INTERNATIONAL STANDARD

ISO 9652-4

First edition
2000-09-15

Masonry —

Part 4: Test methods

Maçonneries —

Partie 4: Méthodes d'essai

Reference number
ISO 9652-4:2000(E)

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this part of ISO 9652 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 9652-4 was prepared by Technical Committee ISO/TC 179, *Masonry*, Subcommittee SC 3, *Test methods*.

ISO 9652 consists of the following parts, under the general title *Masonry*:

— *Part 1: Unreinforced masonry design by calculation*

— *Part 2: Unreinforced masonry design by simple rules*

— *Part 3: Code of practice for design of reinforced masonry*

— *Part 4: Test methods*

— *Part 5: Vocabulary*

Annex A forms a normative part of this part of ISO 9652.

Introduction

ISO/TC 179 is responsible for the International Standards for design of masonry, either by calculation (see ISO 9652-1) or by simple rules (see ISO 9652-2). The test methods given in this part of ISO 9652 are standard reference test methods. They are used to determine the properties of masonry units, mortars and masonry elements needed in the design of structures.

Test methods in national standards for determining the resistance of masonry units and elements to loads show considerable differences. This no doubt reflects both the history of the derivation of the test and the purpose to which the results are put, but the effect is that design methods are different in different countries. Researchers into masonry problems may use test methods, which differ again.

National standards are appropriate for use in a particular country, as are research methods for specific investigations. However, parallel tests following the methods given in this part of ISO 9652 are necessary in order to establish a relationship between them and in order that a precise comparison of test results using different test methods may be obtained with confidence.

The results from the reference test methods in this part of ISO 9652 are intended to provide a basic common datum against which data obtained by different test methods may be strictly compared. More attention has been paid to precision and repeatability than to the provision of test methods of universal applicability.

Even if all laboratories do not have the equipment to carry out these standard reference tests, there will usually be a national, often governmental, laboratory that has.

Masonry —

Part 4:
Test methods

1 Scope

This part of ISO 9652 specifies reference methods for testing

a) the compressive strength of masonry units;

b) the compressive strength of masonry;

c) the flexural strength of masonry;

d) the water absorption of clay units; and

e) the compressive strength of mortar.

It is applicable to masonry built with units of fired clay, calcium silicate, concrete (including autoclaved aerated concrete), natural stone or manufactured stone.

NOTE The methods may be suitable for testing other walling materials, but they have not been examined as reference tests in this respect.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 9652. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 9652 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 2591-1, *Test sieving — Part 1: Methods using test sieves of woven wire cloth and perforated metal plate*.

ISO 4287, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters.*

ISO 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method.*

ISO 9652-5, *Masonry — Vocabulary*.

3 Terms and definitions

For the purposes of this part of ISO 9652, the terms and definitions given in ISO 9652-5 apply.

4 Sampling

The method of sampling and the number of specimens shall be stated in the test report and shall be chosen so that the sample is representative of the batch to be tested. If the testing laboratory does not carry out the sampling, this shall be stated in the test report.

5 Determination of compressive strength of masonry units

5.1 General

The load at which a masonry unit fails in a compression test machine divided by the loaded area is defined as the crushing strength of that single unit. The compressive strength is defined as the arithmetical mean of the crushing strengths of a sample. The standard reference test requires a sample of 10 specimens, but provision is made for a smaller sample of 6 to be used when the coefficient of variation is known to be low. It is the best guide to the strength of the consignment from which the sample was taken and may be used in conjunction with information about the composition of the mortar used in construction to estimate the strength of the resulting masonry wall.

The test procedure uses a standard method of preparation to ensure that the surfaces are essentially plane and parallel so that the load is evenly distributed over the tested area. Specimens are tested wet but factors are provided to enable the results to be modified to give an approximate value for an air-dried specimen and to transform the result by means of a shape factor correction to bring different sized units to assumed equivalence.

In the test report there is provision for "Remarks" under which exceptional features (e.g. badly cracked, chipped or misshapen specimens) should be recorded.

5.2 Sample size

Sampling shall be carried out in accordance with clause 4. The number of specimens shall be at least 10. If the coefficient of variation is known to be not greater than 15 %, the number of specimens may be reduced to 6.

5.3 Preparation of specimens

5.3.1 Test specimens

Use test specimens sampled in accordance with clause 4. Concrete masonry units other than autoclaved ones shall be stored for the required number of days before testing. This shall be recorded in the test report (see 5.7).

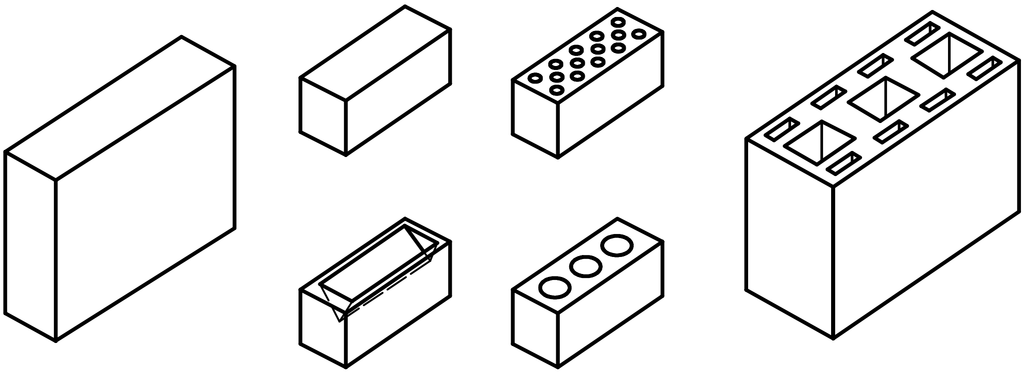
For certain forms of construction, it will be necessary to test the units in more than one orientation.

Units used in the normal manner are understood to be laid with their bed faces horizontal, as shown in Figure 1.

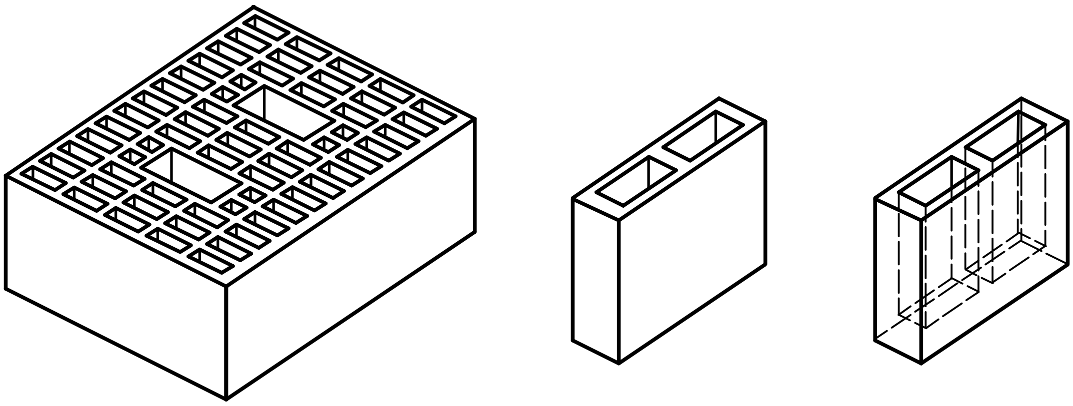
5.3.2 Dimensions of units

5.3.2.1 General

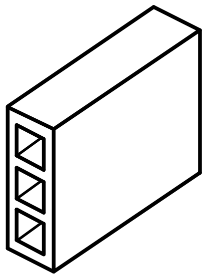
In order to meet the requirements of d) and e) of the test report (see 5.7), make a sketch and description of the unit using the following procedures (see Figure 2).



a) Group I Units which are solid or with $\leqslant$ 25 % by volume of formed vertical holes that may or may not pass right through the unit, or units with $\leqslant$ 25 % by volume of frogs in the bed faces

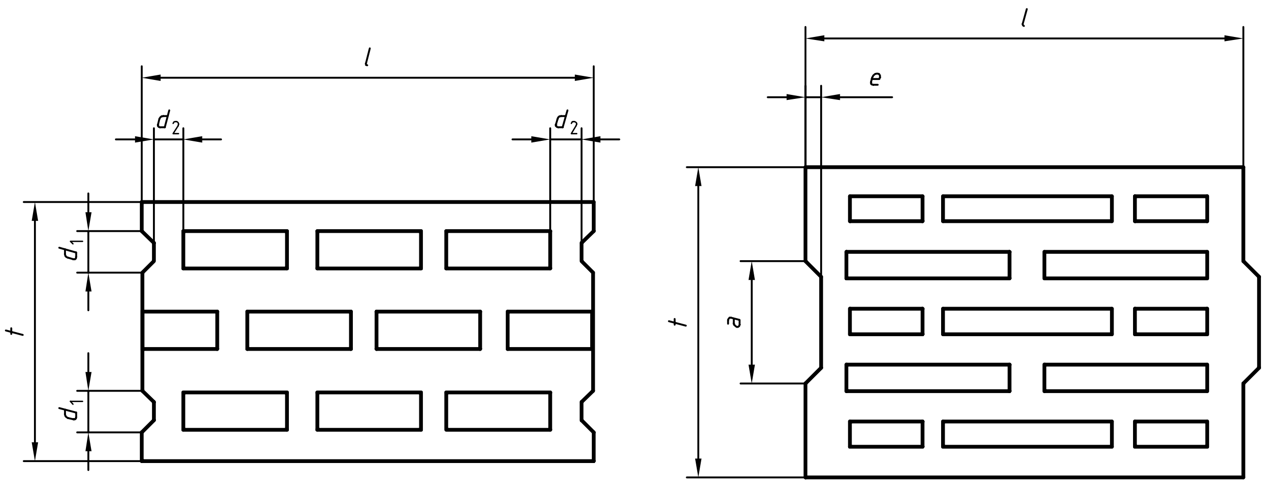


b) Group II Units with $>$ 25 % and $<$ 60 % by volume of formed vertical holes which may or may not pass through the units



c) Group III Units with $<$ 50 % by volume of formed horizontal holes, which may or may not pass through the units

Figure 1 — Units in normal aspect



l = length

t = width

Figure 2 — Example of dimensions

5.3.2.2 Gross area of the loaded surface

This subclause applies to all types of masonry unit, including those to be used with a divided joint (face-shell bedded), that is, the gap between the twin strips of mortar is included in the overall area (see 5.5.1).

Make three measurements of the dimensions of the gross plan area to the nearest 1 mm at the top, middle and bottom of the unit. Multiply the means of these three measurements of length and width together to calculate the gross area.

5.3.2.3 Determination of the proportion and size of voids

Measure the dimensions of the voids directly if they are large enough. Calculate and record the total cross-sectional area of voids and express it as a percentage of the gross area. Otherwise proceed as follows.

a) Make three measurements of the height of the unit to the nearest 1 mm at the middle and two ends. Use the mean to multiply by the gross area to obtain the gross volume that is recorded to the nearest 1 000 mm^3.

b) Place the unit on a thin sheet of foam rubber with the holes in a vertical position. Using a measuring cylinder filled with fine dry sand, fill the holes and record the volume of sand used, to the nearest 1 000 mm^3.

c) Express the volume of sand as a percentage of the gross unit volume.

5.3.2.4 Net area

If the voids were measured directly, subtract the cross-sectional area of voids from the gross area to obtain the net area. To find the average net area of units with voids too small to be measured directly, subtract the volume of the voids from the gross volume and divide by the mean height.

5.3.3 Bed face preparation

5.3.3.1 General

Prepare each specimen so that the bed faces are plane to a tolerance of 0,1 mm per 100 mm of gauge length and the top surface lies between two parallel planes not greater than 1 mm apart in 500 mm and parallel to the bottom surface. If the unit already meets these requirements, then test it directly. Otherwise use grinding or, as an alternative, capping with mortar as described in 5.3.3.2. Fill frogs and allow the mortar to cure before grinding.

5.3.3.2 Capping procedure

5.3.3.2.1 General

Immerse the specimens in water for 18 h and then allow them to drain for approximately 10 min. Wipe off the surplus water.

Use a capping mortar consisting of one part by volume of clean, well-graded sand with a maximum grain size of 2 mm, mixed with one part by volume of cement. The compressive strength of the mortar at the time of the test, determined as described in clause 6, shall be not less than 30 N/mm^2.

Treat each of the two bed faces in turn as described below, using mortar of the same composition made with the same constituents

5.3.3.2.2 Units without holes or with holes unfilled

NOTE Ground plate glass or machined steel plates are the most suitable materials. The flatness tolerance can be checked by measuring deviations from straightness along a line parallel to, and close to, each specimen edge; along each diagonal and along each centreline, using a straight edge raised by pads of equal thickness at each end of the specimen and an appropriate gauge at the centre. The deviation from flatness may be obtained be relating the deviations from straightness at the centre point of the plate and at other points where the lines described intersect.

5.3.3.2.2.1 Bed each specimen in the mortar on a smooth rigid plate, at least 25 mm longer and wider than the specimen, and plane to within 0,05 mm, using the following procedure.

a) Support the plate firmly with the machined face uppermost and level it in two directions at right angles, using a spirit level. Coat the plate with a film of mould-release oil or a sheet of thin paper to prevent mortar adhering.

b) Spread a uniform layer of mortar about 5 mm thick on the plate. Press one bed face of the specimen firmly into it. Check that the vertical axis of the specimen is perpendicular to the plane of the plate using a square or vertical level to check each vertical face. When bedding hollow blocks, it will be found an advantage to shape the mortar layer so that it is a little thicker in the middle than at the edges so that air is not trapped under the block when it is pressed into the mortar.

c) Ensure the mortar bed is at least 3 mm thick over the whole area and that any cavity normally filled when the units are laid in the wall is completely filled with mortar. Do not fill other cavities.

d) Trim off surplus mortar flush with the sides of the specimen. Cover it with a cloth, kept damp. Allow the bedded specimen to remain undisturbed for at least 16 h and then carefully remove it from the plate without damaging the mortar.

e) Examine the mortar bed for defects such as lack of compaction, cracking and lack of adhesion to the specimen. Replace such defective specimens.

5.3.3.2.2.2 Bed the second bed face using the same process.

5.3.3.2.3 Units with frogs intended to be filled

Treat each of the two bed faces in turn as described below.

a) Fill the frog with capping mortar and strike off level.

b) At the time that the top frog is filled, bed the base of the unit in a similar mortar mix as described in 5.3.3.2.1. For bricks with two frogs, fill the lower frog before inverting the brick onto the mortar bed. Store under damp sacking, polyethylene or similar material until the mortar has hardened.

5.3.3.2.4 Units to be face-shell bedded

5.3.3.2.4.1 Bed each specimen in the mortar on a smooth rigid plate (see Note in 5.3.3.2.4.2) at least 25 mm longer and wider than the specimen, and plane to within 0,05 mm, using the following procedure.

a) Support and coat the plate as described in 5.3.3.2.2.

b) Lay two parallel strips of mortar about 5 mm thick on the plate such that each strip is about 25 mm longer than the length of the unit and about 10 mm wider than the face shell.

c) Press one bed face of the unit into the mortar such that the thickness of the mortar over the face-shells is at least 3 mm. Check that the vertical axis of the specimen is perpendicular to the plane of the plate using a square or vertical level to check each vertical face.

d) Trim off any surplus mortar and store the specimen in accordance with 5.3.3.2.2.

e) Examine in accordance with 5.3.3.2.2.

5.3.3.2.4.2 Bed the second face using the same process.

NOTE The distance between the strips should be approximately equal to the distances between the face-shells less 10 mm.

5.3.3.3 Storage of specimens

After the second capping layer has hardened sufficiently (3 to 7 days), immerse the specimens in water or cure them under sacks kept damp throughout the curing period or in a conditioning chamber at greater than 90 % relative humidity.

5.3.4 Conditioning of specimens before testing

Immerse the specimens in water for at least 24 h. Remove and allow to drain without drying out before testing (normally about 15 min).

5.4 Apparatus

Test the specimens in an appropriate machine regularly calibrated to ensure that it complies with the requirements given in Table 1.

Table 1 — Requirements for testing machines (for masonry units)

Maximum permissible repeatability of forces as a percentage of indicated force	Maximum permissible mean error of forces as a percentage of indicated force	Maximum permissible error of zero force as percentage of maximum force of range
1,0	± 1,0	± 0,2

The testing machine shall have adequate capacity to crush all the test specimens, but the scale used shall be such that the ultimate load on the specimen exceeds one-fifth of the full-scale reading.

The machine shall be provided with a load pacer or equivalent means to enable the load to be applied at the rate given in 5.5.2.

The testing machine shall be equipped with two steel bearing platens of adequate stiffness (see Note). The testing faces, where case-hardened, shall have a Vickers hardness of at least HV 600 when tested in accordance with ISO 6507-1. When the platens are through-hardened, the steel shall have a tensile strength of not less than 1 000 N/mm^2.

NOTE Grade 36 CrNiMo6 as specified in ISO 683-1 is known to be suitable.

Both the stiffness of the platens and the manner of load transfer shall be such that the deformation of the platen surface at ultimate load shall be less than 0,1 mm measured over 250 mm, assuming a uniformly distributed load.

One platen of the machine shall be able to align freely with the specimen as contact is made but the platens shall be restrained by friction or other means from tilting with respect to one another during loading. The other compression platen shall be a plane non-tilting block. The bearing faces of both platens shall be larger than the size of the loaded face of the largest unit to be tested. Where auxiliary platens are used, they shall be properly located and of sufficient hardness, stiffness and planeness to ensure uniformity of load. The bearing surfaces of the platens shall not depart from a plane by more than 0,05 mm.

To meet this requirement, the platens, when new, should be somewhat more accurate and should be refaced when they approach this limit.

The surface texture shall not be greater than Ra 3,2 (see ISO 4287). Auxiliary platens shall meet these requirements on both faces.

5.5 Test procedure

5.5.1 Placing specimens in the testing machine

Wipe the bearing surfaces of the testing machine clean and remove any loose grit from the bed faces of the specimen. Align the specimen carefully with the centre of the ball-seated platen so that a uniform seating is obtained. Do not use any packing material except for units intended to be face-shell bedded, which have been prepared by grinding. Then use four stiff steel strips, the same width as the face-shells and 50 mm longer, positioned two at the top and two at the bottom, overlapping equally at each end.

5.5.2 Loading

Apply load to the specimen without shock and increase it continuously. Initially, use any convenient rate of loading, but when about half the expected maximum load has been applied, adjust the rate so that loading will be completed in a further time of between 0,5 min and 2 min. Record the maximum load.

NOTE With some specimens the recorded load may fluctuate before maximum load is reached. This will be indicated by a reduction in load as the specimen yields, followed by an increase to a new maximum as loading is continued. This temporary reduction may occur several times before the specimen finally fails.

5.6 Calculation of results

Calculate the crushing strength of each specimen by dividing the failure load by its gross loaded area (see 5.3.2) and express it to the nearest 0,1 N/mm^2.

Calculate the average value and record it as the compressive strength of the units, to the nearest 0,1 N/mm^2.

Calculate the standard deviation of the sample and the coefficient of variation.

5.7 Test report

The test report shall contain the following information:

a) the number and date of this part of ISO 9652;

b) the date of production of the unit in the case of concrete units other than autoclaved concrete units, including aerated;

c) the date of testing;

d) a description of the masonry unit, including the type, dimensions, cross section, proportion of voids, minimum thickness of solid material in the webs and shells, pattern of voids and such other information as is necessary to identify the unit clearly;

e) a sketch of the masonry unit showing its height and the extent of the loaded area and the orientation of loading;

f) the name of the organization that carried out the sampling and the method used;

g) the number of specimens in the sample;

h) whether specimens were capped or ground;

i) for each specimen, the dimensions in millimetres, including the height of the specimen after surface preparation, if any, the failure load in newtons, and the crushing strength in newtons per square millimetre;

j) the compressive strength of the sample in newtons per square millimetre to the nearest 0,1 N/mm^2;

k) the standard deviation;

l) the coefficient of variation;

m) remarks.

An addendum may be added to the test report (see 5.8).

5.8 Normalized compressive strength

5.8.1 General

For design purposes, modify the compressive strength obtained from the test report to the air-dried strength of an equivalent 100 mm × 100 mm unit, ($h \times t$) i.e. f_b, by factors as given in 5.8.2 and 5.8.3.

5.8.2 Conversion to equivalent results for air-dried specimens

To convert to a nominal value for the air-dried condition, multiply the compressive strength for fired clay units by 1,1 and for all other units by 1,2.

5.8.3 Shape factor

To allow for the height and width of the masonry unit as tested, multiply the strength of the units by a factor δ given in annex A. Alternatively, a statistically rigorous value may be obtained by experiment when the details of the calculation shall be recorded.

5.8.4 Calculation of normalized compressive strength

$$f_b = \omega \delta f_c$$

where

f_b is the normalized compressive strength of the masonry unit;

f_c is the compressive strength of the sample (see 5.7);

ω is a moisture factor for converting to the normal value for the air-dried condition:

ω = 1,1 for fired-clay units,

ω = 1,2 for all other units;

δ is a shape factor given in annex A for converting to the normal value of units with a vertical cross section of 100 mm × 100 mm.

The modified results are an addendum to the test report.

6 Determination of compressive strength of mortar

6.1 Introduction

This clause specifies methods for determining the compressive strength of mortars. It is not intended to be used for mortars consisting of lime and sand only. These methods are not suitable for specimens of set mortar cut from masonry. The air content and bulk density may be determined in accordance with standard methods if requested and then should be recorded in the test report.

6.2 Sampling

Obtain samples by taking uniformly distributed increments (preferably from material in motion, provided this can be carried out in safety), and mixing them thoroughly to form a combined sample. The number of increments and size of bulk sample necessary depend on the quantity of the material and its variability. The bulk sample may be further reduced by taking sufficient scoops from random positions throughout the mixed material.

Mix the batch well before filling the moulds. Because batch variations in the mortar are likely to be much greater than testing variations, when testing a single sample of mortar from site, prepare specimens from three separate batches (see 6.3.3).

6.3 Preparation and storage of test specimens

6.3.1 Dimensions of specimens

Use either prisms 160 mm × 40 mm × 40 mm or cubes of side 70,7 mm. A minimum of three prisms or six cubes are required. When prisms are used, break them in half to provide six test pieces.

6.3.2 Apparatus

6.3.2.1 Steel moulds

Each mould consists of a rigid base plate, two end plates and four side plates, at least 10 mm thick, rigidly clamped together. Each mould thus has three compartments. The surface of each internal face shall be at least HV 400 Vickers hardness value in accordance with the requirements of ISO 6507-1.

A typical mould is shown in Figure 3.

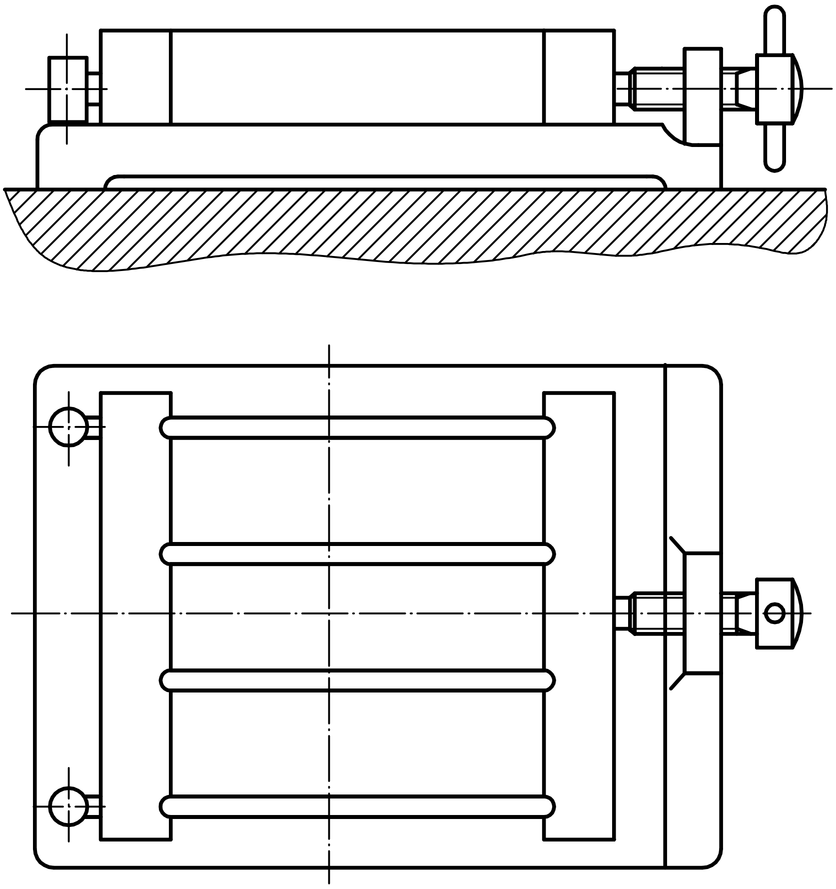


Figure 3 — Typical mould for forming mortar prism specimens 160 mm × 40 mm × 40 mm

The assembled moulds shall comply with the following requirements:

a) Dimensions

1) Prisms: the depth and internal width of each compartment, each based on the average of six measurements symmetrically placed along the axis of the compartment, shall be 40 mm + 0,1 mm; the length of each compartment shall be 160 mm + 0,4 mm.

2) Cubes: the depth of the mould and the distance between either pair of opposite internal faces, each based on the average of four symmetrically placed measurements, shall be 70,7 mm + 0,15 mm.

b) Flatness

The surface of each internal face shall lie between two parallel planes 0,03 mm apart. The joints between the sections of the mould and between the bottom surface of the mould and the top surface of the base plate shall lie between two parallel planes 0,06 mm apart.

c) Squareness

The surface of each internal face shall lie between two parallel planes 0,05 mm apart which are perpendicular to the bottom surface of the mould and also to the adjacent internal faces.

d) Parallelism

The top surface of the mould shall lie between two parallel planes 1,0 mm apart and parallel to the bottom surface.

e) Surface texture

The surface texture of each internal surface shall be not greater than *Ra* 3,2 (see ISO 4287).

While the cleaned mould is being assembled ready for use, seal the joints between all the sections of the mould to prevent the escape of water (using, for example, grease). Remove excess sealant from the assembled mould and coat the internal faces with mould oil to prevent adhesion of the mortar.

6.3.3 Preparation of test specimens

Sample the mortar in accordance with 6.2. Prepare three prisms or cubes for testing at each of two ages, 7 days and 28 days being preferred. If specimens are required to determine the age at which masonry is to be tested (see 7.3.2) make sufficient for that purpose. Make the specimens as soon as practicable after mixing, but not later than 1 h after the addition of water to the mix, except in the case of retarded mixes.

Fill the mould to about half height with mortar and compact by ramming in a uniform manner with neither segregation nor excessive laitance. Use a 12 mm square compacting bar having a mass of 50 g for prisms or 25 mm square and a mass of 1,8 kg for cubes. The number of strokes of the compacting bar to compact the specimen will vary according to the consistence of the mortar but in no case give fewer than 25 strokes. Overfill the mould with more mortar and compact this layer as before. Strike off the surface plane and level with the top of the mould using a palette knife or trowel having a straight edge long enough to span the mould.

Place the mould in a humidity chamber or plastic bag, seal and store it at a temperature of 20 °C ± 3 °C, protecting it from drying for one to three days, depending on the early strength of the mortar. Then demould the specimens without damage, mark them for later identification and transfer them immediately to the appropriate surroundings for subsequent curing.

6.3.4 Storage of test specimens

6.3.4.1 General

Two types of curing are permitted:

a) under water for mortars that derive their strength mainly from hydration of cement (see 6.3.4.2); and

b) moist air curing, without carbonation, for other mortars (see 6.3.4.3).

6.3.4.2 Curing under water

Immerse the specimens in lime-saturated water at room temperature and keep them there until 2 min before testing. Support the specimens so as to allow the water free access to all parts of each face.

Fill the containers in which the specimens are to be cured to a sufficient depth to submerge the specimens and maintain at this level by topping up as required. At least once a month, empty and clean out the container and renew the water. Do not immerse specimens made from mortars of different types in the same water; however, specimens made from mortars of different classes of the same type may be immersed together.

6.3.4.3 Moist air curing

Store the specimens over water in a closed airtight container having a volume not greater than 0,015 m^3 at room temperature. Immerse specimens in water at 20 °C + 3 °C for 4 h to 6 h immediately before testing.

6.4 Determination of compressive strength

6.4.1 Apparatus

6.4.1.1 Prisms

6.4.1.1.1 Testing machine

Use a machine of sufficient capacity and sensitivity for the test and capable of applying the load at the rate specified in 6.4.2.4. The machine shall be regularly calibrated to ensure that it complies with the requirements in Table 1. The upper machine platen shall be able to align freely as contact is made with the specimen but the platens shall be restrained from tilting with respect to one another during loading.

6.4.1.1.2 Bearing plates

Use two bearing plates made of tungsten carbide or of steel of surface hardness at least HV 600 Vickers hardness value in accordance with the requirements of ISO 6507-1. The plates shall be 40,0 mm long, 40,0 ± 0,1 mm wide and 10 mm thick. The dimensional tolerance for the width shall be based on the average of four symmetrically placed measurements. The flatness tolerance for the contact faces shall be 0,01 mm.

6.4.1.1.3 Compression jig

Use a compression jig to locate the bearing plates. A suitable jig is shown in Figure 4. The base plate of the jig shall be of hardened and tempered tool steel and the faces shall have a flatness tolerance of 0,01 mm. A device to provide positive centring on the lower platen of the testing machine shall be provided. The hardened and tempered steel pillars shall be symmetrically placed about the centering device so that the gap in one direction is the nominal width of the prism plus 0,3 mm and in the other direction is the nominal width of the prism plus 0,8 mm. The top face of the base plate shall be marked with an arrow in the direction of the greater distance between the pillars to indicate the direction of the long axis of the bearing plates.

6.4.1.2 Cubes

6.4.1.2.1 Testing machine

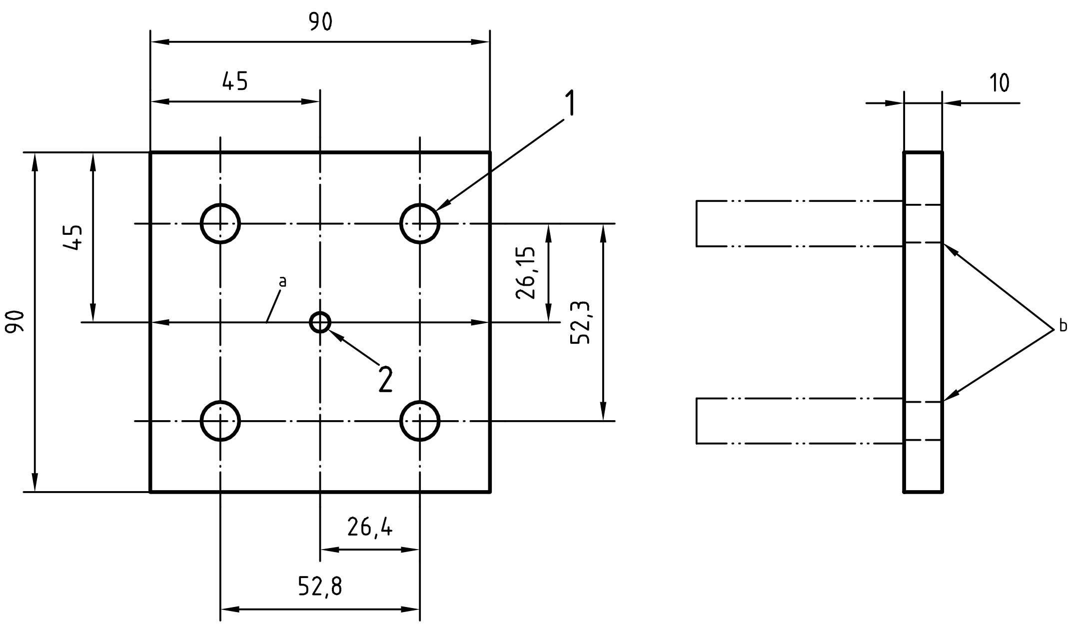
Use a testing machine as described in 6.4.1.1, equipped with two rigid steel bearing platens at least as large as the nominal size of the specimen to which the load is applied. The surface shall have a Vickers hardness value of at least HV 600 in accordance with the requirements of ISO 6507-1. The flatness tolerance for the area to be in contact with the specimen and the surface texture requirements are as given respectively in 6.3.2.1 b) and e).

6.4.2 Test procedure

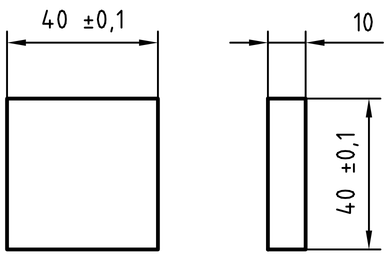
6.4.2.1 General

Test the specimen immediately on removing from the curing water in which it has been stored and while still in a wet condition. Remove any loose grit or other material from the sides of the specimen as-cast. Wipe the bearing surfaces of the testing machine and, for prisms, the bearing plates and jig, with a clean cloth and place the specimen in the machine in such a manner that the load is applied to the opposite sides of the specimen as-cast, that is not to the top and bottom.

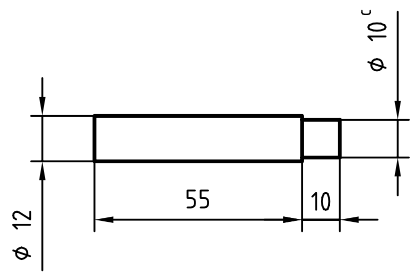
Dimensions in millimetres



a) Hardened and tempered tool steel base plate



b) Hardened and tempered tool steel bearing plates



c) Hardened and tempered steel pillars

Key

1 Four holes, ϕ 10 mm reamed

2 Centring hole (e.g. ϕ 5 mm and 6 mm deep)

a Arrows marked to indicate long axis of bearing plates

b Slight taper

c Press fit

Figure 4 — Compression jig for 160 mm × 40 mm × 40 mm mortar specimens

6.4.2.2 Prisms

Arrange the prisms so that the cast end is 16 mm from the nearer edges of the platens or bearing plates. Discard any specimens that do not provide a cube of solid material between the top and bottom platens or bearing plates. Carefully align the specimen so that the load will be applied to the whole width of the faces in contact with the platens. When using the bearing plates and jig, place one bearing plate on the upper surface of the jig with its long axis parallel to the indicating arrow, ensuring that it makes close contact over the whole surface. Place the specimen in the jig, between the pillars, with its long axis perpendicular to the arrow and place the other bearing plate on top of the specimen parallel to the lower bearing plate. Carefully centre the compression jig assembly on the lower platen of the test machine.

6.4.2.3 Cubes

Carefully centre the cube on the lower platen. Do not use any packing other than auxiliary steel platens between the faces of the specimen and the steel platen of the testing machine.

6.4.2.4 Loading

Apply the load without shock and, according to the likely strength of the mortar, increase it continuously at a rate within the range 0,03 N/(mm^2·s) to 0,1 N/(mm^2·s) until failure occurs.

Record the maximum load applied, in newtons, during the test.

6.4.3 Calculations

For prisms, calculate the strength as the maximum load divided by the cross-sectional area of the test piece in contact with the platen or bearing plate. For cubes, calculate the strength as the maximum load divided by the cross-sectional area of the cube.

Record the strength to the nearest 0,05 N/mm^2 for individual results and to the nearest 0,1 N/mm^2 for the compressive strength, that is the mean strength of the test pieces.

6.5 Test report

The test report shall contain the following information:

a) the number and date of this part of ISO 9652;

b) the origin of the mortar sample;

c) the number and type of specimens;

d) the date of moulding;

e) the date of demoulding;

f) the date of testing;

g) a description of the mortar including type, intended mortar class, composition (i.e. mix ratio with, where possible, precise identification of the individual constituents including the make of cement), source of the sand and any additions and admixtures;

h) sieve analysis of the sand using the method given in ISO 2591-1;

i) individual and mean values for the mortar strength to the nearest 0,05 N/mm^2 and 0,1 N/mm^2 respectively;

j) if requested, individual and mean values for the bulk density of the mortar, air content calculated from the bulk density of the mortar and the specific gravity of the constituent materials or measured by a standard method;

k) remarks.

7 Determination of the compressive strength of masonry

7.1 General

The compressive strength of masonry may either be derived from the strength of storey height masonry walls or from the strength of small masonry specimens tested to destruction.

The value for the strength of a masonry specimen is that obtained by testing according to this clause. However, the compressive strength of the units supplied may be different from that specified and the mortar may not have exactly the mean compressive strength nominated in Table 2, column 2. A method of adjusting the results to give an estimate of the strength of masonry at other strengths of units and, mortar is given in 7.8.1. Such adjustments shall only be carried out within the ranges specified in 7.8.1 and shall be clearly shown in an addendum to the test report as a calculated value.

7.2 Number of specimens

Sample the consignment of units from which the masonry specimens are to be built in accordance with clause 4.

Construct at least three wallettes or three storey height walls.

7.3 Preparation of specimens

7.3.1 Masonry units

Record the moisture content of the units at the time of laying. Determine the compressive strength f_b of a sample of structural units using the test method given in clause 5. Record the properties listed in 5.7.

It is recommended that the moisture content of autoclaved aerated concrete units and calcium silicate units at the time of laying should be between 5 % and 8 % by mass.

Where the strength of the masonry units will change with time, carry out the compressive strength test on the units on the same day as the masonry

7.3.2 Mortar

Use the mortar consisting of weighed amounts of material on the dry basis determined from the volume proportions corresponding to the appropriate composition. If damp sand is used, make an allowance for the moisture content. For the first batch use the amount of water needed to achieve a satisfactory working consistence. Do not change this amount for subsequent batches. Take samples of mortar to make mortar specimens and determine the bulk density and compressive strength in accordance with clause 6. Carry out compressive tests at various ages so that the time of masonry testing can be determined, that is, the time at which the mortar strength falls within the ranges given for the appropriate class in Table 2. If the masonry specimens are to be tested at a set time (e.g. 28 days), determine the strength of the mortar at that age.

Table 2 — Permissible ranges of strength within which masonry may be tested and the strength corrected to nominal values

Mortar class	Nominal strength N/mm^2	Mortar strength at time of testing N/mm^2
M 1	1	1 to 1,5
M 2	2	1,6 to 3,5
M 5	5	3,6 to 7,5
M 10	10	7,6 to 15,0
M 20	20	15,1 to 30,0

7.3.3 Construction of masonry specimens

7.3.3.1 General

Use the materials, construction and bonding pattern corresponding to those to be used in practice. Build specimens using conventional masonry techniques.

7.3.3.2 Using small specimens

Use at least three specimens having the sizes given in Table 3 and Figure 5, producing half units by sawing. If units are of such a size that the wallette would be storey height, then proceed as in 7.3.3.3.

Table 3 — Specimen sizes for testing the compressive strength of masonry

Length in unit lengths b	Thickness in unit widths t	Height h
2	1	$3 \leqslant h/t \leqslant 15$ $h/b \geqslant 1$ $h \geqslant 5$ courses

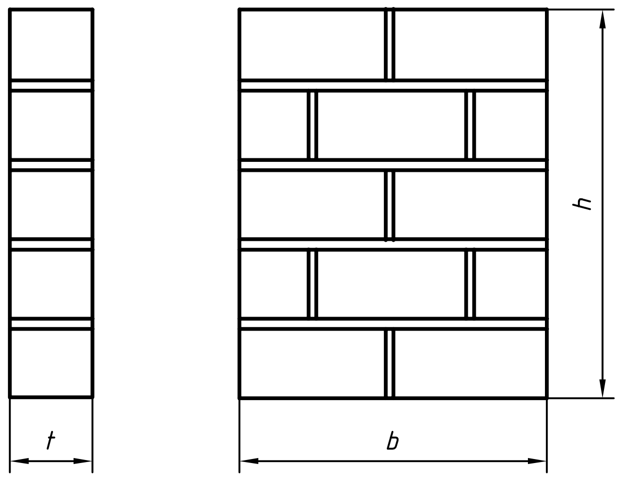


Figure 5 — Small masonry specimens (reference test)

7.3.3.3 Using storey height wall specimens

Prepare three identical panels 1,2 m to 1,8 m in length and 2,4 m to 2,7 m in height with a minimum cross-sectional area of 0,125 m^2.

When walls having dimensions outside these limits are to be tested, the general principles laid down in this procedure should be applied and the details should be reported.

7.3.4 Curing

Take appropriate steps to prevent the test panels from drying out during the first 3 days after construction, for example by covering them with polyethylene sheets. Then leave them uncovered in a laboratory-controlled environment (15 °C to 25 °C, 60 % + 10 % relative humidity) until tested when they should be in an air-dried condition.

7.3.5 Preparation of specimens for testing

Use mortar to fix to the upper loading surface of each specimen a flat steel plate or a stiff loading beam. Any out-of-planeness of the upper surface of the steel plate shall not exceed 1/1 000 of its length. For face shell bedded specimens, this mortar capping should be confined to the face shells. Prevent mortar from falling into the holes.

If the plate or the loading beam is not applied at the same time as the specimen is built, but later (e.g. only when the specimen is put into the loading machine), ensure that the mortar used reaches at least the same strength as the mortar in the masonry at the time the masonry is tested. Check that the load distribution faces are parallel to one another and at right angles to the main axis of the specimen. If rapid setting mixes are needed for convenience, gypsum plaster may be used for low-strength masonry up to 10 N/mm^2 and high-alumina cement/sand mixes for stronger masonry specimens.

7.3.6 Age at testing

Test the panels after 7 days or more when the mortar strength falls within the ranges given in Table 2 for the appropriate class. Determine the compressive strength of the mortar in accordance with clause 6 at the age at which the panels are tested.

7.4 Apparatus

Test specimens in an appropriate testing machine, regularly calibrated to ensure that it conforms to the requirements given in Table 4. The platens or cross heads through which the load is applied shall be restrained against rotation to produce a flat ended condition.

The testing machine shall be equipped with loading beams if these have not already been fitted to the specimens (see 7.3.5). The stiffness of the loading beams shall be sufficient to ensure even displacement of the top and bottom surfaces of the specimen under load. This stiffness condition shall be considered to be fulfilled if the length of the loading beam beyond the edge of the platen does not exceed the depth of the loading beam.

Provide a means for measuring the lateral deflection of slender specimens at the mid-height.

Table 4 — Requirements for testing machines (for masonry specimens)

Maximum permissible repeatability of forces as a percentage of indicated force	Maximum permissible mean error of forces as a percentage of indicated force	Maximum permissible error of zero force as a percentage of maximum force of range
1,2	± 2,0	± 0,2

7.5 Test procedure

7.5.1 Placing the specimen in the testing machine

Locate the specimen so that it and the testing machine are in full-face contact at the load application faces. To achieve this when parallelism or smoothness of the specimen is inadequate, thin compensating layers of a suitable material may be included (e.g. as described in 7.3.5), provided that these do not cause any undesirable effects on the specimen such as tensile stresses transverse to the direction of loading.

Place the specimen centrally so that its longitudinal axis lies in the axis of the testing machine.

7.5.2 Loading

Apply the load uniformly over the whole area of the top and bottom of the panel. Increase the load steadily so that failure is reached after 15 min to 30 min.

NOTE The maximum load F_{max} can be estimated from the equation given in 7.6.

7.5.3 Measurements

Record the following:

a) the size of the loaded cross section of each specimen;

b) the maximum load, in newtons;

c) the load at which visible cracks occur, in newtons;

d) the length of time from the start of loading until the maximum load is achieved;

e) the lateral deflection at the mid-height close to the moment of failure.

7.6 Calculations of compressive strength

Calculate the compressive strength of each masonry specimen, $f_{1,2,3}$, in newtons per square millimetre, using the following formula:

$$f_i = \frac{F_{\text{max},i}}{A}$$

where

$F_{\text{max},i}$ is the maximum failure load, in newtons, of the i th specimen determined in the course of testing;

A is the loaded cross section of the masonry specimen, in square millimetres.

Calculate the mean compressive strength f for all specimens, in newtons per square millimetre to the nearest 0,1 N/mm^2.

The maximum load, F_{max}, can be estimated from the equation:

$$F_{\text{max}} = 0{,}6\left(f_{\text{b}}\right)0{,}65\, f_{\text{m}}^{0{,}25} A$$

where

f_{b} is the normalized compressive strength of the masonry units, in newtons per square millimetre;

f_m is the compressive strength of the mortar, in newtons per square millimetre;

A is the loaded cross section of the masonry, in square millimetres.

7.7 Test report

The test report shall contain the following information:

a) the number and date of this part of ISO 9652;

b) the number of specimens;

c) the date of building;

d) the date of testing;

e) curing conditions (temperature and humidity);

f) a description of the specimens, including dimensions, loaded cross-sectional area and bonding;

g) description of the masonry units and the mortar, preferably consisting of the appropriate test reports, securely attached, or of extracts taken from these reports (see 5.7 and 6.5);

h) the compressive strength of the masonry units, in newtons per square millimetre to the nearest 0,1 N/mm^2, and the coefficient of variation;

i) the moisture content of units by mass at the time of laying;

j) the compressive strength of the mortar, in newtons per square millimetre to the nearest 0,1 N/mm^2, and the coefficient of variation, at the time of testing the wall and at 28 days;

k) individual and mean values for the compressive strength of the masonry, in newtons per square millimetre to the nearest 0,1 N/mm^2;

l) the stress, calculated in newtons per square millimetre, at which the first visible cracks occurred based on the loaded cross section;

m) the pattern of the fracture;

n) the lateral deflection at the mid-height of slender specimens;

o) remarks.

An addendum may be added to the test report (see 7.8)

7.8 Modified results

7.8.1 Adjustment for unit and mortar strengths

If the mean compressive strength of the masonry, f, is to be converted into a different compressive strength, f', which is related to a unit strength, f_b, and a mortar strength, f_m, different from those specified by the designer, the following equation may be used:

$$f' = f\left(\frac{f'_b}{f_b}\right)^{0,65}\left(\frac{f'_m}{f_m}\right)^{0,25}$$

This may be necessary if the compressive strength of the units, f_b, and of the mortar, f_m, at the time of masonry testing deviate from the minimum permissible mean values for masonry units of the appropriate strength class f'_b or for mortar of the appropriate mortar class f'_m and the masonry compressive strength values determined during testing need to be converted to match these minimum values.

Conversion of compressive strength values for units shall only be carried out when the tested mean strength is within ± 30 % of the specified strength.

7.8.2 Conversion factor

When storey-height wall specimens up to 250 mm thick, built according to 7.3.3.3, are tested, multiply the individual and mean values for the compressive strength of masonry by 1,1 and use these values for the calculation of the characteristic compressive strength in 7.8.3.

7.8.3 Characteristic compressive strength

The characteristic compressive strength f_k may be taken to be

$$f_k = \frac{f}{1{,}2} \text{ or } \frac{f'}{1{,}2} \text{ or } f_{min} \text{ or } f'_{min}$$

whichever is smaller, where

f_{min} is the smallest individual value;

f'_{min} is the smallest corrected individual value.

The characteristic strength of the masonry is calculated in newtons per square millimetre and expressed to the nearest 0,1 N/mm^2.

The modified results are an addendum to the test report.

8 Determination of the flexural strength of masonry

8.1 General

The flexural strength of masonry is related to the type and properties of the masonry unit and the designation of the mortar used. The flexural strength of masonry for use in design may be obtained by testing small wallettes under four point loading. These test pieces should be built from the units and mortar representative of those to be used in the design and should contain sufficient units to be reasonably representative of the finished masonry. For bonded specimens the number and spacing of the joints in the test pieces should represent as closely as possible those in the intended work.

8.2 Sample size

Sample the consignment of units from which the masonry specimens are to be built in accordance with clause 4.

Construct at least 10 wallettes of each format (see 8.3.2 and 8.5).

8.3 Preparation of specimens

8.3.1 Conditioning masonry units

Use masonry units and mortar representative of those for which data are required. Condition the units as follows.

a) Concrete masonry units including autoclaved aerated concrete

If instructed by the manufacturer, immerse concrete masonry units in water for 5 min to 6 min and allow to drain prior to building the wallettes. Alternatively adjust the water retentivity of the mortar.

b) Fired clay units

For fired clay masonry units having a suction rate of 1,5 kg/(m^2·min) or more, briefly immerse the units in water to ensure that the suction rate does not exceed this value. Unless the time required for immersion is known from experience, determine this by experiment. Alternatively adjust the water retentivity of the mortar.

c) Calcium silicate masonry units

Aim at a moisture content within the range (6 ± 2) % by mass. If necessary, immerse the units in water until the desired moisture content is obtained. Alternatively adjust the water retentivity of the mortar.

Record the method of conditioning the masonry units and the composition, water/cement ratio, consistence, density, air content and compressive strength determined in accordance with clause 6, of the mortar.

8.3.2 Construction of wallettes

If the units have been conditioned by immersion in water, build the wallettes within 30 min of removal from the water. Use mortar within 1 h of mixing unless it is designed to be used over a more prolonged period. Complete the work without interruption.

Build the wallettes in stretcher bond with a thickness equal to the width of the unit. The size of the wallettes depends on the size of the units. Minimum dimensions are given in Table 5 and typical specimens are shown in Figure 6.

Table 5 — Dimensions of wallettes

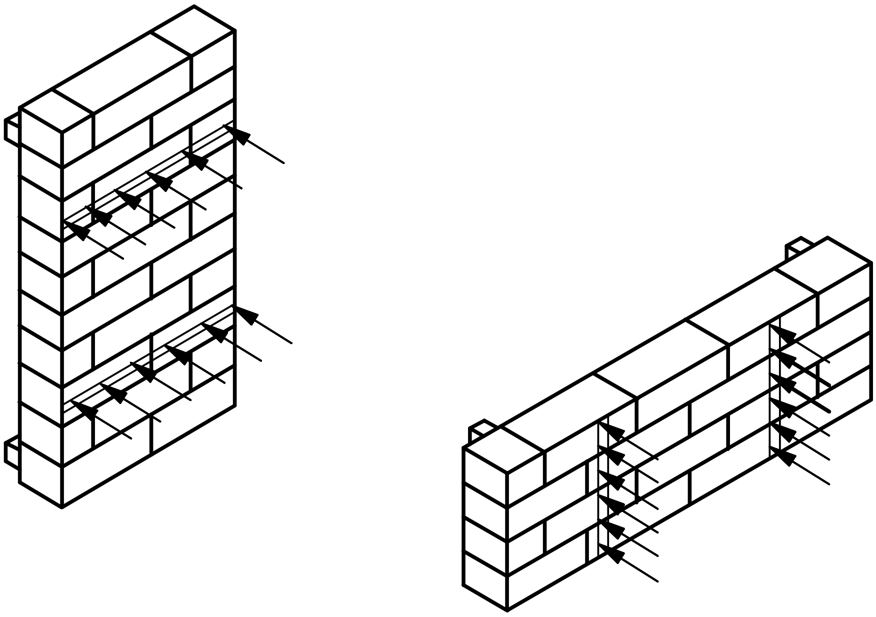
Unit type	Unit size			Direction	Minimum dimension		Minimum number of joints	
	l_u	h_u	t_u		h	b	Bed	Perp.
Brick	⩽ 300	< 75	< 120	P[a]	$10h_u$	$> 2l_u$	9	15
				R[b]	$4h_u$	$4l_u$	3	14
Block	⩾ 300	⩾ 75	⩾ 100	P[a]	$5h_u$	$1,5l_u$	4	5
		⩾ 250	⩾ 250	R[b]	$4h_u$	$2,5l_u$	3	8
Block	> 300	> 250	> 250	P[a]	$5h_u$	$1,5l_u$	2	3
				R[b]	$2h_u$	$2,5l_u$	1	4

[a] Parallel to bed joints.

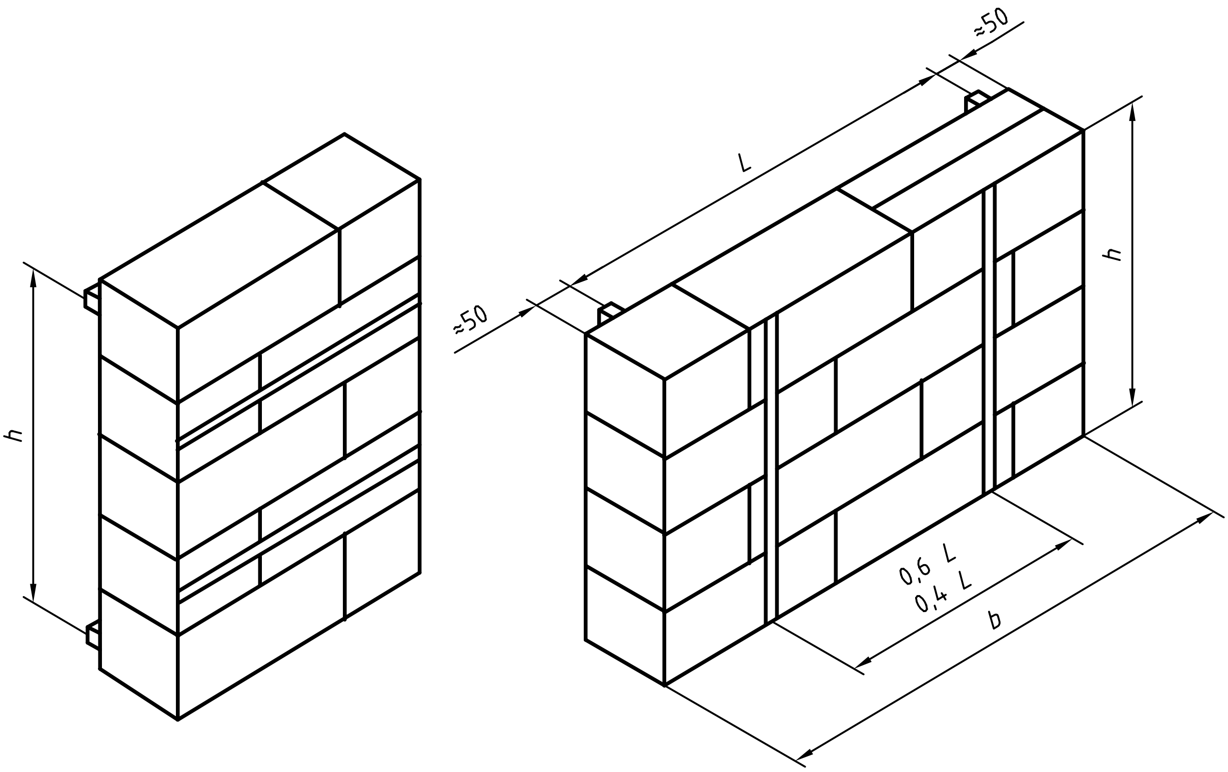
[b] Perpendicular to bed joints.

8.3.3 Curing

Immediately after building, precompress each wallette by a uniformly distributed mass equal to 250 kg/m^2 to 300 kg/m^2. Then cure the wallette by close covering using a material (e.g. polyethylene) that does not permit water vapour penetration. Maintain undisturbed until testing.



a) Type A



b) Type B

Figure 6 — Types of masonry wallette

8.4 Apparatus

The equipment shall accommodate variations of plane. Use suitable means at the contact area of the bearings to ensure that contact is provided over the full width of the masonry. For example, use a hollow rubber bolster of at least 7 mm wall thickness and 10 mm bore containing an 8 mm diameter steel rod or an hydraulic bolster consisting of 18 mm o.d. polyester-reinforced PVC hose filled with water and sealed.

The outer bearing shall be approximately 50 mm from the edge of the wallette. The spacings of the inner bearings may be varied to suit the format of the masonry but shall be between 0,4 and 0,6 times the spacing of the outer bearings. The distance between the inner and outer bearings shall not be less than the thickness of the masonry unit. If necessary, the size of the wallette shall be adjusted to ensure this. The inner bearings shall be located so that they are, as far as is practicable, midway between the nearest mortar joints, which are parallel to the bearings.

The base of each wallette shall be free from frictional restraint.

NOTE For example, by setting it on two layers of polytetrafluorethylene (PTFE) or on ball, needle or roller bearings.

8.5 Test procedure

Test each wallette at an age of 28 days ± 1 day in a vertical attitude under 4-point loading (see Figure 6). Test the specimens either in an appropriate testing machine regularly calibrated to ensure that it complies with the requirements given in Table 1 or use a special hydraulic loading system. In the latter case, preferably place a calibrated load cell between the hydraulic actuator and the load distribution beam. If a load cell is not used, the hydraulic system shall comply with the requirements of Table 4.

The rate of increase in flexural stress shall be between 0,3 N/(mm^2·min) and 0,4 N/(mm^2·min).

Record the load at which each specimen fails. In calculations discount any failure other than one occurring between the inner bearings, but record all the results [see 8.7 k)].

8.6 Calculations

Calculate the flexural strength of each wallette, in newtons per square millimetre, using the following formula:

$$f = \frac{3W(L - l)}{2bt^2}$$

where

f is the flexural strength, in newtons per square millimetre;

W is the applied load, in newtons;

L is the separation of the outer bearings, in millimetres;

l is the separation of the inner bearings, in millimetres;

b is the width/height of the specimen, in millimetres;

t is the thickness of the specimen, in millimetres.

In calculations discount any failure other than one occurring between the inner bearings. Use 10 individual results to obtain the mean flexural strength.

8.7 Test report

The test report shall contain the following information:

a) the number and date of this part of ISO 9652-4;

b) the number of specimens in each direction;

c) the date of building the specimens;

d) the date of testing;

e) curing conditions and temperature and humidity;

f) descriptions of the masonry units and the mortar, preferably consisting of the appropriate test reports, securely attached, or of extracts taken from these reports (see 5.7 and 6.5);

g) the method of conditioning the masonry units;

h) a description of the specimens, dimensions and bonding, direction of span;

i) the compressive strength of the masonry units, in newtons per square millimetre, to the nearest 0,1 N/mm^2 and the coefficient of variation;

j) the compressive strength of the mortar, in newtons per square millimetre, to the nearest 0,1 N/mm^2 and the coefficient of variation at the time of testing the wallettes and at 28 days;

k) individual flexural strengths, with notes on any unusual form of failure and any discarded results;

l) mean flexural strength;

m) remarks.

An addendum may be added to the test report (see 8.8).

8.8 Modified results

Obtain the characteristic flexural strength as follows. If the flexural strengths obtained from the replicates are

$$f_{x1}, f_{x2}, f_{x3} \ldots\ldots f_{xn}$$

calculate the values $y_1, y_2, y_3 \ldots\ldots y_n$

where

n is the number of replicates;

$y_i = \lg f_{xi}$ (i =1 to 10)

Then $y_c = \bar{y} - ks$

where

$\bar{y}$ is the mean of y_i;

s is the standard deviation of y_i (i = 1 to 10) and

k is a function of n.

Where results have been discarded, a minimum of 8 may be used for the characteristic flexural strength, adjustment of the results being made in accordance with Table 6.

Table 6 — Constant k as a function of number of replicates

n	k
8	2,01
9	1,96
10	1,92

Take the characteristic flexural strength to be $f_{xk} = \text{antilog}\,(y_\text{c}) = 10^{y_\text{c}}$

The modified results are an addendum to the test report.

9 Water absorption test for clay units (5-h boil)

9.1 Test specimens

The test specimens shall normally consist of whole units, but representative portions may be used when testing large units. Test 10 specimens.

9.2 Accuracy of weighings

Weigh each specimen to an accuracy of 0,1 %.

9.3 Preparation of specimens

Dry the test specimens to constant mass in a ventilated oven at 110 °C to 115 °C. Weigh each specimen when cool (see Note). Where only parts of whole units are to be tested, the pieces shall be sawn form the whole units, not snapped, and the pieces shall be as representative of the whole units as possible. If reasonably representative pieces cannot be obtained, then test all the pieces generated by the cutting process.

NOTE It may be assumed that heating for at least 48 h at 110 °C will assure constant mass, but it should be noted that several hours may be required before the specimens reach 110 °C if they are wet when put into the oven. The 48 h should be reckoned from the time the specimens reach 110 °C.

9.4 Test procedure

Immerse the specimens in a tank of water after weighing so that water can circulate freely on all sides of them. Provide the tank with a grid to ensure free circulation of water between bricks and the bottom of the tank. Heat the water to boiling in approximately 1 h and boil continuously for 5 h. Then allow to cool to room temperature by natural loss of heat for not less than 16 h or more than 19 h. Remove the specimens, wipe the surface water off with a damp cloth and weigh. When wiping perforated bricks, shake them to disperse any water that might otherwise be left in the perforations. Complete the weighing of any one specimen within 2 min of its removal from the water.

9.5 Calculations

Report the water absorption, A_W, as a percentage increase in mass of the dry specimens, calculated to the nearest 0,1 %:

$$A_W = \frac{100(M - m)}{m} \%$$

where

m is the dry mass, in grams;

M is the mass after boiling, in grams.

Record the arithmetic mean of the absorption of the ten specimens.

9.6 Test report

The test report shall contain the following information:

a) the number and date of this part of ISO 9652;

b) the date of testing;

c) the name of the organization that carried out the sampling and the method used;

d) the number of specimens in the sample and whether whole or part;

e) if portions of larger units are used, the size of the test specimens;

f) a description of the masonry unit, including type, dimensions, cross section and proportion and pattern of perforation;

g) the mass, in grams, of each specimen dry and after boiling;

h) the individual and mean values of water absorption, to the nearest 0,1 % stated as “water absorption, 5-h boil %”;

i) remarks.

Annex A
(informative)

Values of shape factor δ

Height [a] mm	Width mm				
	90	**100**	**150**	**200**	**250 and over**
50	0,80				
65	0,90	0,80	0,75	0,70	0,65
100	1,05	1,00	0,95	0,85	0,75
150	1,25	1,20	1,10	1,00	0,95
200	1,40	1,35	1,30	1,20	1,05
250 and over	1,50	1,40	1,35	1,25	1,20

NOTE Interpolation is permitted.

[a] After surface preparation.

Bibliography

[1] ISO 683-1, *Heat-treatable steels, alloy steels and free-cutting steels — Part 1: Direct-hardening unalloyed and low-alloyed wrought steel in form of different black products.*

[2] ISO 9652-1, *Masonry — Part 1: Unreinforced masonry design by calculation.*

[3] ISO 9652-2, *Masonry — Part 2: Unreinforced masonry design by simple rules.*

ICS 91.080.30

Price based on 28 pages