

Methods of testing cement

Part 1. Determination of strength

The European Standard EN 196-1 : 1994 has the status of a
British Standard

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National foreword

This British Standard has been prepared under the direction of the Technical Committee B/516, Cement and lime. It is the English language version of EN 196-1 : 1994 *Methods of testing cement Part 1: Determination of strength* published by the European Committee for Standardization (CEN). EN 196-1 was drawn up by CEN Technical Committee 51, Cement and building limes, as Part 1 of a series on testing cement which was originally accepted by CEN on 15 November 1985 and made available on 12 May 1987. The UK gave a negative vote at the final voting stage and, under the CEN Rules then in force, was not obliged to implement this Part. A second formal vote was taken in November 1992 when the UK again gave a negative vote but, under the CEN Rules now in force, is obliged to implement this Part.

The method described in this standard is that referred to as the ISO mortar prism test in the foreword to BS 4550 : Section 3.1 : 1978. Prisms of 40 mm square cross section are cast from a 1 : 3 mortar and broken in flexure after 28 days curing. The two halves are then tested for compressive strength. This method has been referred to for the determination of strength in the 1991 revisions of the specifications for cement in BS 12, BS 146, BS 4027, BS 4246, BS 6588 and BS 6610 and in the 1992 first edition of BS 7583, all of which are based on the European Prestandard ENV 197-1. However, BS 4550 : Section 3.4 : 1978 on the determination of cement strength using concrete or mortar cubes will not be withdrawn until November 1994 to allow these methods to be used in support of the specifications in BS 915, BS 1370 and BS 4248 until these are also revised.

EN 196-1 specifies the reference procedure for the preparation and testing of mortar prisms made with CEN Standard sands from various sources and compacted by a standard jolting apparatus but permits the use of alternative compaction equipment and procedures in well defined cases; national annexes NA, NB, and NC give the requirements for UK purposes for CEN Standard sand, for the alternative compaction procedure and for the verification of the mass requirements for the jolting table, respectively.

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

EUROPEAN STANDARD

EN 196-1

NORME EUROPÉENNE

EUROPÄISCHE NORM

December 1994

ICS 91.100.10

Supersedes EN 196-1 : 1987

Descriptors: Cements, mortars (materials), composition: property, tests, compressive strength, flexural strength, conformity tests, specimen preparation, test equipment, certification

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 1994-12-12. 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.

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

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Ref. No. EN 196-1 : 1994 E

Foreword

This European Standard was drawn up by the Technical Committee CEN/TC 51, Cement and building limes, the Secretariat of which is held by IBN.

The standard EN 196 on methods of testing cement consists of 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
ENV 196-4	Methods of testing cement — Part 4: Quantitative determination of constituents
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 196-21	Methods of testing cement — Part 21: Determination of the chloride, carbon dioxide and alkali content of cement

This European Standard shall be given the status of a National Standard, either by publication of an identical text or by endorsement, at the latest by June 1995, and conflicting national standards shall be withdrawn at the latest by June 1995.

This European Standard supersedes EN 196-1 : 1987.

According to the CEN/CENELEC Internal Regulations, the following countries are bound to implement this European Standard: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom.

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1 Scope

This European Standard describes a method of determining the compressive and flexural strengths of cement mortar.

This standard describes the reference procedure; it allows the use of alternative procedures only in well defined cases provided that they do not affect the results significantly as specified in clause 11. In the event of a dispute, only the reference procedure described in this standard is used, excluding any alternatives.

The method applies to the cement types defined in ENV 197-1. It may not be applicable to other cement types, for instance on account of their initial setting time.

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.

- | | |
|------------------|--|
| ENV 197-1 : 1992 | <i>Cement — Composition, specifications and conformity criteria —
Part 1: Common cements</i> |
| ISO 409-1 : 1982 | <i>Metallic materials — Hardness test — Tables of Vickers hardness values for use in tests made on flat surfaces —
Part 1: HV 5 to HV 100</i> |
| ISO 565 : 1990 | <i>Test sieves — Woven metal wire cloth, perforated metal plate and electroformed sheet — Nominal sizes of openings</i> |
| ISO 1101 : 1983 | <i>Technical drawings — Geometrical tolerancing — Tolerancing of form, orientation, location and run-out — Generalities, definitions, symbols, indications on drawings</i> |
| ISO 1302 : 1992 | <i>Technical drawings — Method of indicating surface texture</i> |

- | | |
|-------------------|---|
| ISO 2591-1 : 1988 | <i>Test sieving —
Part 1: Methods using test sieves of woven wire cloth and perforated metal plate</i> |
| ISO 3310-1 : 1990 | <i>Test sieves — Technical requirements and testing —
Part 1: Test sieves of metal wire cloth</i> |
| ISO 4200 : 1991 | <i>Plain end steel tubes, welded and seamless — General tables of dimensions and masses per unit length</i> |
| ISO 6507-1 : 1982 | <i>Metallic materials — Hardness test — Vickers test —
Part 1 : HV 5 to HV 100</i> |

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 and three parts by mass of standard sand with a water/cement ratio of 0,50. 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).

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

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

At the required age, the specimens are taken from their wet storage, broken in flexure into two halves 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 continuously maintained at a temperature of $(20 \pm 1) ^\circ\text{C}$ and a relative humidity of not less than 90 %.

The temperature of the water in the storage containers shall be maintained at $(20 \pm 1) ^\circ\text{C}$.

The temperature and relative humidity of the air in the laboratory and the temperature of 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. 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 on the drawings (figures 1 to 3) 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 or adjusted or repaired where possible. 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 European Standard 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.

4.3 Test sieves

Wire cloth test sieves conforming to the requirements of ISO 2591-1 and 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) a stainless steel bowl with a capacity of about 5 l and of the general shape and size shown in figure 1, and 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;

b) a stainless steel blade of the general 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 by an electric motor at controlled speeds. The two directions of rotation shall be opposite and the ratio between the two speeds shall not be a whole number.

Where more than one mixer is used, blades and bowls shall form sets which are always used together.

The gap between blade and bowl shown in figure 1 shall be checked every month. The gap of $(3 \pm 1) \text{ mm}$ 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.

The mixer shall operate at the speeds given in table 2.

Table 2. Speeds of mixer blade

	Rotation min^{-1}	Planetary movement min^{-1}
Low speed	140 ± 5	62 ± 5
High speed	285 ± 10	125 ± 10

4.5 Moulds

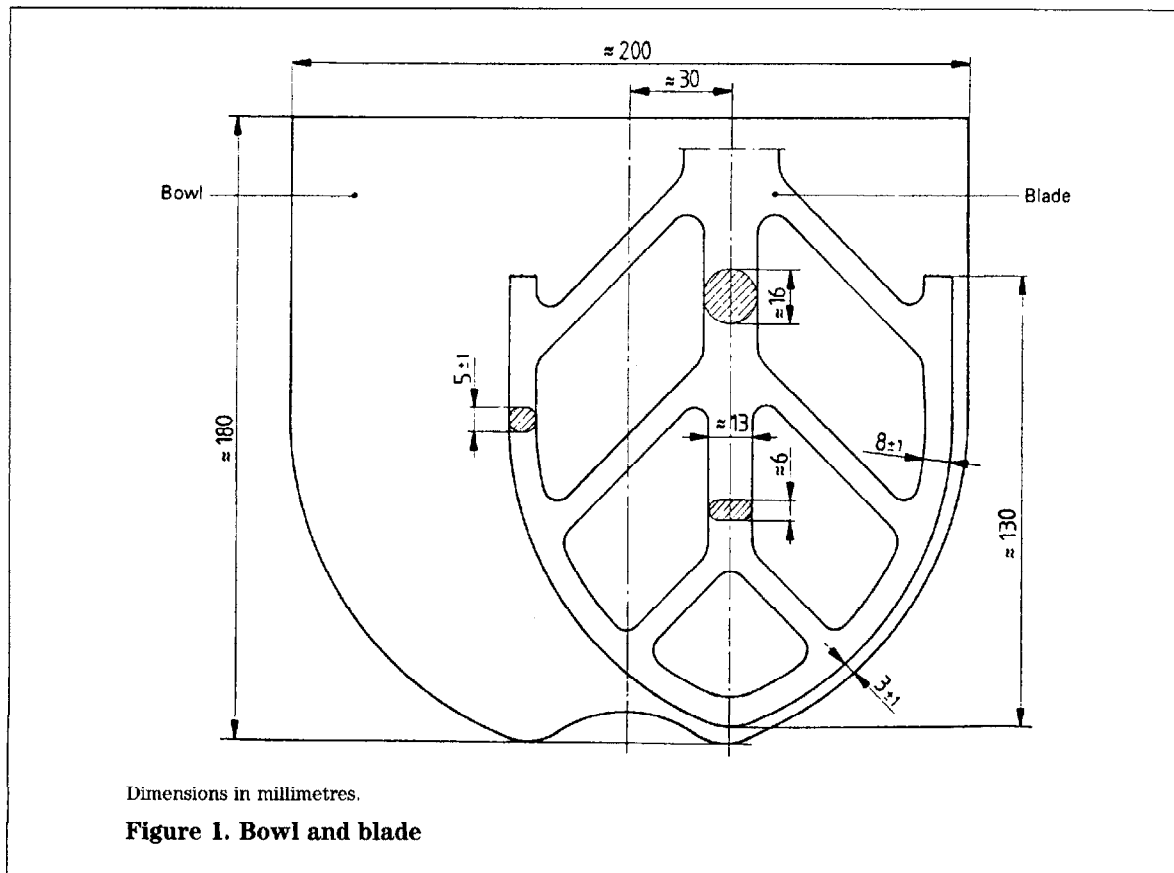
The mould shall consist of three horizontal compartments so that three prismatic specimens 40 mm x 40 mm in cross section and 160 mm in length can be prepared simultaneously.

A typical design is shown in figure 2.

The mould shall be made of steel with walls at least 10 mm thick. The surface Vickers hardness of each internal side face shall be at least HV 200 (see ISO 409-1 and ISO 6507-1).

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 leakage. 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 tables 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 compliance with the specified tolerances. Similar parts of separate mould assemblies shall not be interchanged.

The assembled mould shall comply with the following requirements.

- a) The internal dimensions and tolerances of each mould compartment, based on four symmetrically-placed measurements, shall be as follows:

length: $(160,0 \pm 0,8)$ mm;
width: $(40,0 \pm 0,2)$ mm;
depth: $(40,1 \pm 0,1)$ mm.

- b) The flatness tolerance (see ISO 1101, 14.2) over the whole of each internal side face shall be 0,03 mm.

- c) The perpendicularity tolerance (see ISO 1101, 14.8) for each internal face with respect to the bottom surface of the mould and the adjacent internal face as datum faces shall be 0,2 mm.

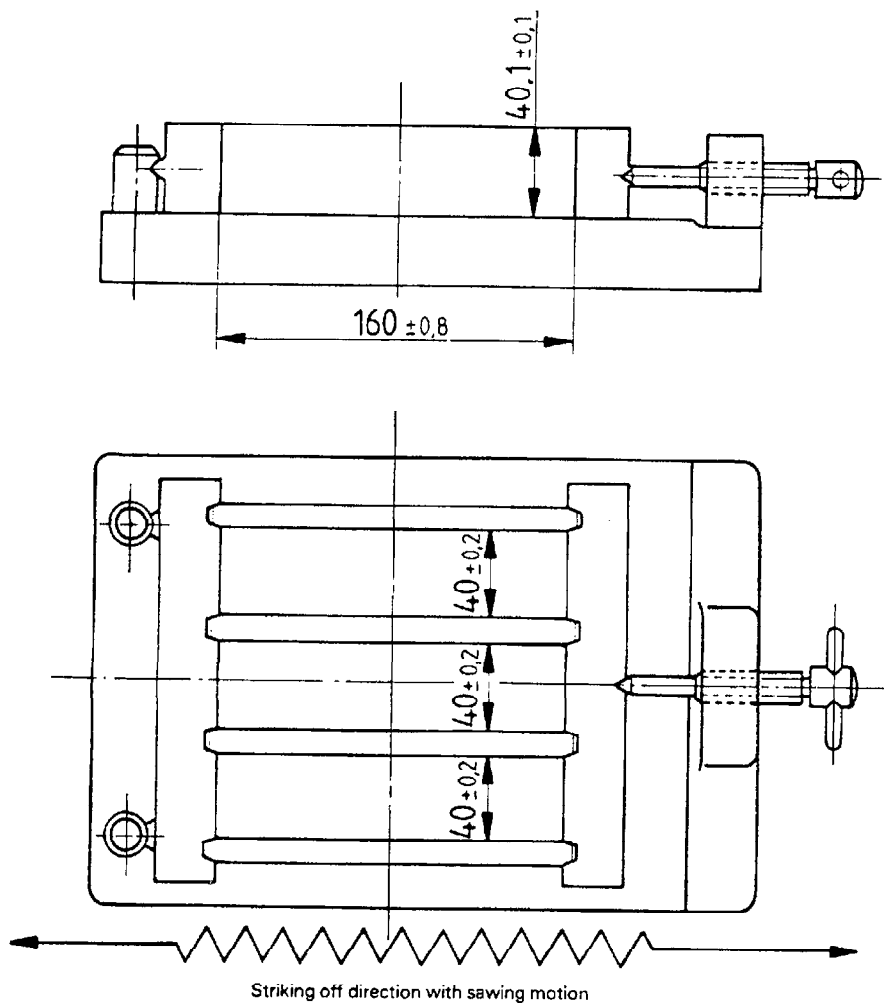
- d) The surface texture (see ISO 1302) of each internal side face shall be not rougher than N8.

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 assembling 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.

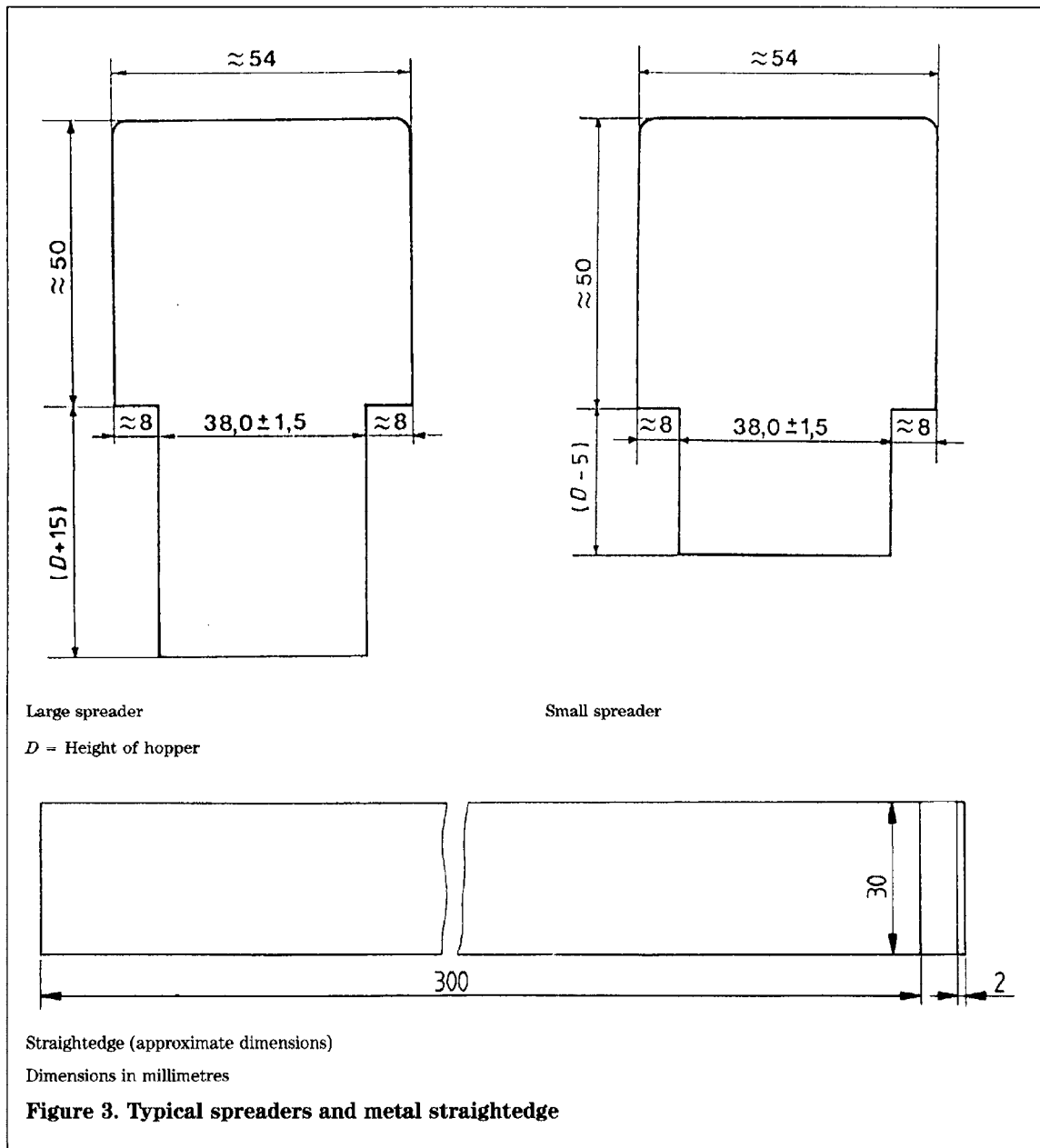
To facilitate the filling of the mould a tightly fitting metal hopper with vertical walls 20 mm to 40 mm in height shall be provided. When viewed in plan, the hopper walls shall overlap the internal walls of the mould by not more than 1 mm. The outer walls of the hopper shall be provided with a means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

Figure 2. Typical mould



4.6 Jolting apparatus

The jolting apparatus (a typical design is shown in figure 4) shall comply with the following requirements.

The apparatus consists essentially of a rectangular table rigidly connected by two light arms to a pivot at 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 projecting 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 (see ISO 409-1). 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 steel of at least HV 400 Vickers hardness value and its shaft shall be mounted in ball bearings of such construction that the free drop 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 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.

4.7 Flexural strength testing machine

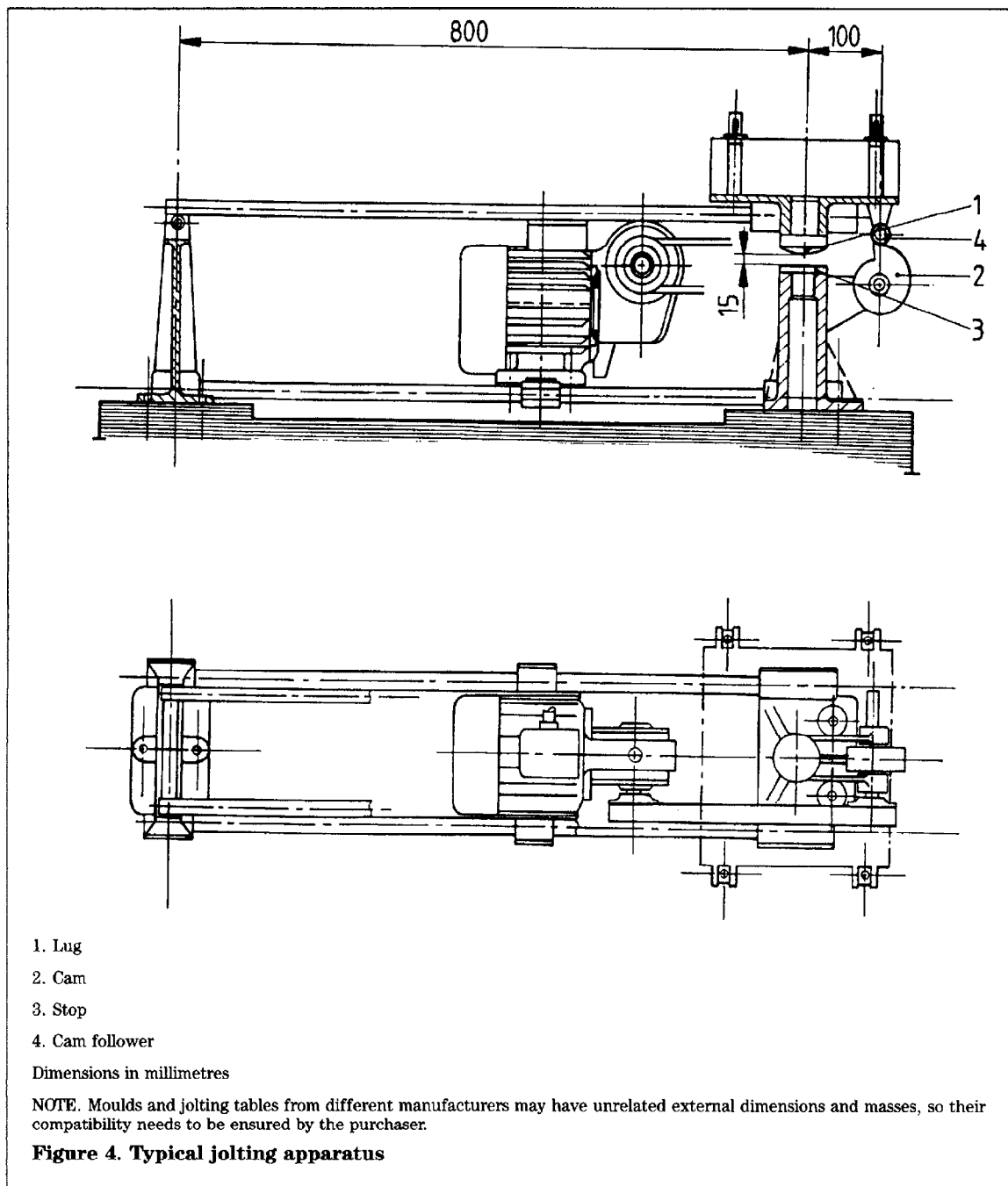
The testing machine for the determination of flexural strength shall be capable of applying loads up to 10 kN, with an accuracy of $\pm 1,0 \%$ of the recorded load in the upper four-fifths of the range being used, at a rate of loading of (50 ± 10) N/s. The machine shall be provided with a flexure device 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 'a' of these rollers shall be between 45 mm and 50 mm. The loading arrangement is shown in figure 5.

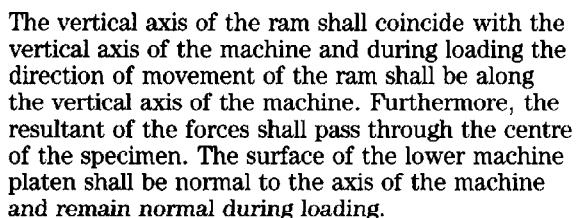
The three vertical planes through the axes of the three rollers shall be parallel and remain parallel, equidistant and normal to the direction of the specimen under test. One of the supporting rollers and the loading roller shall be capable of tilting slightly to allow a uniform distribution of the load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

NOTE. The determination of flexural strength may be carried out in a compressive strength testing machine. In this case a device conforming to the specification in this subclause has to be used.

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 and it shall provide a rate of load increase of (2400 ± 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 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 ± 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 hard steel, with a Vickers hardness (see ISO 409-1) of at least HV 600, or preferably of tungsten carbide. These platens shall be at least 10 mm thick, $(40,0 \pm 0,1)$ mm wide, and $(40,0 \pm 0,1)$ long. The flatness tolerance according to 14.2 of ISO 1101 over the entire contact surface with the specimen shall be 0,01 mm. The surface texture according to ISO 1302 shall be not smoother than N3 and not rougher than N6.

Alternatively, two auxiliary plates of hard steel, or preferably of tungsten carbide, at least 10 mm thick and complying with the requirements for the platens may be provided. Provision shall be made for centring the auxiliary plates with respect to the axis of the loading system with an accuracy of ± 0.5 mm.

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 according 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. It is considered advisable for the machine to 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. However, machines whose axis is not vertical are also permitted provided that they satisfy an acceptance testing procedure analogous to that in 11.7 and that the other requirements of 4.8 are fulfilled.

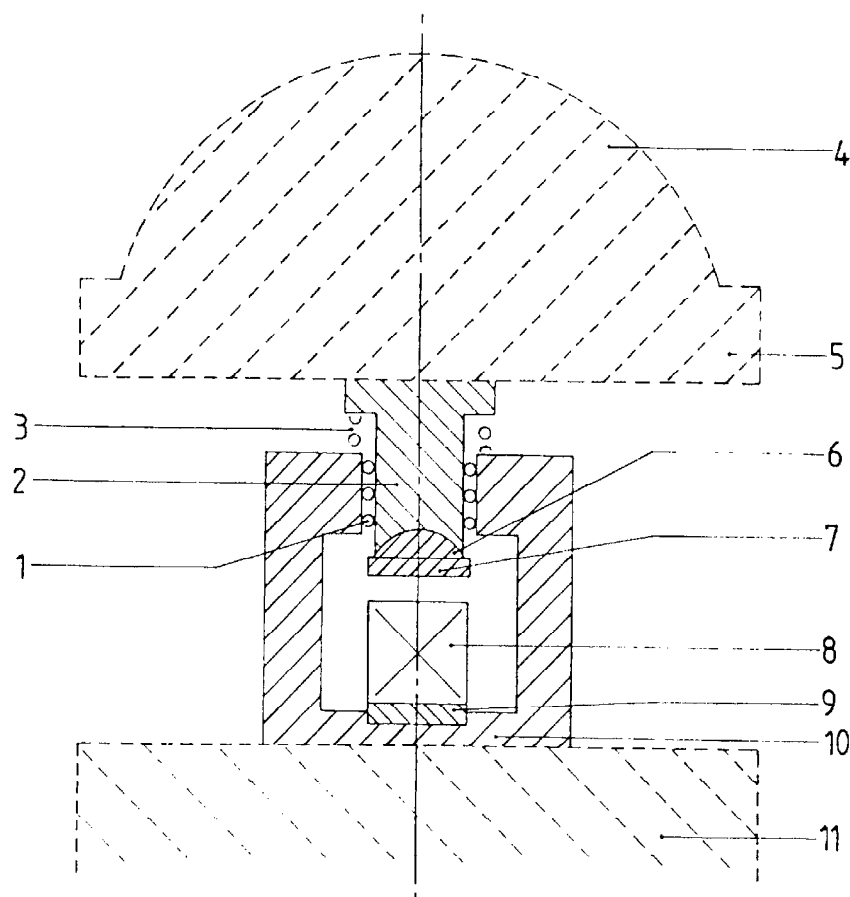
4.9 Jig for compressive strength testing machine

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 rotate 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.



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

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 standard. 'CEN Standard sand, EN 196-1' shall conform to the requirements stated in 5.1.3. The conformity shall be attested by the national standardization organization within whose area of jurisdiction the CEN Standard sand, EN 196-1 was produced.

The national standardization organization shall ensure that the CEN Standard sand, EN 196-1, during its subsequent production is continuously monitored in accordance with this European Standard.

In view of the difficulties of specifying CEN Standard sand completely and unambiguously it is necessary during certification and quality control testing to standardize the sand against the CEN Reference sand. 'CEN Reference sand, EN 196-1' is described in 5.1.2¹⁾.

5.1.2 CEN Reference sand

The CEN Reference sand shall be a natural, siliceous sand consisting preferably of rounded particles and has a silica content of at least 98 %. Its particle size distribution shall lie within the limits defined in table 3.

Table 3. Particle size distribution of the CEN Reference sand

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

The sieve analysis of the sand shall be carried out with a representative sample. 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 2 h drying at 105 °C to 110 °C and expressed as a percentage by mass of the dried sample.

5.1.3 CEN Standard sand

CEN Standard sand shall comply with the particle size distribution and moisture content specified and determined as in 5.1.2. During production these determinations shall be carried out at least once a day. These requirements are insufficient to ensure that the Standard sand is equivalent to the Reference sand. Such equivalence shall be maintained by a certification testing programme comprising comparison of the Standard sand with the Reference sand. This programme and the associated calculation are described in 11.6.

CEN Standard sand may be delivered in separate fractions or premixed in plastics bags with a content of (1350 ± 5) g; the type of material used for the bags shall have no effect on the results of the strength testing.

5.2 Cement

When the cement to be tested is 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.

5.3 Water

Distilled water shall be used for reference testing. For other tests, drinking water may be used.

6 Preparation of mortar

6.1 Composition of the mortar

The proportions by mass shall be one part of the cement (5.2), three parts of 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 ± 2) g of cement, (1350 ± 5) g of sand and (225 ± 1) g of water.

6.2 Batching of mortar

The cement, sand, water and apparatus shall be at the laboratory temperature (4.1). Carry out weighing by means of a balance accurate to ± 1 g.

NOTE. If water is added from automatic 225 ml pipettes they have to be accurate to ± 1 ml.

¹⁾ For all information on how to obtain this reference sand, please contact DIN Deutsches Institut für Normung, Burggrafenstrasse 6, D-1000 Berlin 30, Germany.

6.3 Mixing of mortar

Mix each batch of mortar mechanically using the mixer (4.4). With the mixer in the operating position:

- a) pour the water into the bowl and add the cement;
- b) then start the mixer immediately at the low speed (see table 2) and, after 30 s²⁾, add the sand steadily during the next 30 s. When separate sand fractions are used, add the required quantities of each fraction in succession starting with the coarsest. Switch the mixer to the high speed (see table 2) and continue the mixing for an additional 30 s;
- c) stop the mixer for 1 min 30 s. During the first 15 s, remove by means of a rubber scraper all 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.

The timing of the various mixing stages shall be adhered to within ± 1 s.

7 Preparation of test specimens

7.1 Size of specimens

The test specimens shall be
40 mm \times 40 mm \times 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 larger spreader (see figure 3), held 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. Introduce the second layer of mortar, level with the smaller 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 and moved slowly, with a transverse sawing motion (see figure 2) once in each direction. Smooth the surface of the specimens using the same straightedge held almost flat.

Label or mark the moulds to identify the specimens and their position relative to the jolting table.

8 Conditioning of test specimens

8.1 Handling and storage before demoulding

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

Place a 210 mm \times 185 mm plate glass sheet of 6 mm thickness on the mould. A plate of steel or other impermeable material of similar size may be used.

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

Place each covered mould, suitably identified, 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 with due precautions³⁾.

Carry out demoulding, for 24 h tests, not more than 20 min before the specimens are tested⁴⁾.

Carry out demoulding, for tests at ages greater than 24 h, between 20 h and 24 h after moulding⁴⁾.

NOTE. 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. Mention delayed demoulding 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.

8.3 Conditioning of specimens in water

Submerge the marked specimens without delay in a convenient manner, either horizontally or vertically, in water at $(20 \pm 1)^\circ\text{C}$ in suitable containers (see 4.1). With horizontal storage, keep vertical faces as cast vertical, and the struck-off surface uppermost.

Place the specimens on non-corrodible gratings and keep them apart from each other so that the water has free access to all six sides 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.

NOTE. Wooden gratings are not suitable.

Only store specimens made with cements of similar chemical composition in each container.

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, complete replacement of water is not permitted.

²⁾ Automatic devices for control of these operations and timings can be used.

³⁾ Plastics or rubber hammers, or devices specially made, can be used for demoulding.

⁴⁾ 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.

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 from the time of mixing of the cement and water at the beginning of the test.

Make strength tests at different ages within the following limits:

- 24 hours \pm 15 minutes
- 48 hours \pm 30 minutes
- 72 hours \pm 45 minutes
- 7 days \pm 2 hours
- \geq 28 days \pm 8 hours

9 Testing the specimens

9.1 Testing procedures

Use the centre-point loading method to determine the flexural strength by means of the equipment specified in 4.7.

Test the half prisms obtained in the flexural test in compression on the moulded side faces over an area of 40 mm \times 40 mm.

When the flexural strength value is not required, this test may be omitted. The compressive strength tests shall then be carried out on the two halves of the prism broken by suitable means which do not subject the prism halves to harmful stresses.

9.2 Flexural strength

Place the prism in the testing machine (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 damp until tested in compression.

Calculate the flexural strength R_f in N/mm² from:

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

where:

- R_f is the flexural strength, in Newtons per square millimetre;
- 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.

9.3 Compressive strength

Test the prism halves in compression on the side faces by means of the equipment specified 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 (2400 \pm 200) N/s over the entire load application until fracture.

Where the load increase is regulated by hand, make adjustment for the decrease of the loading rate near the fracture load.

Calculate the compressive strength R_c in N/mm² from:

$$R_c = \frac{F_c}{1600}$$

where:

R_c is the compressive strength, in Newtons per square millimetre;

F_c is the maximum load at fracture, in Newtons;

1600 = 40 mm \times 40 mm
is the area of the platens or auxiliary plates, in square millimetres.

10 Conformity testing of cement

10.1 General

The method of compressive strength determination has two major applications, i.e. conformity testing and acceptance testing.

This clause describes conformity testing, i.e. the means by which a cement is judged to comply with a compressive strength specification.

Acceptance testing is dealt with in clause 11.

10.2 Definition of test result

The test result is expressed as the arithmetic mean of the six compressive strength determinations made on a set of three prisms.

If one result within the six determinations varies by more than \pm 10 % from the mean of the six, discard this result and calculate the mean of the five remaining results. If a further result within these five determinations varies by more than \pm 10 % from their mean, discard the set of results.

10.3 Calculation of test result

From the individual strength results obtained from prism halves expressed to the nearest 0,1 N/mm² calculate the mean in accordance with 10.2 and express this to the nearest 0,1 N/mm².

10.4 Reporting of results

Record all individual results. Report the calculated mean and whether any result has been discarded in accordance with 10.2.

10.5 Measures of the precision of the method

The precision of the method is measured by its repeatability (see 11.5) and its reproducibility (see 10.6).

The precision of the test method for conformity testing is measured by its reproducibility.

The precision of the test method for acceptance testing and for production control purposes is measured by its repeatability.

10.6 Reproducibility

The reproducibility of the method of compressive strength determination is a quantitative expression of the error associated with test results obtained with nominally identical samples of a cement, by different operators working in different laboratories, at different times, using standard sands of different origin and different sets of equipment.

For the 28-day compressive strength the reproducibility under these conditions between well-experienced laboratories, expressed as the coefficient of variation, may be expected to be less than 6 %.

This implies that the difference between two corresponding test results obtained in different laboratories may be expected (probability 95 %) to be less than about 15 %.

11 Acceptance testing of sand and of alternative equipment**11.1 General**

As indicated in clause 3, the testing of a cement in accordance with this standard cannot be based on the use of a single, universally available, test sand: consequently it is necessary that several test sands, to be identified as CEN Standard sands, are available.

Similarly, but for a different reason, the standard does not require the test laboratory to use one specific type of compaction equipment. The term 'alternative materials and equipment' has therefore been introduced. Clearly this freedom of choice, linked with the inevitable requirements of a European Standard, has to lead to certain limitations in respect of the alternatives. Consequently, one of the principal features of this standard is that the alternatives have to be subjected to a testing programme to ensure that the strength results obtained in conformity testing are not significantly influenced by the use of alternatives in place of the specified 'Reference' materials or equipment.

This acceptance testing programme comprises certification testing, which establishes that a proposed new alternative complies with the requirements of the standard, and verification testing, which ensures that a certification-tested alternative remains in compliance with this standard.

Since the two most important alternatives are the sand and the compaction equipment, the testing of these is described in 11.6 and 11.7 respectively as an illustration of the general principle of acceptance testing.

11.2 Definition of test result

The test result is expressed as the arithmetic mean of the six compressive strength determinations made on the three prisms of one batch.

11.3 Calculation of test result

See 10.3.

11.4 Precision of the test method

The precision of the test method for acceptance testing and for production control purposes is measured by its repeatability (for reproducibility see 10.6).

11.5 Repeatability

The repeatability of the method of compressive strength determination is a quantitative expression of the error associated with test results obtained in one laboratory with nominally identical samples of a cement, under nominally identical conditions (same operator, same equipment, same sand, short interval of time, etc.).

For the 28-day compressive strength the repeatability under these conditions within a well-experienced laboratory, expressed as the coefficient of variation, may be expected to lie between 1 % and 3 %.

11.6 CEN Standard sands**11.6.1 Certification testing of sand**

A sand to be used as a test sand in accordance with this standard shall be certified and shall then be designated 'CEN Standard sand, EN 196-1'.

Certification testing during the initial production period (minimum of 3 months) of a proposed new CEN Standard sand is necessary to prove its suitability (in addition, an annual verification test is required to ensure long-term uniformity of quality, see 11.6.2). The certification testing is based on a standardized procedure for comparing the proposed CEN Standard sand with the CEN Reference sand, as described in 11.6.3.

The certification testing shall be based on compressive strength testing at the age of 28 days and shall be undertaken by testing laboratories approved for this purpose by the appropriate national standardization organization.

The approved testing laboratories shall collaborate internationally and take part in co-operative testing schemes⁵⁾ to ensure that the properties of Standard sands from producers in different countries are comparable with regard to the international acceptance criteria.

11.6.2 Verification testing of sand

The verification testing procedure, which is required for the annual renewal of the certificate, comprises an annual test of a random sample of sand by an approved testing laboratory and an inspection by the certification agency of the sand producer's records of his quality control tests.

The programme for verification testing is based on the same principles as those for certification testing and is described in 11.6.4.

The sand producer's quality control tests shall be carried out regularly by the producer's laboratory or by a service laboratory (monthly in the case of continuous production). The records of the results of the quality control tests for at least three years shall be available to the certification agency for inspection as part of the verification procedure.

11.6.3 Method of certification testing of CEN Standard sand

11.6.3.1 General

During the initial production period of at least three months three independent samples of the sand, for which certification as a CEN Standard sand has been requested, shall be taken for certification testing by the certification agency. A comparative test with the CEN Reference sand shall be carried out with each of these three samples using a different one of three cements selected for this purpose by the certification agency.

When each of these comparative tests, at an age of 28 days, leads to acceptance of the respective sample, the proposed sand is acceptable as a CEN Standard sand.

11.6.3.2 Acceptance criterion

This standard is based on an acceptance criterion such that a sand, which in the long run would give a 28-day compressive strength differing by about 5 % from that obtained with the CEN Reference sand, has a probability of at least 95 % of being rejected.

11.6.3.3 Execution of each comparative test.

Using samples of the cement selected for this purpose, prepare 20 pairs of batches of mortar using the proposed CEN Standard sand for one batch and the CEN Reference sand for the other.

Prepare the two batches in each pair in a randomized order, one immediately after the other, in accordance with this standard. After a curing time of 28 days test all six prisms of a pair of batches for compressive strength and calculate the test result for each sand in accordance with 10.3, as x for the proposed CEN Standard sand and as y for the CEN Reference sand.

11.6.3.4 Evaluation of each comparative test

Calculate the following parameters:

- the mean compressive strength (\bar{y}) over all 20 batches prepared with the CEN Reference sand;
- the mean compressive strength (\bar{x}) over all 20 batches prepared with the proposed CEN Standard sand.

Evaluate $D = \frac{100 (\bar{x} - \bar{y})}{\bar{y}}$ to the nearest 0,1, ignoring sign.

11.6.3.5 Treatment of outliers

If the presence of an outlying difference is suspected, calculate the following parameters:

- the algebraic difference ($d = x - y$) between each pair of test results;
- the mean value of the 20 differences ($\bar{d} = \bar{x} - \bar{y}$);
- the standard deviation of the 20 differences (s);
- the value of $3s$;
- the arithmetic difference between the highest value of d , (d_{\max}) and \bar{d} and between the lowest value of d , (d_{\min}) and \bar{d} . Where one of these differences is greater than $3s$, discard the relevant value (d_{\max} or d_{\min}) and repeat the calculations for the remaining 19 differences.

11.6.3.6 Requirement for acceptance

The proposed CEN Standard sand shall be considered acceptable for certification where each of the three values of D , calculated in accordance with 11.6.3.4, is less than 5,0. Where one or more of the calculated values of D is equal to, or greater than, 5,0 the sand is not acceptable.

11.6.4 Method of verification testing of CEN Standard sand

11.6.4.1 Annual test by the certification agency

A single random sample of the sand shall be taken by the certification agency in accordance with 11.6.2 and shall be tested in accordance with the general procedure described in 11.6.3, using one cement selected for this purpose by the certification agency.

⁵⁾ The requirements for these schemes will form part of a future certification scheme.

Where the value of D , calculated as in 11.6.3.4, is less than 5,0, the sample shall be considered to comply with the requirements of the verification test. Where the value of D is equal to, or greater than, 5,0, a further three random samples shall be tested according to the complete certification testing procedure described in 11.6.3.

11.6.4.2 Monthly test by the sand producer

A monthly test shall be carried out by the sand producer, in the same way as the verification test described in 11.6.4.1, but making at least ten comparisons, by comparing a random sample of the sand produced during that month with a certification tested CEN Standard sand, using one cement selected for this purpose by the certification agency.

Where the value of D , calculated as in 11.6.3.4, is greater than 2,5 more than twice within a series of 12 successive monthly comparative tests, the certification agency shall be informed, and shall undertake a complete certification testing procedure on three random samples in accordance with 11.6.3.

11.7 Acceptance testing of alternative compaction equipment

11.7.1 General

Where acceptance testing of alternative compaction equipment is requested, the certification agency shall select three commercially available sets of the equipment which shall be placed in an approved testing laboratory, alongside a standard set of equipment complying with 4.6.

The equipment under test shall be accompanied by:

- a full technical description of the design and construction;
- the instructions for servicing;
- a list of checks to ensure the correct operation;
- a full description of the proposed compaction procedure.

The certification agency shall make a careful comparison of the technical characteristics of the equipment under test with the technical description provided. An approved testing laboratory shall then carry out three comparative tests using for each set a different one of three cements selected for this purpose by the certification agency and CEN Reference sand.

When each of these three tests leads to acceptance of the alternative equipment, the proposed compaction equipment is considered as an acceptable alternative.

11.7.2 Testing of alternative equipment

11.7.2.1 Acceptance criterion

This standard is based on an acceptance criterion such that equipment making use of a method of compaction, which in the long run would give a 28-day compressive strength differing by about 5 % from that obtained with the method described in this standard has a probability of at least 95 % of being rejected.

11.7.2.2 Execution of each comparative test

Using samples of the cement selected for this purpose, 20 pairs of batches of mortar shall be prepared and shall be compacted using the proposed alternative procedure for one batch and the standard procedure for the other.

The two batches in each pair shall be prepared in a randomized order, one immediately after the other. The treatment of the prisms after compaction shall be carried out in accordance with this standard. After a curing time of 28 days all six prisms of a pair of batches shall be tested for compressive strength and the test result for each method of compaction shall be calculated in accordance with 11.3, with x for the proposed alternative compaction method and with y for the standard jolting table.

11.7.2.3 Evaluation of each comparative test

Calculate the following parameters:

- the mean compressive strength (\bar{y}) over all 20 batches prepared with the standard equipment;
- the mean compressive strength (\bar{x}) over all 20 batches prepared with the proposed alternative compaction equipment.

Evaluate $D = \frac{100(\bar{x} - \bar{y})}{\bar{y}}$ to the nearest 0,1, ignoring sign.

11.7.2.4 Treatment of outliers

See 11.6.3.5.

11.7.2.5 Requirement for acceptance of the proposed alternative equipment

The alternative equipment shall be considered acceptable when each of the three values of D , calculated in accordance with 11.7.2.3, is less than 5,0.

In such a case the technical description of the equipment shall be deemed to be an annex to 4.6, and the description of the compaction procedure shall be deemed to be an annex to 7.2.

Where one or more of the calculated values of D is equal to, or greater than, 5,0 the alternative equipment is not acceptable.

National annex NA (normative)

CEN Standard sand

NA.1 At the time of publication of this British Standard, a certified CEN Standard sand is not being produced in the UK. Hence the requirements in 5.1.1 for the national standardization organization to attest the compliance and in 11.6.1 to approve the testing laboratories for certification testing are not applicable to BSI.

NA.2 However, CEN Standard sands conforming to 5.1.3 are produced in several European countries and may be used for tests in accordance with this standard. However, for the purpose of testing cement for acceptance inspection at delivery, in accordance with clause 11 of the 1991 edition of each of the following, BS 12, BS 146, BS 4027, BS 4246, BS 6588 and BS 6610, and clause 12 of BS 7583 : 1992, unless otherwise agreed between the purchaser and the manufacturer, the pit/quarry from which the CEN Standard sand is obtained shall be that supplying the cement manufacturer at the time when the cement was originally tested during operation of the manufacturer's autocontrol scheme.

National annex NB (normative)

Alternative compaction procedure

NB.1 General

The reference jolting apparatus is described in 4.6. However, clause 1 'allows the use of alternative procedures only in well defined cases provided that they do not affect the results significantly as specified in clause 11'. An acceptance testing procedure has been undertaken on the vibrating table* described in NB.2 in accordance with 11.7 and has satisfied the requirement in the first paragraph of 11.7.2.5. It is therefore an acceptable alternative equipment. The technical description of the equipment is given in NB.2 as an alternative to 4.6 and the description of the compaction procedure is given in NB.3 as an alternative to 7.2.

NB.2 Vibrating table

The vibrating table that may be used as an alternative compaction equipment comprises:

- a) magnetic vibrator having a 240 V, single phase, 50 Hz supply that can produce a sinusoidal vibration. The air gap between the magnet of the vibrator and the plate is 4.0 mm to 4.2 mm;
- b) a vibrating plate made from a single layer of mild steel plate, nominally 630 × 250 mm and (13 ± 2) mm finished thickness, with support ribs and drive plate having a ground surface finish;

- c) swing clamps suitable for holding a 40 mm × 40 mm × 160 mm three compartment prism mould and hopper assembly on the plate during vibration.

The vibrating table is permanently fixed to the floor and levelled by means of adjustable feet at the corners of the base frame so that the surface of the vibrating plate does not deviate from the horizontal by more than 1 mm per metre run.

With an empty mould and hopper in position the vibrating mass, excluding the drive unit, is (43.0 ± 2.0) kg. The natural frequency of vibration is (55.5 ± 0.25) Hz and the operating vertical acceleration is (4.5 ± 0.25) *g* rms when measured on the base of the mould at the centre of the middle compartment. The maximum acceleration in any horizontal direction is 0.5 *g* rms.

NB.3 Compaction procedure with the vibrating table

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 (4.5 ± 0.25) *g* rms.

Mould the specimens immediately after the preparation of the mortar. Switch the vibrator on and 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 ± 1) s switch off the vibrator either manually or automatically.

Then follow the procedures in paragraphs 2 and 3 of 7.2.

NB.4 Acceptance inspection testing of cement

For the purpose of testing cement for acceptance inspection at delivery, in accordance with clause 11 of the 1991 edition of each of the following, BS 12, BS 146, BS 4027, BS 4246, BS 6588 and BS 6610, and clause 12 of BS 7583 : 1992, unless otherwise agreed between the purchaser and the manufacturer, use the compaction procedure in use by the cement manufacturer at the time when the cement was originally tested during operation of the manufacturer's autocontrol scheme.

* For information on the availability of a suitable vibrating table, write to Customer Information, BSI, 389 Chiswick High Road, London, W4 4AL.

National annex NC (normative)

Verification of the mass requirements for the jolting table

NC.1 General

This annex describes the procedure to be used by the manufacturer of the apparatus to check that a jolting table conforms to the mass requirements specified in 4.6. The total mass of the two arms, including any cross bracing is to be (2.25 ± 0.25) kg. The combined mass of the table, including arms, empty mould, hopper and clamps is to be (20.0 ± 0.5) kg.

NC.2 Procedure

NC.2.1 Connecting arms

Measure the length of the arms to an accuracy of ± 0.5 mm and their outside and internal diameters to an accuracy of ± 0.1 mm. Determine the mass of the arms by calculating their volume in cubic metres and multiplying by 7850 kg/m^3 (the theoretical density of steel). Where any cross bracing is used, determine its mass and add this to the calculated mass of the arms to arrive at the mass of the connecting arms and cross bracing.

NC.2.2 Combined mass

Dismantle the table and arm assembly from the pivotal point on the apparatus. Weigh the table and arm assembly plus associated hopper and mould to an accuracy of ± 10 g. In cases where the pivot bearing, spindle and housing form an integral part of the table and arm assembly, calculate the volume and hence determine the mass of the pivot bearing, spindle and housing. Subtract this calculated mass from the measured mass of the table and arm assembly to give the final combined mass.

NOTE. If the same hopper is always used, then the only variable will be the mass of the mould. Hence, an individual specification for the mass of the moulds to be used can be determined for the particular jolting apparatus.

National annex ND (informative)

Recommendation for carrying out the test procedure in the UK

ND.1 Laboratory (see 4.1)

The high humidity required in moist air curing rooms is normally produced by spraying water as a fine aerosol. The bacterium *Legionella pneumophila* is widespread in nature and is present in the water systems of many buildings. Scale in pipework and chemical nutrients in the water supply may encourage growth of this organism which multiplies between 25°C and about 45°C . Inhaling infected aerosols is a known route for transmission of legionellosis. It is

therefore advisable to maintain cold water supplies below 20°C where possible and to store hot water above 60°C . Cold water supplies may be disinfected by chlorination to at least 5 mg/L free chlorine. Regular periodic checking for the presence of *Legionella* species in industrial water supplies is a sensible precaution.

ND.2 Mixing of mortar (see 6.3)

When cement is mixed with water, alkali is released. Take precautions to avoid dry cement entering the eyes, mouth and nose when mixing mortar. Prevent skin contact with wet cement or mortar by wearing suitable protective clothing. If cement or mortar enters the eye, immediately wash it out thoroughly with clean water and seek medical treatment without delay. Wash wet mortar off the skin immediately.

ND.3 Moulding of test specimens (see 7.2)

In striking off the excess mortar, place the metal straightedge (see figure 3) centrally across the mould and, with a transverse sawing motion, move it slowly outwards, once in each direction and then once along the entire mould before smoothing the surface (see figure 2).

ND.4 Handling and storage before demoulding (see 8.1)

Insert a suitable compressible gasket between the mould and the plate.

ND.4 Curing of specimens in water (see 8.3)

Wear rubber or vinyl gloves when placing specimens into, or removing them from, the curing water tanks.

National annex NE (informative)**Committees responsible**

The United Kingdom participation in the preparation of this European Standard was entrusted by Technical Committee B/516 Cement and lime, to Subcommittee B/516/4, upon which the following bodies were represented.

British Cement Association
British Civil Engineering Test Equipment Manufacturers' Association
British Ready Mixed Concrete Association
Cementitious Slag Makers' Association
Department of the Environment (Building Research Establishment)
Electricity Association
Quality Ash Association
Society of Chemical Industry

National annex NF (informative)**Cross-references**

Publication referred to	Corresponding British Standard
ENV 197-1 : 1992	DD ENV 197-1 : 1994 <i>Cement. Composition, specifications and conformity criteria</i> <i>Part 1. Common cements</i>
ISO 1302 : 1978	BS 308 <i>Engineering drawing practice</i> <i>Part 2 : 1985 Recommendations for dimensioning and tolerancing of size</i>
ISO 2591-1 : 1988	BS 1796 <i>Test sieving</i> <i>Part 1 : 1989 Methods using test sieves of woven wire cloth and perforated metal plate</i>

NOTE. The mesh sizes for the wire cloth sieves of the R20 series in ISO 565 : 1990 are not all included in BS 410 : 1986 *Specification for test sieves* but UK manufacturers can supply the ISO 565 sizes.

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