal is equivalent to one newton per square millimetre).
- c) The requirement for a flexural strength testing machine (4.7) is now optional.
- d) Estimates of the precision for compressive strength testing (10.2.3) have been revised to include both short and long term repeatability together with reproducibility data for laboratories of 'normal' performance and an indication of precision data for 'expert' laboratories.

- e) The procedure for validation testing of CEN Standard sand (11.2) includes initial certification testing, validation criteria, verification testing and annual confirmation testing.
- f) The procedure for validation testing of alternative compaction equipment (11.3) has been revised and a normative annex (annex A) has been introduced detailing two alternative vibration compaction equipments which have been validated.

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

## 1 Scope

This document describes the method for the determination of the compressive and, optionally, the flexural strength of cement mortar. The method applies to common cements and to other cements and materials, the standards for which call up this method. It may not apply to other cement types that have, for example, a very short initial setting time.

The method is used for assessing whether the compressive strength of cement is in conformity with its specification and for validation testing of a CEN Standard sand, EN 196-1, or alternative compaction equipment.

This document describes the reference equipment and procedure and allows alternative compaction equipment and procedures to be used provided that they have been validated in accordance with the appropriate provisions in this document. In the event of a dispute, only the reference equipment and procedure are used.

## 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.

EN 197-1, *Cement — Part 1: Composition, specifications and conformity criteria for common cements*

EN 196-7, *Methods of testing cement — Methods of taking and preparing samples of cement*

EN ISO 1302, *Geometrical Product Specifications (GPS) — Indication of surface texture in technical product documentation (ISO 1302:2002)*

EN ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines - Verification and calibration of the force-measuring system (ISO 7500-1:2004)*

ISO 565, *Test sieves — Metal wire cloth, perforated metal plate and electroformed sheet — Nominal sizes of openings*

ISO 1101, *Geometrical Product Specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out*

ISO 3310-1, *Test sieves — Technical requirements and testing — Part 1: Test sieves of metal wire cloth*

ISO 4200, *Plain end steel tubes, welded and seamless; general tables of dimensions and masses per unit length*

## 3 Principle

The method comprises the determination of the compressive, and optionally the flexural, strength of prismatic test specimens 40 mm × 40 mm × 160 mm in size.

These specimens are cast from a batch of plastic mortar containing one part by mass of cement, three parts by mass of CEN Standard sand and one half part of water (water/cement ratio 0,50). CEN Standard sands from various sources and countries may be used provided that they have been shown to give cement strength results which do not differ significantly from those obtained using the CEN Reference sand (see Clause 11).

In the reference procedure the mortar is prepared by mechanical mixing and is compacted in a mould using a jolting apparatus. Alternative compaction equipment and procedures may be used provided that they have been shown to give cement strength results which do not differ significantly from those obtained using the reference jolting apparatus and procedure (see Clause 11 and Annex A).

The specimens are stored in the mould in a moist atmosphere for 24 h and, after demoulding, specimens are stored under water until strength testing.

At the required age, the specimens are taken from their wet storage, broken in flexure, determining the flexural strength where required, or broken using other suitable means which do not subject the prism halves to harmful stresses, and each half tested for strength in compression.

## **4 Laboratory and equipment**

### **4.1 Laboratory**

The laboratory where preparation of specimens takes place shall be maintained at a temperature of  $(20 \pm 2) ^\circ\text{C}$  and a relative humidity of not less than 50 %.

The moist air room or the large cabinet for storage of the specimens in the mould shall be maintained at a temperature of  $(20,0 \pm 1,0) ^\circ\text{C}$  and a relative humidity of not less than 90 %.

The storage containers for curing the specimens in water, and the grates with which they are fitted, shall be of material which does not react with cement. The temperature of the water shall be maintained at  $(20,0 \pm 1,0) ^\circ\text{C}$ .

The temperature and relative humidity of the air in the laboratory and the temperature of the water in the storage containers shall be recorded at least once a day during working hours. The temperature and relative humidity of the moist air room or cabinet shall be recorded at least every 4 h.

Cement, CEN Standard sand (see 5.1.3), water and apparatus used to make and test specimens shall be at a temperature of  $(20 \pm 2) ^\circ\text{C}$ .

Where temperature ranges are given, the target temperature at which the controls are set shall be the middle value of the range.

### **4.2 General requirements for the equipment**

The tolerances shown in Figures 1 to 5 are important for correct operation of the equipment in the testing procedure. When regular control measurements show that the tolerances are not met, the equipment shall be rejected, adjusted or repaired. Records of control measurements shall be kept.

Acceptance measurements on new equipment shall cover mass, volume, and dimensions to the extent that these are indicated in this document paying particular attention to those critical dimensions for which tolerances are specified.

In those cases where the material of the equipment can influence the results, the material is specified and shall be used.

The approximate dimensions shown in the figures are provided as guidance to equipment manufacturers or operators. Dimensions, which include tolerances, are obligatory.

### **4.3 Test sieves**

Wire cloth test sieves conforming to ISO 3310-1 shall be of the sizes from ISO 565 given in Table 1 (series R 20).



Table 1 — Aperture of test sieves

Square mesh size (mm)					
2,00	1,60	1,00	0,50	0,16	0,08

#### 4.4 Mixer

The mixer shall consist essentially of:

- a stainless steel bowl with a capacity of about 5 litres of the typical shape and size shown in Figure 1, provided with means by which it can be fixed securely to the mixer frame during mixing and by which the height of the bowl in relation to the blade and, to some extent, the gap between blade and bowl can be finely adjusted and fixed;
- a stainless steel blade of the typical shape, size and tolerances shown in Figure 1, revolving about its own axis as it is driven in a planetary movement around the axis of the bowl at controlled speeds by an electric motor. The two directions of rotation shall be opposite and the ratio between the two speeds shall not be a whole number.

Blades and bowls shall form sets which shall always be used together.

The gap between blade and bowl shown in Figure 1 shall be checked regularly. The gap of  $(3 \pm 1)$  mm refers to the situation when the blade in the empty bowl is brought as close as possible to the wall. Simple tolerance gauges ('feeler gauges') are useful where direct measurement is difficult.

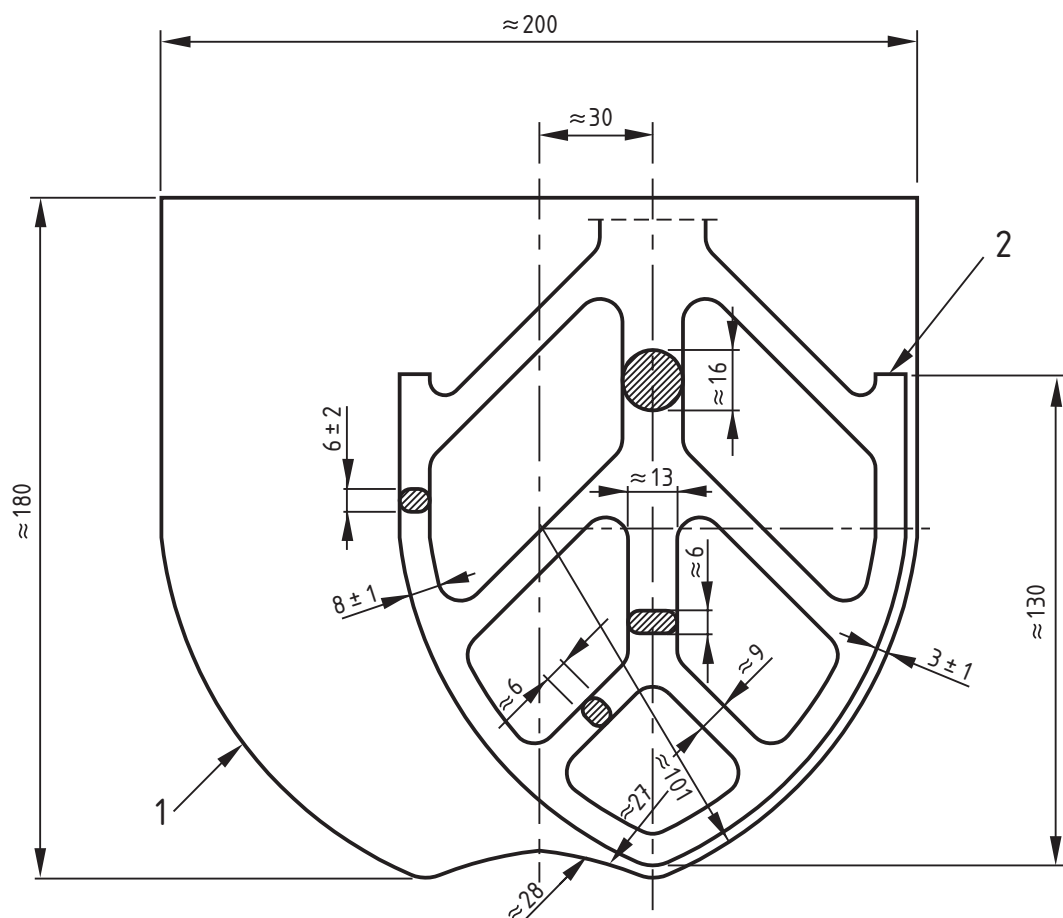
NOTE The dimensions marked as approximate on Figure 1 are for the guidance of manufacturers.

The mixer shall operate at the speeds given in Table 2 when mixing the mortar.

Table 2 — Speeds of mixer blade

	Rotation min <sup>-1</sup>	Planetary movement min <sup>-1</sup>
Low speed	140 ± 5	62 ± 5
High speed	285 ± 10	125 ± 10

Dimensions in millimetres

**Key**

- 1 Bowl
- 2 Blade

**Figure 1 — Typical bowl and blade****4.5 Moulds**

The mould shall consist of three horizontal compartments so that three prismatic specimens 40 mm × 40 mm in cross section and 160 mm in length can be prepared simultaneously.

A typical design is shown in Figure 2.

The mould shall be made of steel with walls approximately 10 mm thick. Each internal side face of the mould shall be case hardened to a Vickers hardness of at least HV 200, as supplied.

NOTE 1 A minimum Vickers hardness value of HV 400 is recommended.

The mould shall be constructed in such a manner as to facilitate the removal of moulded specimens without damage. Each mould shall be provided with a machined steel or cast iron baseplate. The mould, when assembled, shall be positively and rigidly held together and fixed to the baseplate.

The assembly shall be such that there is no distortion or visible leakage during operation. The baseplate shall make adequate contact with the table of the compacting apparatus and be rigid enough not to induce secondary vibrations.

NOTE 2 Moulds and jolting apparatus from different manufacturers may have unrelated external dimensions and masses, so their compatibility needs to be ensured by the purchaser.

Each part of the mould shall be stamped with identifying marks to facilitate assembly and to ensure conformity to the specified tolerances. Similar parts of separate mould assemblies shall not be interchanged.

The assembled mould shall conform to the following requirements.

- a) The internal dimensions and tolerances of each mould compartment shall be as follows:
  - length:  $(160 \pm 1)$  mm;
  - width:  $(40,0 \pm 0,2)$  mm;
  - depth:  $(40,1 \pm 0,1)$  mm.
- b) The flatness tolerance (see ISO 1101) over the whole of each internal side face shall be not greater than 0,03 mm.
- c) The perpendicularity tolerance (see ISO 1101) for each internal face with respect to the bottom surface of the mould and the adjacent internal face as datum faces shall be not greater than 0,2 mm.
- d) The surface texture (see EN ISO 1302) of each internal side face shall be not rougher than N8, as supplied.

Moulds shall be replaced when any one of the specified tolerances is exceeded. The mass of the mould shall accord with the requirement for the combined mass in 4.6.

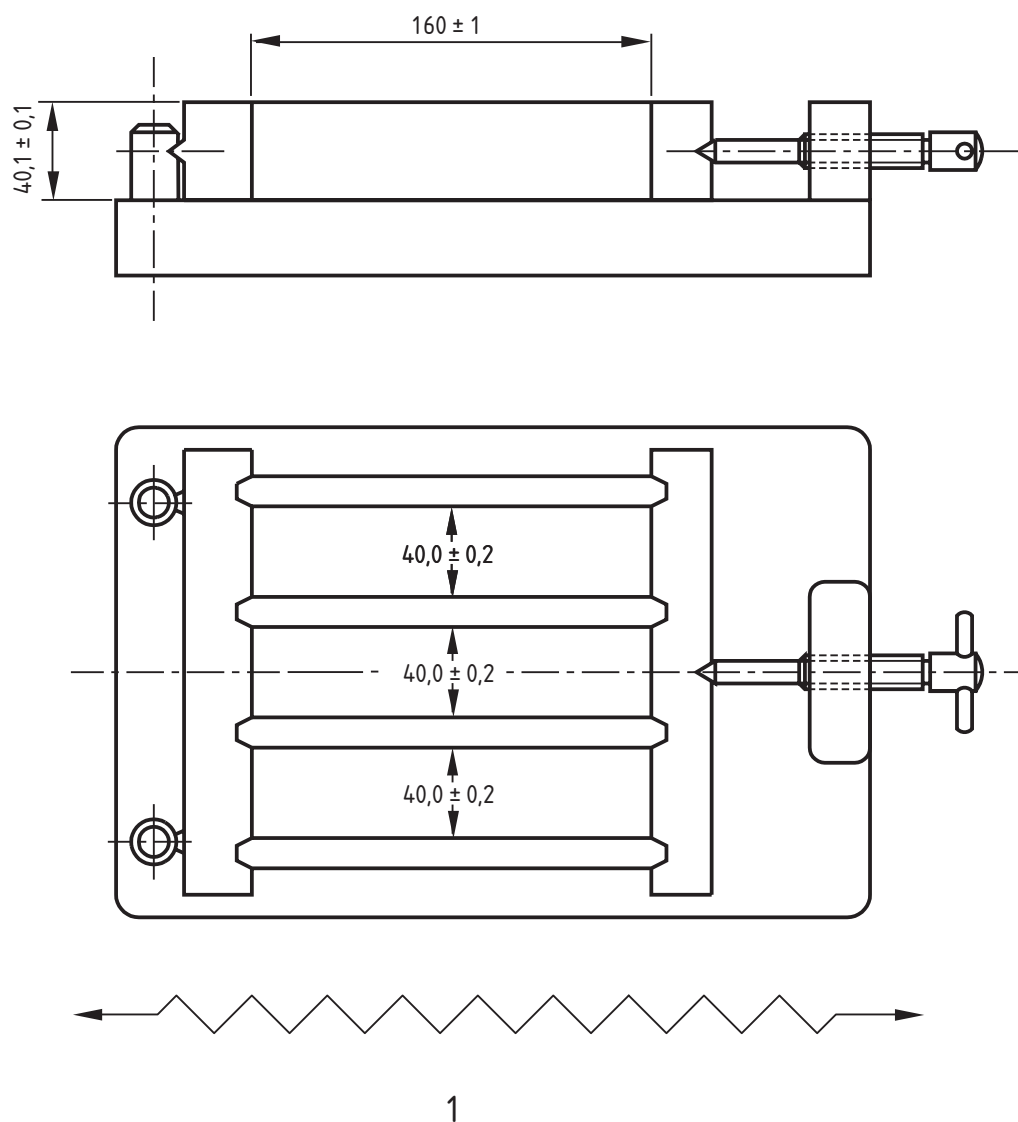
In preparing the cleaned mould ready for use, a suitable sealing material shall be used to coat the outer joints of the mould. A thin film of mould oil shall be applied to the internal faces of the mould.

NOTE 3 Some oils have been found to affect the setting of cement; mineral-based oils have been found to be suitable.

To facilitate the filling of the mould a tightly fitting metal hopper with vertical walls 20 mm to 40 mm in height shall be provided. When viewed in plan, the hopper walls shall overlap the internal walls of the mould by not more than 1 mm. The outer walls of the hopper shall be provided with a means of location to ensure correct positioning over the mould.

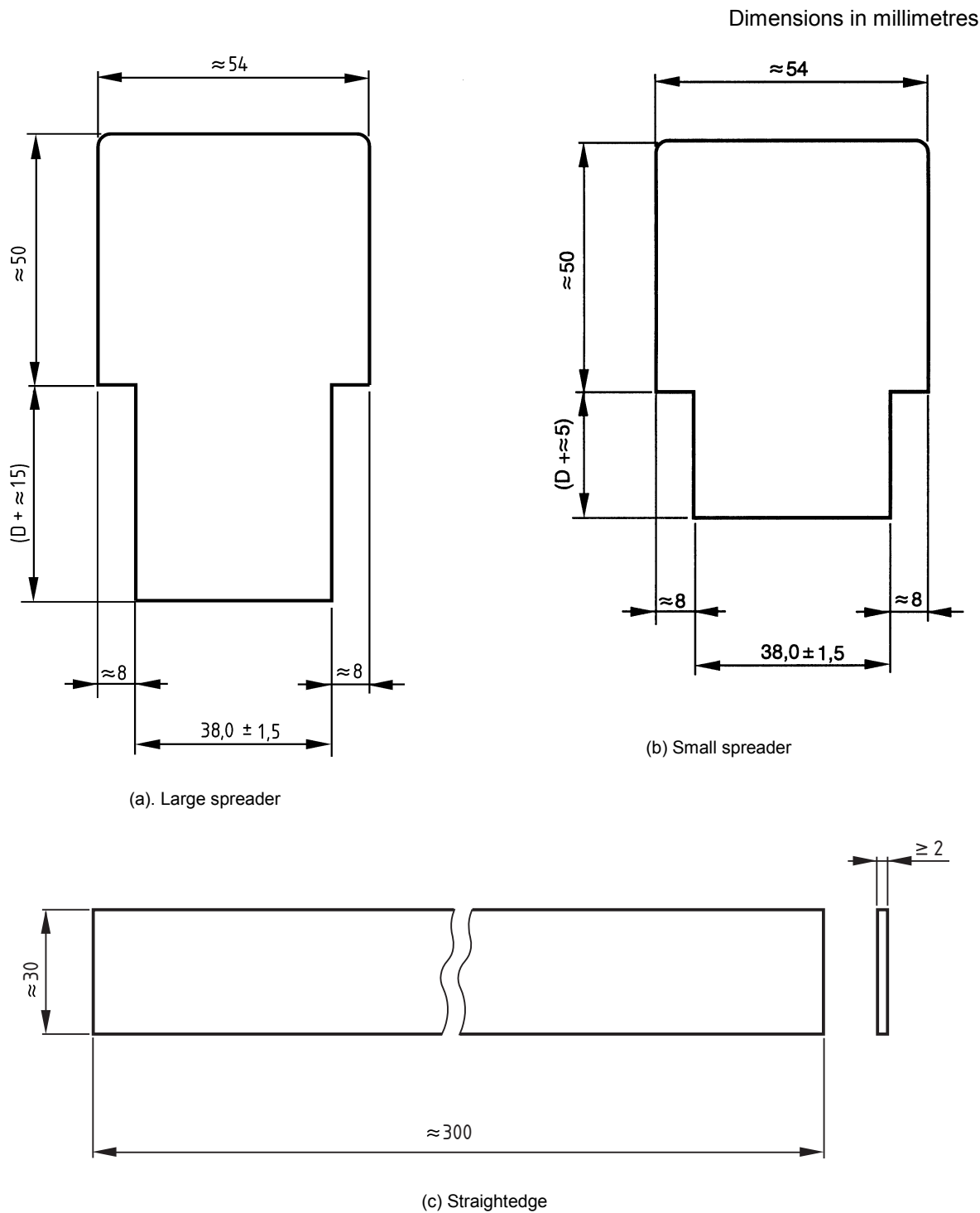
For spreading and striking off the mortar two spreaders and a metal straightedge of the type shown in Figure 3 shall be provided.

Dimensions in millimetres

**Key**

- 1 Striking off direction with sawing motion

**Figure 2 — Typical mould**



**Key**

D = Height of hopper

**Figure 3 — Typical spreaders and metal straightedge**

#### 4.6 Jolting apparatus

The jolting apparatus (a typical design is shown in Figure 4) shall conform to the following requirements.

The apparatus shall consist of a rectangular table rigidly connected by two light arms to a pivot at nominally 800 mm from the centre of the table. The table shall incorporate at the centre of its lower face a projecting lug with a rounded face. Beneath the projecting lug shall be a small stop with a plane upper surface. In the rest position, the common normal through the point of contact of the lug and the stop shall be vertical. When the lug rests on the stop, the top face of the table shall be horizontal so that the level of any of the four corners does not deviate from the mean level by more than 1,0 mm. The table shall have dimensions equal to or greater than those of the mould baseplate, and a plane machined upper surface. Clamps shall be provided for firm attachment of the mould to the table.

The combined mass of the table, including arms, empty mould, hopper and clamps shall be  $(20,0 \pm 0,5)$  kg.

The arms connecting the table assembly to the pivot shall be rigid and constructed of round tubing with an outside diameter lying in the range 17 mm to 22 mm selected from tube sizes given in ISO 4200. The total mass of the two arms, including any cross bracing, shall be  $(2,25 \pm 0,25)$  kg. The pivot bearings shall be of the ball or roller type and protected from ingress of grit or dust. The horizontal displacement of the centre of the table as caused by the play of the pivot shall not exceed 1,0 mm.

The lug and the stop shall be made of through-hardened steel of at least HV 500 Vickers hardness value. The curvature of the lug shall be about  $0,01 \text{ mm}^{-1}$ .

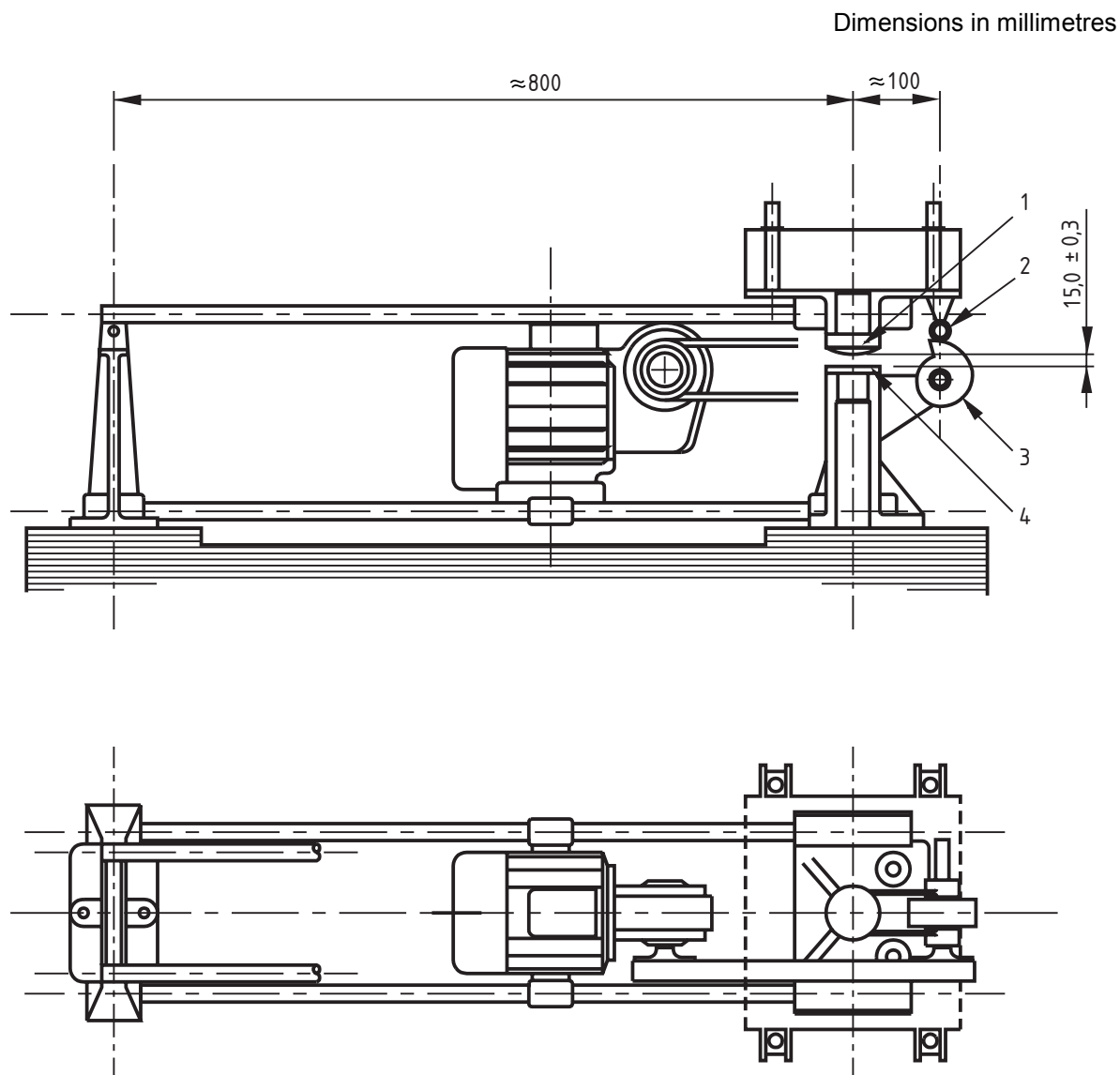
In operation, the table is raised by a cam and allowed to fall freely from a height of  $(15,0 \pm 0,3)$  mm before the lug strikes the stop.

The cam shall be made of through hardened steel of at least HV 400 Vickers hardness value and its shaft shall be mounted in ball bearings of such construction that the free fall is always  $(15,0 \pm 0,3)$  mm. The cam follower shall be of a construction which ensures minimal wear of the cam. The cam shall be driven by an electric motor of about 250 W through a reduction gear at a uniform speed of one revolution per second. A control mechanism and a counter shall be provided which ensures that one period of jolting of  $(60 \pm 3)$  s comprises exactly 60 jolts.

The position of the mould on the table shall be such that the longitudinal dimension of the compartments is in line with the direction of the arms and perpendicular to the axis of rotation of the cam. Suitable reference marks shall be provided to facilitate the positioning of the mould in such a way that the centre of the central compartment is directly above the point of impact.

The apparatus shall be firmly mounted on a concrete block of mass of about 600 kg and volume of about  $0,25 \text{ m}^3$  and of dimensions giving a suitable working height for the mould. The entire base of the concrete block shall stand on an elastic pad, e.g. natural rubber, having a suitable isolation efficiency preventing external vibrations from affecting the compaction.

The base of the apparatus shall be fixed level to the concrete base by anchor bolts and a thin layer of mortar shall be placed between the base of the apparatus and the concrete base to ensure overall and vibration free contact.



## Key

- 1 Lug
- 2 Cam follower
- 3 Cam
- 4 Stop

Figure 4 — Typical jolting apparatus

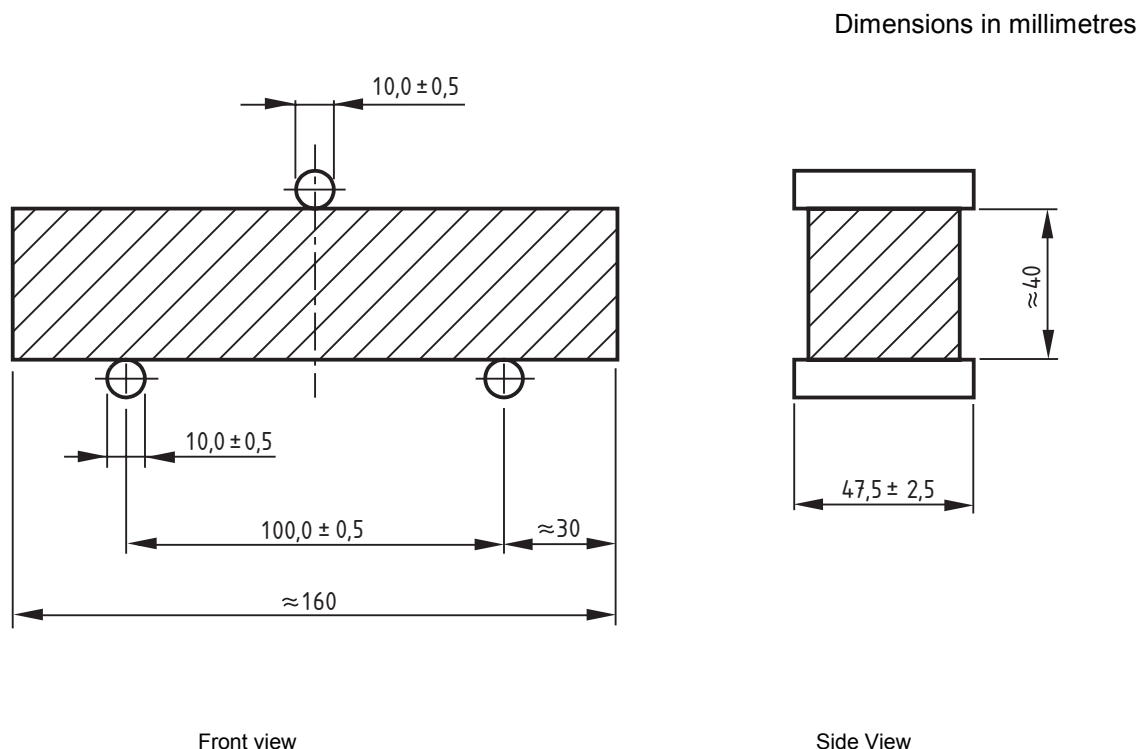
## 4.7 Flexural strength testing apparatus

NOTE The provision of this apparatus is optional. If only the compressive strength is to be measured, prisms may be broken using other suitable means which do not subject the prism halves to harmful stresses.

The flexural strength can be measured by using a flexural strength testing machine or by using a suitable device in a compression testing machine. In either case the apparatus shall conform to the following requirements:

The apparatus for the determination of flexural strength shall be capable of applying loads up to 10 kN with an accuracy of  $\pm 1,0$  % of the recorded load in the upper four-fifths of the range being used, at a rate of loading of  $(50 \pm 10)$  N/s.

The apparatus shall be provided with a flexure device incorporating two steel supporting rollers of  $(10,0 \pm 0,5)$  mm diameter spaced  $(100,0 \pm 0,5)$  mm apart and a third steel loading roller of the same diameter placed centrally between the other two. The length of these rollers shall be between 45 mm and 50 mm. The loading arrangement is shown in Figure 5.



**Figure 5 — Arrangement of loading for determination of flexural strength**

The three vertical planes through the axes of the three rollers shall be parallel and remain parallel, equidistant and normal to the direction of the specimen under test. One of the supporting rollers and the loading roller shall be capable of tilting slightly to allow a uniform distribution of the load over the width of the specimen without subjecting it to any torsional stresses.

#### 4.8 Compressive strength testing machine

The testing machine for the determination of compressive strength shall be of suitable capacity for the test (see Note 1): it shall have an accuracy of  $\pm 1,0$  % of the recorded load in the upper four-fifths of the range being used when verified in accordance with EN ISO 7500-1. It shall provide a rate of load increase of  $(2\,400 \pm 200)$  N/s. It shall be fitted with an indicating device which shall be so constructed that the value indicated at failure of the specimen remains indicated after the testing machine is unloaded. This can be achieved by the use of a maximum indicator on a pressure gauge or a memory on a digital display. Manually operated testing machines shall be fitted with a pacing device to facilitate the control of the load increase.

The vertical axis of the ram shall coincide with the vertical axis of the machine and during loading the direction of movement of the ram shall be along the vertical axis of the machine. Furthermore, the



resultant of the forces shall pass through the centre of the specimen. The surface of the lower machine platen shall be normal to the axis of the machine and remain normal during loading.

The centre of the upper platen spherical seating shall be at the point of intersection of the vertical machine axis with the plane of the lower surface of the upper machine platen with a tolerance of  $\pm 1$  mm. The upper platen shall be free to align as contact is made with the specimen, but during loading the relative attitude of the upper and lower platens shall remain fixed.

The testing machine shall be provided with platens made of tungsten carbide, or alternatively through hardened steel with a Vickers hardness of at least HV 600. These platens shall be at least 10 mm thick,  $(40,0 \pm 0,1)$  mm wide and  $(40,0 \pm 0,1)$  mm long. The flatness tolerance according to ISO 1101, over the entire contact surface with the specimen shall be not greater than 0,01 mm. The surface texture according to ISO 1302 shall be not smoother than N3 and not rougher than N6, as supplied.

Alternatively, two auxiliary plates of tungsten carbide, or through hardened steel with a Vickers hardness of at least HV 600 and at least 10 mm thick and conforming to the requirements for the platens may be provided. Provision should be made for centring the auxiliary plates with respect to the axis of the loading system with an accuracy of  $\pm 0,5$  mm. Provision should be made for aligning the auxiliary plates with a tolerance not greater than  $\pm 0,5$  mm from the centre of each other.

Where there is no spherical seating in the testing machine or where the spherical seating is blocked, or where the diameter of the spherical seating is greater than 120 mm, a jig conforming to 4.9 shall be used.

NOTE 1 The testing machine may be provided with two or more load ranges. The highest value of the lower range should be approximately 1/5 of the highest value of the next higher range.

NOTE 2 The machine should be provided with an automatic method for adjusting the rate of loading and with equipment for recording the results.

NOTE 3 The spherical seating of the machine may be lubricated to facilitate adjustment on contact with the specimen but only to such an extent that movement of the platen cannot take place under load during the test. Lubricants which are effective under high pressure are not suitable.

NOTE 4 The terms 'vertical', 'lower' and 'upper' refer to conventional testing machines which are normally aligned in the vertical axis. However, machines whose axis is not vertical are also permitted.

#### 4.9 Jig for compressive strength testing machine

When 4.8 requires the use of a jig (see Figure 6) it shall be placed between the platens of the machine to transmit the load of the machine to the compression surfaces of the mortar specimen.

A lower plate shall be used in this jig and it can be incorporated in the lower platen. The upper platen receives the load from the upper platen of the machine through an intermediate spherical seating. This seating forms part of an assembly which shall be able to slide vertically without appreciable friction in the jig guiding its movement. The jig shall be kept clean and the spherical seating shall be free to move in such a way that the platen will accommodate itself initially to the shape of the specimen and then remain fixed during the test. All requirements stated in 4.8 apply equally when a jig is used.

NOTE 1 The spherical seating of the jig may be lubricated but only to such an extent that movement of the platen cannot take place under load during the test. Lubricants which are effective under high pressure are not suitable.

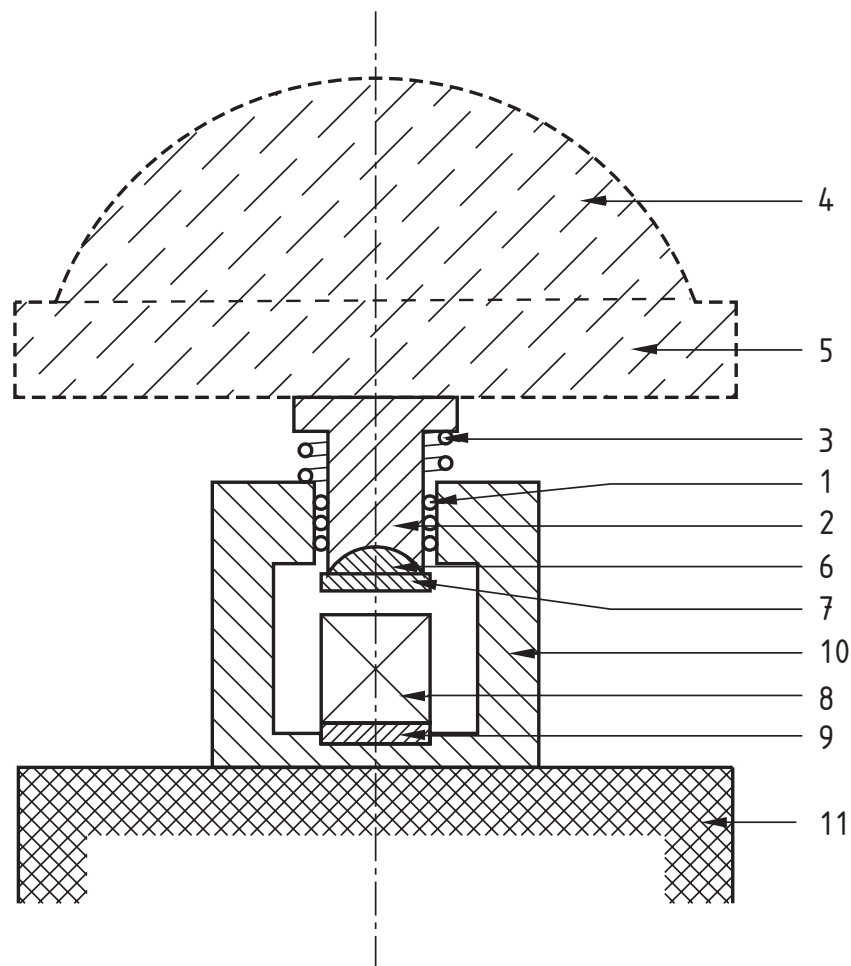
NOTE 2 It is desirable that the assembly should return automatically to its initial position after crushing the specimen.

#### 4.10 Balance

Balance, capable of weighing to an accuracy of  $\pm 1$  g.

#### 4.11 Timer

Timer, capable of measuring to an accuracy of  $\pm 1$  s.



#### Key

- 1 Ball bearings
- 2 Sliding assembly
- 3 Return spring
- 4 Spherical seating of machine
- 5 Upper platen of machine
- 6 Spherical seating of the jig
- 7 Upper platen of the jig
- 8 Specimen
- 9 Lower platen of the jig
- 10 Jig
- 11 Lower platen of the machine

**Figure 6 — Typical jig for compressive strength testing**

## 5 Mortar constituents

### 5.1 Sand

#### 5.1.1 General

CEN Standard sands, which are produced in various countries, shall be used to determine the strength of cement in accordance with this document. 'CEN Standard sand, EN 196-1' shall conform to the requirements stated in 5.1.3. Producers of CEN Standard sand shall apply verification testing which shall be inspected under the authority of a certification body.

In view of the difficulties of characterising CEN Standard sands completely they shall be validated against the CEN Reference sand described in 5.1.2 by means of certification and verification testing, as described in Clause 11.

#### 5.1.2 CEN Reference sand

The CEN Reference sand, of which a limited stockpile is maintained as reference material, is a natural, siliceous sand consisting of rounded particles and has a silica content of at least 98 %.

Its particle size distribution lies within the limits given in Table 3.

**Table 3 — Particle size distribution of the CEN Reference sand**

<b>Square mesh size (mm)</b>	2,00	1,60	1,00	0,50	0,16	0,08
<b>Cumulative sieve residue (%)</b>	0	7 ± 5	33 ± 5	67 ± 5	87 ± 5	99 ± 1

NOTE Information on the CEN Reference sand may be obtained from Normensand GmbH, D-59269 Beckum, Germany.

#### 5.1.3 CEN Standard sand

CEN Standard sand shall comply with the particle size distribution specified in 5.1.2 as determined by sieve analysis on a representative sample of sand of total mass not less than 1 345 g. Sieving shall be continued until the amount of sand passing through each sieve is less than 0,5 g/min.

The moisture content shall be less than 0,2 % determined as the loss of mass of a representative sample of sand after drying at 105 °C to 110 °C to constant mass and expressed as a percentage by mass of the dried sample.

During production these determinations shall be carried out at least once a day. These requirements are insufficient to ensure that the CEN Standard sand gives equivalent performance to the CEN Reference sand. Such equivalence shall be initiated and maintained by the validation testing described in Clause 11.

CEN Standard sand shall be pre-packed in bags with a content of (1 350 ± 5) g; the type of material used for the bags shall have no effect on the results of the strength testing and the contents of each bag shall comply with the particle size distribution specified in 5.1.2.

NOTE CEN Standard sand should be carefully stored to prevent damage or contamination, particularly with moisture, prior to use.

## 5.2 Cement

The cement to be tested shall be exposed to ambient air for the minimum time possible. When it is to be kept for more than 24 h between sampling and testing, it shall be stored in completely filled and airtight containers made from a material which does not react with cement.

The laboratory sample shall be homogenised, by machine or other means as described in EN 196-7, before taking sub-samples for testing.

## 5.3 Water

Distilled, or deionised, water shall be used for validation testing. For other tests, drinking water may be used. In the case of dispute distilled or deionised water shall be used.

# 6 Preparation of mortar

## 6.1 Composition of mortar

The proportions by mass shall be one part of the cement (5.2), three parts of CEN Standard sand (5.1), and one half part of water (5.3) (water/cement ratio 0,50).

Each batch for three test specimens shall consist of  $(450 \pm 2)$  g of cement,  $(1\,350 \pm 5)$  g of sand and  $(225 \pm 1)$  g of water.

## 6.2 Mixing of mortar

Weigh the cement and water by means of the balance (4.10). When water is added by volume it shall be dispensed with an accuracy of  $\pm 1$  ml. Mix each batch of mortar mechanically using the mixer (4.4). The timing of the various mixing stages refers to the times at which mixer power is switched on/off and shall be maintained within  $\pm 2$  s.

The mixing procedure shall be as follows:

- a) place the water and the cement into the bowl, taking care to avoid loss of water or cement;
- b) immediately the water and cement are brought into contact start the mixer at the low speed (see Table 2) whilst starting the timing of the mixing stages. In addition, record the time to the nearest minute, as 'zero time'. After 30 s of mixing, add the sand steadily during the next 30 s. Switch the mixer to the high speed (see Table 2) and continue the mixing for an additional 30 s;

NOTE 1 'Zero time' is the point from which the times for demoulding specimens (see 8.2) and for determining strength (see 8.4) are calculated.

- c) stop the mixer for 90 s. During the first 30 s, remove by means of a rubber or plastics scraper the mortar adhering to the wall and bottom part of the bowl and place in the middle of the bowl;
- d) continue the mixing at the high speed for 60 s.

NOTE 2 Normally these mixing operations are carried out automatically. Manual control of these operations and timings may be used.

## 7 Preparation of test specimens

### 7.1 Size of specimens

The test specimens shall be 40 mm × 40 mm × 160 mm prisms.

### 7.2 Moulding of test specimens

Mould the specimens immediately after the preparation of the mortar. With the mould and hopper firmly clamped to the jolting table, introduce, using a suitable scoop, in one or more increments, the first of two layers of mortar (each about 300 g) into each of the mould compartments, directly from the mixing bowl.

Spread the layer uniformly using the large spreader (see Figure 3), held almost vertically with its shoulders in contact with the top of the hopper and drawn forwards and backwards once along each mould compartment. Then compact the first mortar layer using 60 jolts of the jolting apparatus (4.6). Introduce the second layer of mortar, ensuring that there is a surplus of mortar, level with the small spreader (see Figure 3) and compact the layer with a further 60 jolts.

Lift the mould gently from the jolting table and remove the hopper. Immediately strike off the excess mortar with the metal straightedge (see Figure 3), held almost vertically but inclined in the direction of striking. Move slowly pulling with a transverse sawing motion once in each direction. Repeat this striking off procedure with the straightedge held at a more acute angle to smooth the surface.

**NOTE** The number of sawing motions and the angle of the straightedge will depend on the consistency of the mortar; stiffer mortars will require more sawing motions and a more acute angle; a smaller number of transverse sawing motions are required for smoothing than for striking off (see Figure 2).

Wipe off the mortar left on the perimeter of the mould as a result of the striking-off.

Label or mark the moulds for identification purposes.

## 8 Conditioning of test specimens

### 8.1 Handling and storage before demoulding

Place a plate of glass, steel or other impermeable material which does not react with cement of approximate size 210 mm × 185 mm × 6 mm on the mould.

**NOTE** In the interest of safety, ensure that any glass plates used have ground edges.

Place each covered mould, without delay, on a horizontal base in the moist air room or cabinet (see 4.1). The moist air shall have access to all sides of the mould. Moulds shall not be stacked one upon the other. Each mould shall be removed from storage at its appropriate time for demoulding.

### 8.2 Demoulding of specimens

Carry out demoulding taking care not to damage specimens. Plastics or rubber hammers, or devices specially made, can be used for demoulding. Carry out demoulding, for 24 h tests, not more than 20 min before the specimens are tested. Carry out demoulding, for tests at ages greater than 24 h, between 20 h and 24 h after moulding.

**NOTE 1** Demoulding may be delayed by 24 h if the mortar has not acquired sufficient strength at 24 h to be handled without risk of damage. Any delay in demoulding should be recorded in the test report.

Keep the demoulded specimens selected for testing at 24 h (or at 48 h when delayed demoulding was necessary) covered by a damp cloth until tested. Suitably mark specimens selected for curing in water for identification later, e.g. by water-resistant ink or crayon.

NOTE 2 As a check on the mixing and compacting operations and air content of the mortar, it is recommended that the specimens from each mould be weighed.

### 8.3 Curing of specimens in water

Submerge the marked specimens without delay in a convenient manner, either horizontally or vertically, in water at  $(20,0 \pm 1,0) ^\circ\text{C}$  in the containers. With horizontal storage, keep vertical faces as cast vertical.

Place the specimens on the gratings (see 4.1) and keep them apart from each other so that the water has free access to all six faces of the specimens. At no time during storage shall the spaces between the specimens or the depth of water above the upper faces of the specimens be less than 5 mm.

Unless it has been established that the composition of the cement to be tested does not influence the strength development of other cements under test, separate storage shall be provided; cements known to contain more than 0,1 % chloride ion shall be stored separately.

Use tap water for initial filling of the containers and for occasional topping up to maintain a reasonably constant level. During storage of the specimens, not more than 50 % of the water shall be replaced at any one time.

The installation shall ensure uniform storage temperature; if a system of circulation within the storage container is used the flow rate shall be as low as possible and not cause visible turbulence.

Remove the specimens required for testing at any particular age (other than 24 h, or 48 h in cases of delayed demoulding) from the water not more than 15 min before the test is carried out. Remove any deposit on the test faces. Cover the specimens with a damp cloth until tested.

### 8.4 Age of specimens for strength tests

Calculate the age of specimens as that from zero time (see 6.2). Carry out strength tests at the different ages within the following limits:

24 h  $\pm$  15 min

48 h  $\pm$  30 min

72 h  $\pm$  45 min

7 d  $\pm$  2 h

$\geq$  28 d  $\pm$  8 h.

## 9 Testing procedures

### 9.1 Flexural strength

Use the three-point loading method with one of the types of apparatus described in 4.7.

Place the prism in the apparatus (4.7) with one side face on the supporting rollers and with its longitudinal axis normal to the supports. Apply the load vertically by means of the loading roller to the opposite side face of the prism and increase it smoothly at the rate of  $(50 \pm 10)$  N/s until fracture.

Keep the prism halves covered with a damp cloth until tested in compression.

Calculate the flexural strength,  $R_f$ , in megapascals from:

$$R_f = \frac{1,5 \times F_f \times l}{b^3} \quad (1)$$

where

$R_f$  is the flexural strength, in megapascals;

$b$  is the side of the square section of the prism, in millimetres;

$F_f$  is the load applied to the middle of the prism at fracture, in newtons;

$l$  is the distance between the supports, in millimetres.

## 9.2 Compressive strength

Carry out the test on halves of the prism broken either as described in 9.1 or by using suitable means which do not subject the prism halves to harmful stresses.

Test each prism half by loading its side faces using the equipment described in 4.8 and 4.9.

Centre the prism halves laterally to the platens of the machine within  $\pm 0,5$  mm, and longitudinally such that the end face of the prism overhangs the platens or auxiliary plates by about 10 mm.

Increase the load smoothly at the rate of  $(2\,400 \pm 200)$  N/s over the entire load application until fracture.

Where the load increase is regulated by hand, care should be taken when making adjustment for the decrease of the loading rate near the fracture load as this can significantly affect the result.

Calculate the compressive strength  $R_c$  in megapascals from:

$$R_c = \frac{F_c}{1600} \quad (2)$$

where

$R_c$  is the compressive strength, in megapascals;

$F_c$  is the maximum load at fracture, in newtons;

1 600 is the area of the platens or auxiliary plates (40 mm  $\times$  40 mm), in square millimetres.

## 10 Results

### 10.1 Flexural strength

#### 10.1.1 Calculation and expression of test results

Calculate the flexural strength test result as the arithmetic mean of the three individual results, each expressed at least to the nearest 0,1 MPa, obtained from a determination made on a set of three prisms.

Express the arithmetic mean to the nearest 0,1 MPa.

#### **10.1.2 Reporting of results**

Record all individual results. Report the calculated mean.

### **10.2 Compressive strength**

#### **10.2.1 Calculation and expression of test results**

Calculate the compressive strength test result as the arithmetic mean of the six individual results, each expressed at least to the nearest 0,1 MPa, obtained from the six determinations made on a set of three prisms.

If one result within the six individual results varies by more than  $\pm 10\%$  from the mean, discard this result and calculate the arithmetic mean of the five remaining results. If one result within the five remaining results varies by more than  $\pm 10\%$  from their mean, discard the set of results and repeat the determination.

Express the arithmetic mean to the nearest 0,1 MPa.

#### **10.2.2 Reporting of results**

Record all individual results. Report the calculated mean and whether any result has been discarded in accordance with 10.2.1.

#### **10.2.3 Estimates of the precision of the method for compressive strength**

##### **10.2.3.1 Short-term repeatability**

Short-term repeatability of the method for compressive strength testing gives the closeness of agreement between test results obtained on nominally identical samples of cement, using the same CEN Standard sand, tested in the same laboratory by the same operator using the same equipment within short intervals of time.

In the case of 28 day compressive strength, the short-term repeatability for “normal performance” achievable under the above conditions, should be less than 2,0 % when expressed as the coefficient of variation.

**NOTE** Experience has indicated that better performance is achievable and can be routinely met in some laboratories. It corresponds to a value of 1 % for short-term repeatability, when expressed as the coefficient of variation.

Short-term repeatability is a measure of the precision of the test method when used for validation testing of CEN Standard sand and alternative compaction equipment.

##### **10.2.3.2 Long-term repeatability**

Long-term repeatability of the method for compressive strength testing, gives the closeness of agreement between test results obtained from frequent testing of different samples taken from the same homogenised sample of cement, tested in the same laboratory, under the following conditions: possibly different operators, possibly different equipment, same CEN Standard sand and over long time periods (up to one year).

In the case of 28 day compressive strength, the long-term repeatability for “normal performance” achievable under the above conditions, should be less than 3,5 % when expressed as the coefficient of variation.



NOTE Experience has indicated that better performance is achievable and can be routinely met in some laboratories. It corresponds to a value of 2,5 % for long term repeatability, when expressed as the coefficient of variation.

Long-term repeatability is a measure of the precision of the test method when used for the autocontrol testing of cement or the monthly verification testing of CEN Standard sand and for assessing the maintenance of the laboratory's precision over time.

### 10.2.3.3 Reproducibility

Reproducibility of the method for compressive strength testing gives the closeness of agreement between test results obtained on nominally identical samples of cement tested in different laboratories under the following conditions: different operators, different equipment, possibly different CEN Standard sands and possibly at different times.

In the case of 28 d compressive strength, the reproducibility, between laboratories achieving "normal performance" under the above conditions, should be less than 4,0 % when expressed as the coefficient of variation.

NOTE Experience has indicated that better performance is achievable and can be routinely met in some laboratories. It corresponds to a value of 3 % for reproducibility, when expressed as the coefficient of variation.

Reproducibility is a measure of the precision of the test method when used for evaluation of conformity of cement or CEN Standard sand.

## 11 Validation testing of CEN Standard sand and of alternative compaction equipment

### 11.1 General

A CEN Standard sand complying with 5.1.3 or an alternative compaction equipment may be used, according to Clause 3, provided that they have been shown to give cement strength results which do not differ significantly from those obtained using the CEN Reference sand (5.1.2) or the reference jolting apparatus (4.6) and procedure, respectively.

This clause describes the conditions under which CEN Standard sands and alternative compaction equipment can be validated. Validation shall be provided by a certification body and shall be based on the results of tests carried out by a testing laboratory appointed by the certification body.

NOTE Appointed testing laboratories should participate in proficiency testing programmes to ensure that validation testing is against comparable testing levels.

The test methods which are described and shall be applied are based on comparisons of compressive strength test results at the age of 28 d.

### 11.2 Validation testing of CEN Standard sand

#### 11.2.1 Principle

Validation testing of CEN Standard sand comprises:

- a) certification testing carried out under the authority of a certification body;
- b) verification testing carried out by the producer of sand.

Certification testing of CEN Standard sand is described in 11.2.2. It includes an initial certification testing (11.2.2.1) and an annual confirmation testing (11.2.2.2). Provided that the requirements in

11.2.3.3 are met, the certification body shall issue a certificate of conformity with this document after the initial certification testing, and a renewal of certificate after the annual confirmation testing.

Verification testing of CEN Standard sand is described in 11.2.4. Based on autocontrol testing by the producer of sand and provided that the requirements in 11.2.5.3 are met, it ensures that a certified CEN Standard sand remains in conformity with this document. Autocontrol test results are inspected by the certification body within the framework of the annual confirmation testing.

A validated sand shall be designated "CEN Standard sand, EN 196-1".

## **11.2.2 Certification testing of CEN Standard sand**

### **11.2.2.1 Initial certification testing**

A producer of sand shall demonstrate that the producing plant is operating prior to an application to the certification body for the initial certification testing of the sand.

During a production period of at least three months, three independent samples of the sand shall be taken at the point of release under the authority of the certification body. The number of bags to be taken in each of the three samples shall be calculated in order to provide the sufficient amount of sand required by the method of certification testing according to 11.2.3.1. In addition the size of one of the three samples shall be sufficiently large to provide the amount of sand required by the method of verification testing according to 11.2.5.1 for a period of at least one year. For that purpose, this sample shall be divided under the authority of the certification body and the sub-sample to be used for verification testing, kept by the producer of the sand.

Each of the three samples shall be tested against the CEN Reference sand, applying the method described in 11.2.3, using a different one of three cements of different standard strength classes, selected under the authority of the certification body. Tests shall be carried out in an appointed testing laboratory (see 11.1).

Where each of the results obtained from the three samples, expressed according to 11.2.3.2, fulfil the requirements in 11.2.3.3, the sand shall be validated and the certification body shall issue a certificate of conformity (see 11.2.1).

### **11.2.2.2 Annual confirmation testing**

The renewal of the certificate granted to a producer of sand shall result from the following actions of the certification body:

- a) inspection of records of verification testing carried out by the producer of sand in accordance with 11.2.4 and, provided that the requirements in 5.1.3 and 11.2.5.3 are met,
- b) test by the appointed testing laboratory (see 11.1) of a random sample of sand against the CEN Reference sand, applying the method described in 11.2.3, using a CEM I 42,5N, 42,5R or 52,5N cement conforming to EN 197-1, selected under the authority of the certification body.

The random sample of sand shall be taken at the point of release under the authority of the certification body. The number of bags to be taken shall be calculated in order to provide the sufficient amount of sand required by the method of certification testing according to 11.2.3.1 and by the method of verification testing according to 11.2.5.1 for a period of at least one year. For that purpose the sample shall be divided under the authority of the certification body and the sub-sample to be used for verification testing kept by the producer of sand.

Where the results of the verification testing, a) fulfil the requirements in 5.1.3 and 11.2.5.3 and of, those of the certification testing, and b) fulfil the requirements in 11.2.3.3, the sand shall be validated and the certification body shall issue a renewal of certificate of conformity (see 11.2.1).

### 11.2.3 Method of certification testing

#### 11.2.3.1 Procedure

Prepare 20 pairs of batches of mortar using a sample of the selected cement (see 11.2.2.1 and 11.2.2.2). Use the sand to be validated for one batch and the CEN Reference sand for the other. Prepare the two batches in each pair in a randomised order, one immediately after the other, in accordance with this document.

Test the prisms for compressive strength at 28 d and record all individual results.

#### 11.2.3.2 Calculation and expression of results

For each pair of batches, calculate and express the compressive strength results in accordance with 10.2.1 and report them in accordance with 10.2.2, as  $x$  for the result obtained with the sand to be validated and  $y$  for the result obtained with the CEN Reference sand.

Calculate the coefficient of variation for each of the two sets of results and check that they meet the requirement for short-term repeatability in 10.2.3.1.

If the two sets of results do not fulfil this requirement, discard all results and repeat the whole testing procedure.

If one set of results does not meet this requirement, proceed as follows:

- a) calculate the mean value of the 20 results,  $\bar{x}$  or  $\bar{y}$ ;
- b) calculate the standard deviation of the 20 results,  $s$ ;
- c) calculate the arithmetic difference between each result and the mean value, ignoring the sign;
- d) where one of these differences is greater than  $3s$ , discard the corresponding result and calculate the mean value of the remaining 19 results; where two or more of these differences are greater than  $3s$ , discard all results and repeat the whole testing procedure; where no difference is greater than  $3s$ , keep the 20 results.

Calculate the validation criterion,  $D$ , using the formula:

$$D = 100 \frac{(\bar{x} - \bar{y})}{\bar{y}} \quad (3)$$

where

$D$  is the validation criterion, in percent;

$\bar{x}$  is the mean value of the results obtained with the sand to be validated, in megapascals;

$\bar{y}$  is the mean value of the results obtained with the CEN reference sand, in megapascals.

Report ( $D$ ) to the nearest 0,1 %, ignoring sign.

#### 11.2.3.3 Requirements

For a sand to be validated in accordance with the initial certification testing procedure (see 11.2.2.1), each of the three values of the validation criterion,  $D$ , calculated and expressed in accordance with

11.2.3.2, shall be less than 5,0 %. Where one or more of the calculated values of  $D$  is equal to or greater than 5,0 %, the sand shall not be validated.

For a CEN Standard sand to be validated in accordance with the annual confirmation testing procedure (11.2.2.2), the value of the validation criterion,  $D$ , calculated and expressed in accordance with 11.2.3.2 shall be less than 5,0 %. Where the calculated value of  $D$  is equal to or greater than 5,0 %, the CEN Standard sand shall not be validated, the reason shall be identified and the initial certification testing procedure (11.2.2.1) shall be carried out for a further validation.

#### 11.2.4 Verification testing of CEN Standard sand

In order to demonstrate that a CEN Standard sand remains in conformity with this document, the producer of the sand shall carry out a continuous autocontrol testing which shall comprise:

- a) daily testing of particle size distribution and moisture content in accordance with 5.1.3;
- b) monthly testing in accordance with 11.2.5 of a sample of the CEN Standard sand produced against a sample of the same CEN Standard sand taken under the authority of the certification body (see 11.2.2.1 and 11.2.2.2).

For that purpose, samples shall be taken by the producer of sand at the point of release, once per day for daily testing and once per month for monthly testing.

The producer of sand shall check that requirements in 5.1.3 and 11.2.5.3 are met and shall inform the certification body of any non-conforming result.

All results shall be recorded, made available to the certification body for inspection and kept for at least three years.

#### 11.2.5 Method of verification testing of CEN Standard sand

##### 11.2.5.1 Procedure

Prepare 10 pairs of batches of mortar using a sample of the cement selected under the authority of the certification body for the test by the appointed testing laboratory (11.2.2.2 b)). Use the sample taken once per month by the producer (11.2.4) for one batch and the sample taken once per year under the authority of the certification body (11.2.2.1 and 11.2.2.2) for the other. Prepare the two batches in each pair in a randomised order, one immediately after the other, in accordance with this document.

Test the prisms for compressive strength at 28 d and record all individual results.

##### 11.2.5.2 Calculation and expression of results

For each pair of batches, calculate and express the compressive strength results in accordance with 10.2.1 and report them in accordance with 10.2.2, as  $x$  for the result obtained with the sample taken by the producer and  $y$  for the result obtained with the sample taken under the authority of the certification body.

Calculate the coefficient of variation for each of the two sets of results and apply the procedure in 11.2.3.2 adapted to 10 pairs of batches.

**NOTE** Where one set of results fails to meet the requirements for short-term repeatability, the procedure set out in 11.2.3.2 is carried out based on sets of 10 results reducing to a minimum of 9 results for the purpose of assessment based on 11.2.3.2 d).

Calculate and report the validation criterion,  $D$ , as described in 11.2.3.2.

### 11.2.5.3 Requirements

Within a series of 12 successive monthly tests, the validation criterion,  $D$ , calculated and expressed in accordance with 11.2.5.2 shall not exceed 2,5 % more than twice. If more than two values of  $D$  are greater than 2,5 %, the certification body shall be informed, the reason shall be identified and the initial certification testing procedure (11.2.2.1) shall be carried out for further validation.

## 11.3 Validation testing of alternative compaction equipment

### 11.3.1 General requirements

Where validation testing of alternative compaction equipment is requested, a certification body shall be supplied with the following documents:

- a) full description of the compaction procedure;
- b) full description of the compaction equipment (design and construction);
- c) instructions for servicing, including the checks to ensure correct operation.

The certification body shall select three commercially available sets of the equipment to be validated. The three sets of equipment shall be tested against a reference jolting apparatus conforming to the requirements in 4.6. For that purpose, they shall be placed in a testing laboratory appointed by the certification body.

Under the authority of the certification body, the testing laboratory shall compare the characteristics of the equipment to be validated with the description supplied. Where the correspondence of one with the other is verified, the appointed testing laboratory shall carry out three comparative tests in accordance with 11.3.2 using for each set of the equipment to be validated a different cement. For that purpose three cements of different strength classes shall be selected under the authority of the certification body.

Where the results of each of the three comparative tests fulfil the requirements in 11.3.2.3, the certification body shall validate the alternative compaction equipment.

Following the validation, the technical description of the equipment and the description of the compaction procedure shall be deemed to be a validated alternative to 4.6 and 7.2 respectively.

NOTE The technical description of alternative equipment and description of alternative compaction procedures which have been validated are included in Annex A (normative) to this document.

### 11.3.2 Method of testing of alternative compaction equipment

#### 11.3.2.1 Procedure

Prepare 20 batches of mortar using one of the selected cements (see 11.3.1) and the CEN Reference sand. Prepare the two batches in each pair in a randomised order, one immediately after the other, in accordance with this document.

Compact the specimens using one set of the alternative equipment for one batch and the reference jolting apparatus (4.6) for the other.

After compaction, proceed in accordance with this document.

Test the prisms for compressive strength at 28 d and record all individual results.

**11.3.2.2 Calculation and expression of results**

For each pair of batches, calculate and express the compressive strength results in accordance with 10.2.1 and report them in accordance with 10.2.2, as  $x$  for the result obtained with the set of alternative compaction equipment to be validated and  $y$  for the result obtained with the reference jolting apparatus.

Calculate the coefficient of variation for each of the two sets of results and check that they meet the requirement for short-term repeatability in 10.2.3.1.

If the two sets of results do not fulfil this requirement, discard all results and repeat the whole testing procedure.

If one set of results does not meet this requirement, proceed as follows:

- a) calculate the mean value of the 20 results,  $\bar{x}$  or  $\bar{y}$ ;
- b) calculate the standard deviation of the 20 results,  $s$ ;
- c) calculate the arithmetic difference between each result and the mean value, ignoring the sign;

where one of these differences is greater than  $3s$ , discard the corresponding result and calculate the mean value of the 19 remaining results; where two or more of these differences are greater than  $3s$ , discard all results and repeat the whole testing procedure; where no difference is greater than  $3s$ , keep the 20 results.

Calculate the validation criterion ( $D$ ) using the formula:

$$D = 100 \frac{(\bar{x} - \bar{y})}{y} \quad (4)$$

where

$D$  is the validation criterion, in percent;

$\bar{x}$  is the mean value of the results obtained with the alternative compaction equipment to be validated, in megapascals;

$\bar{y}$  is the mean value of the results obtained with the reference jolting apparatus, in megapascals.

Report ( $D$ ) to the nearest 0,1 %, ignoring sign.

**11.3.2.3 Requirements**

The three values of the validation criterion,  $D$ , calculated and expressed in accordance with 11.3.2.2, each one corresponding to one of the three selected cements and one of the three selected sets of the equipment to be validated, shall be less than 5,0 %. Where one or more of the calculated values of  $D$  is equal to or greater than 5,0 %, the alternative compaction equipment shall not be validated.

## Annex A (normative)

### Alternative vibration compaction equipment and procedures validated as equivalent to the reference jolting compaction equipment and procedure

#### A.1 General

The reference jolting apparatus is described in 4.6. However, Clause 1 allows alternative equipment and procedures to be used "...provided that they have been validated in accordance with the appropriate provisions in this document".

For the purposes of validation, a procedure is described in Clause 11 for validating alternatives to the reference procedure. Validation testing programs have been undertaken on the vibrating tables and compaction procedures, identified as A and B in A.2 and A.3. They are, therefore, examples of validated alternative compaction equipment.

In accordance with 11.3.1, each technical description (see A.2.1 and A.3.1) shall be deemed to be a validated alternative to 4.6 and each description of the compaction procedure (see A.2.2 and A.3.2) shall be deemed to be a validated alternative to 7.2.

#### A.2 Vibrating table, A

##### A.2.1 Technical description

Vibrating table A, which may be used as an alternative compaction equipment, comprises:

- a) Method of operation: electromagnetic vibrator with a nominally sinusoidal vibration
- b) Electrical supply:
  - 1) voltage : 230/240 V
  - 2) phase : single
  - 3) current : maximum 6,3 A
  - 4) frequency : nominal 50 Hz
- c) Vibrating mass (including empty mould, hopper and clamp but excluding the vibrator):
  - :  $(35,0 \pm 1,5)$  kg
- d) Operating peak-to-peak vertical amplitude :  $(0,75 \pm 0,05)$  mm,  
measured at the centre separating walls and the outer corners of the empty mould.

NOTE 1 The vibrating table is designed to produce uniaxial vertical vibrations only. The vertical amplitude of vibration is continuously displayed.

NOTE 2 Acceleration, measured at the centre separating walls and the outer corners of the empty mould may be an alternative characteristic for describing the operational vibration of the table. A value of  $(26,0 \pm 3,0)$  m/s<sup>2</sup> corresponds to the value given in A.2.1 d).

- e) Natural frequency of the vibrating mass : (53,00 ± 0,25) Hz
- f) Vibrating plate: plate with a ground finish to the working surface; minimum dimensions nominally 400 mm × 300 mm consisting of either:
- 1) a rigid single layer of stainless steel, with support ribs or,
  - 2) a rigid double layer of metal (minimum thickness 20 mm), the top layer, made of stainless steel with a minimum thickness of 2 mm, bonded permanently to the bottom layer by means of a frictional and interlocking connection.

NOTE 3 It is recommended that the centre of gravity of the vibrating mass (including clamps but excluding the empty mould and hopper), is marked on the working surface of the vibrating plate at the intersection of two orthogonal vertical axes.

- g) Adjustable fixing lugs: three adjustable fixing lugs which allow the filled mould to be located on the vibrating plate such that its centre of gravity coincides with the centre of gravity of the vibrating mass, as marked on the working surface of the vibrating plate.
- h) Clamp for moulds: fixing attachment suitable for moulds 40 mm × 40 mm × 160 mm, including the mounted hopper.
- i) Mass of vibrating table: greater than 100 kg

NOTE 4 In the case where the vibrating table is built into laboratory furniture, it is recommended that the electromagnetic vibrator is permanently fixed to a mass of concrete, of at least 200 kg, standing on vibration isolating material, in order to minimise transference of vibration to other equipment.

- j) Anti-vibration mounts: rubber springs located between the vibrating plate and the frame, with:
- 1) Shore hardness : 45
  - 2) spring rate : 145 MPa
  - 3) dimensions, diameter : 50 mm  
height : 45 mm
- k) Levelling of vibrating table: with the aid of the adjusting screws (see Figure A.1) attached to the lower surface, set up the vibrating table so that the working surface of the vibrating plate does not deviate from the horizontal by more than 1 mm/m.
- l) Automatic timer: timer, capable of being set at 120 s and of timing operations to an accuracy of ± 1 s.

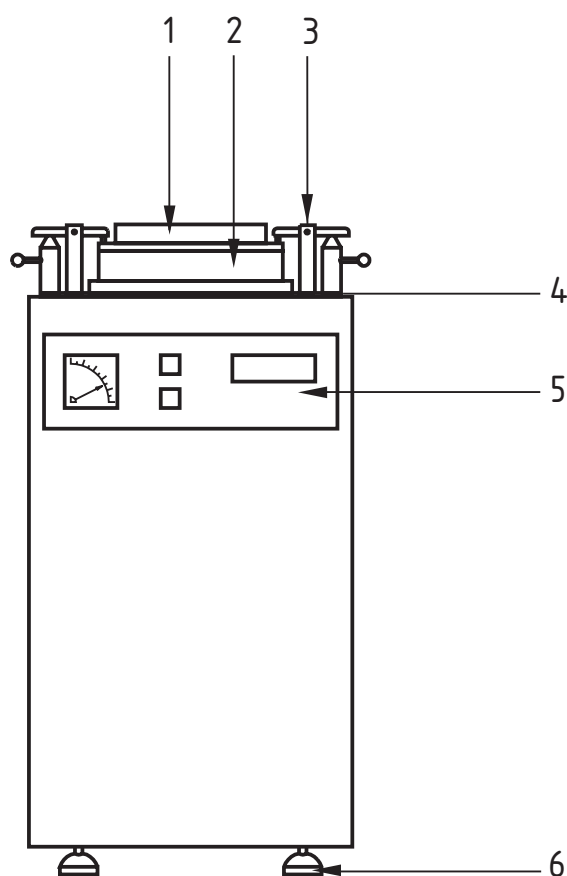
### A.2.2 Compaction procedure using vibrating table, A

Cast the specimens immediately after the preparation of the mortar.

Mount the mould with hopper firmly in the centre on the vibrating table. Set the automatic timer to switch off after a total of (120 ± 1) s. Switch on the vibrator. Fill the compartments of the mould with two layers of mortar within a maximum of 45 s, proceeding as follows.

Working from one end to the other, introduce the first layer of mortar, using a suitable scoop, into the compartments of the mould within 15 s so that the compartments are approximately half-full.





### Key

- |   |   |
|---|---|
| 1 | Hopper  |
| 2 | Mould   |
| 3 | Clamp   |
| 4 | Vibration plate   |
| 5 | Control panel with display of amplitude, amplitude setting, timer and main switch |
| 6 | Adjusting screws  |

**Figure A.1 — Schematic of typical vibrating table, type A**

After an interval of 15 s, introduce the second layer of mortar into the mould within a further 15 s, again working from one end to the other, in the same direction as the first layer was introduced. Use the total amount of mortar.

When the vibrator has switched off after a total of  $(120 \pm 1)$  s, lift the mould gently from the vibrating table and remove the hopper.

Follow the procedures for striking off, wiping and labelling of moulds described in 7.2.

### A.3 Vibrating table, B

#### A.3.1 Technical description

Vibrating table B, which may be used as an alternative compaction equipment, comprises:

- a) Method of operation: electromagnetic vibrator with a nominally sinusoidal vibration.
  - b) Electrical supply:
    - 1) voltage : 230/240 V
    - 2) phase : single
    - 3) current : approximately 6,3 A
    - 4) frequency : nominal 50 Hz
  - c) Vibrating mass (including empty mould and hopper but excluding the vibrator):
    - :  $(43,0 \pm 2,0)$  kg
  - d) Operating vertical acceleration:  $(4,50 \pm 0,25)$  g rms, measured at the base of the mould at the centre of the middle compartment.
- NOTE The maximum acceleration in any horizontal direction is 0,5 g rms.
- e) Natural frequency of the vibrating mass :  $(55,50 \pm 0,25)$  Hz
  - f) Vibrating plate:
    - plate, with a ground finish to the working surface; minimum dimensions nominally 630 mm  $\times$  250 mm consisting of:
      - 1) a rigid single layer of mild steel of finished thickness  $(13 \pm 2)$  mm.
      - 2) support ribs and drive plate.
  - g) Clamp for moulds:
    - swing clamps suitable for moulds
    - 40 mm  $\times$  40 mm  $\times$  160 mm, including the mounted hopper.
  - h) Levelling of vibrating table:
    - the vibrating table is permanently fixed to the floor and levelled so that the working surface of the vibrating plate does not deviate from the horizontal by more than 1 mm/m.
  - i) Automatic timer:
    - timer capable of being set at 120 s and of timing operations to an accuracy of  $\pm 1$  s.

#### A.3.2 Compaction procedure using vibrating table, B

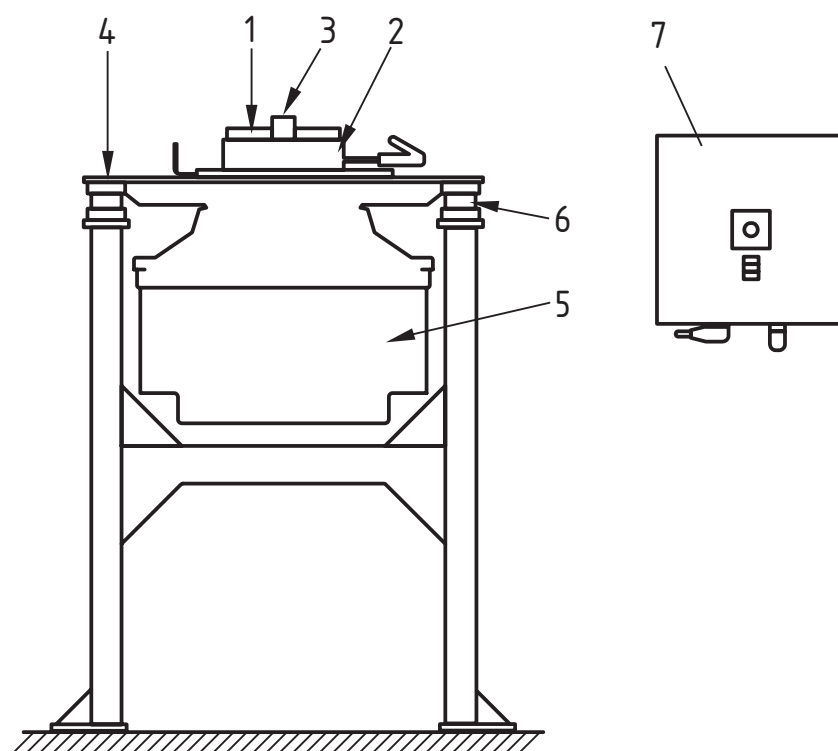
Set the vibrating table top horizontal and clean it. Prepare and assemble the mould in accordance with 4.5. Ensure that the lower surface of the mould base plate is flat and clean. Clamp the mould and filling hopper firmly to the vibrating table and set the acceleration of the vibrating table to be  $(4,50 \pm 0,25)$  g rms.

Mould the specimens immediately after the preparation of the mortar. When using the automatic timer, set it to switch off after a total of  $(120 \pm 1)$  s. Switch on the vibrator. Fill the compartments of the mould with mortar immediately, completing the operation within at most 45 s as follows.

Fill the compartments of the mould, using a suitable scoop, within 15 s, up to about half the depth. Without switching the vibrator off, and after a pause of 15 s, add the second layer within the next 15 s, in the same sequence. The mould should be just slightly overfilled. After a total period of  $(120 \pm 1)$  s, allow the vibrator to switch off automatically, or switch it off manually.

Lift the mould gently from the vibrating table and remove the hopper.

Follow the procedures for striking-off, wiping and labelling of moulds described in 7.2.



#### Key

- 1 Hopper
- 2 Mould
- 3 Swing bolt clamp
- 4 Vibrating plate
- 5 Electromagnetic vibrator
- 6 Anti-vibration mounts
- 7 Control panel

**Figure A.2 — Schematic of typical vibrating table, type B**

# 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](mailto: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](mailto: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](mailto: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

Copyright subsists in all BSI publications. BSI also holds the copyright, in the UK, of the publications of the international standardization bodies. Except as permitted under the Copyright, Designs and Patents Act 1988 no extract may be reproduced, stored in a retrieval system or transmitted in any form or by any means – electronic, photocopying, recording or otherwise – without prior written permission from BSI.

This does not preclude the free use, in the course of implementing the standard, of necessary details such as symbols, and size, type or grade designations. If these details are to be used for any other purpose than implementation then the prior written permission of BSI must be obtained.

Details and advice can be obtained from the Copyright & Licensing Manager.  
Tel: +44 (0)20 8996 7070. Fax: +44 (0)20 8996 7553.  
Email: [copyright@bsi-global.com](mailto:copyright@bsi-global.com).