2.4 MECHANICAL TESTS ON MORTARS AND ASSEMBLAGES

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The mechanical characterisation of mortars sampled from existing masonry is usually very difficult when not impossible. Joints are usually so thin that it is impossible to apply the traditional codified tests that are carried out on new mortars produced in laboratory. Furthermore, it is important to characterise the masonry as a whole rather than as single components. Masonry is a composite material that is frequently inhomogeneous. A relationship between the components and the masonry itself usually does not exist. Nevertheless, a mechanical characterisation of the original mortar can be useful to inform the choice of mortar for repair. In the last decade many proposals have been made of tools for the on-site characterisation of mortars (drills, Schmidt hammer, etc). For the laboratory characterisation of historic mortar samples some tests are proposed below within these Recommendations.

1. Tests on old mortars

1.1. On-site

Some tests can be carried out only on the external part of the mortar joints or to a certain depth. There are several mechanical tests, but the most widely used, that are already recommended by RILEM are the following:

1) *Pointing hardness test*: Carried out with the pendulum Schmidt Hammer. This test is drafted in the RILEM TC127MS D.2.

2) *Penetration tests*: Carried out with special drills (no RILEM drafts currently. However, they are being prepared by RILEM TC177MDT)

Other tests which can be carried out on-site on old masonry assemblages are the following:

3) *Measurement of the stress-strain behaviour in compression by double flat-jack* (new draft to be published by RILEMTC177MDT)

4) *Measurement of bed joint shear strength:* (RILEM 127MS D.6)

5) *Bond strength of mortars using the Bond Wrench:* (pr EN1052-5, March 2002) (modification by RILEMTC167COM)

The use of the *Pointing hardness test* is limited for the application to putty limes or lime mortars very rich in lime. In those cases low rebound values can be recorded. This does not mean that the mortar is in bad condition. As the classification of this test is meant for cement based pointing a new calibration for lime based mortars is recommended.

The use of the *Penetration test* is limited by concerns over the fact that the penetration of the drill is limited to few millimetres. The tests are not currently calibrated for mortars.

The flat-jack test, bond shear strength test and the Bond Wrench test(tests 3,4 and 5) can only be carried out on regular (not rubble) stone or brick masonry and are slightly destructive.

For thick mortar joints, such as a late Roman or Byzantine style masonry, a non-destructive technique can be applied for the evaluation of the dynamic modulus of Elasticity of old mortars:

6) Measurement of velocity by Ultrasonic sonometer: (I. Papayanni)

1.2. Laboratory-based tests on sampled mortars

Generally on samples of mortar joints or pointing it is either very difficult to carry out standard compression tests or the results may not be very meaningful.

When the size of the mortar joint is in the order of 30 to 40mm the following mechanical tests can be carried out:

1) *Compression test* (EN1015-11)
2) *Indirect tensile strength* (RILEMTC76LUMA.3 on hollow bricks)

For thin mortar joints the following two tests are proposed within RILEM TC 167COM.

The reliability of the tests also depends on the ratio of maximum size of aggregate/cube dimension.

1) *Splitting test* **(**Recommendation prepared by RILEMTC167COM**)**
2) *Compression tests on sampled joints* (Recommendation prepared by RILEMTC167COM).

2. Tests on new mortars

2.1. Tests on mortar alone.

On new mortars for repair mechanical tests can be carried out following CEN Standards at different ages in order to follow the hardening process.
The following tests can be carried out:

1) *Compression test* (EN1015-11)
2) *Flexural test* (EN1015-11)
3) *Splitting test* (RILEMTC167COM)

2.2. Bond strength test on masonry assemblages

Several types of tests have been proposed concerning the mechanical bond strength between mortars and brick/stone. The most commonly used are the following:

1) *Shear bond strength* : is carried out on triplets (RILEM 127MS.B.2 or prEN 1052-3 on "Determination of INITIAL shear strength"- Nov 2001)
2) *Bond wrench test* (RILEM 76LUM B.3)
3) *Direct tensile strength on a couplet* (no Recommenation)
4) *Couplet shear test* (no Recommendation)

A modified bond wrench test is proposed for the flexural bond strength of pointing mortar within RILEM TC167COM

These tests are applicable to new production mortars for new building. In the case of new mortars for repair of historic masonry, their properties and requirements might require a careful revision of the existing documents.

3. Conclusions

Tests for application to the mechanical characterisation of relatively thin mortar joints are currently lacking. This also applies to tests on the characteristics of bond in pointing.

In summary draft recommendations have been developed on:

1) Compression (≥ 10mm)
2) Splitting (min 20mm)
3) Modification of bond wrench test

COMX: BOND STRENGTH OF REPOINTING USING THE BOND WRENCH METHOD

CONTENTS

C.X.1 SCOPE

This recommendation is a modification of the draft LUMB3 published by RILEMTC 76LUM which specifies a method of determining the flexural bond strength between masonry units and mortar[Rilem,1991]. This recommendation specifies a method of determining the quality of joint re-pointing and/or to compare different re-pointing mortars, through the flexural bond strength between masonry units and re-pointed mortar joints. The apparatus may be used to test any size of masonry unit (bricks and stones) but the apparatus dimensions will need to be adjusted appropriately. It describes the preparation of the specimens, the conditioning required before testing, the apparatus, the method of test, the method of calculation and the contents of the test report.

C.X.2 SPECIMENS (size, shape and numbers)

Specimens should be in the form of simple stack bonded prism of two or more units. Such specimens represent most faithfully the conditions of cure in a normal masonry wall. For units and mortars with a very low mutual bond strength it may be preferable to build the requisite number of specimens in the form of couplets but each batch should be cured together in a common environment not individually wrapped. Where a good bond is likely, prism of small units up to 11 high may be built. Figure 1 shows a typical 7 units prism. For research purposes the amount of replication necessary is determined by the objectives of the work. To provide data for design or to justify proposed construction, a minimum of five joints shall be made for each determination.

C.X.3 PREPARATION OF SPECIMENS

The specimens shall be constructed on a clean level surface with the sides at right angles to the base and the top parallel to the base (checked with a spirit level). The construction shall be carried out with the units in the same attitude as they will be in the masonry. All joints should

be of uniform thickness and full of mortar, leaving a recessed joint for a depth equal to the depth of the chosen re-pointing (Fig. 2a).
Care should be taken to ensure that the units are in a moisture state appropriate to the objective of the tests and that the consistence of the mortar is properly adjusted to the state of the units. When the results are to be used for design purposes the following standard moisture states are suggested:
Units having an initial rate of suction rate of more than 1.5 $Kg/m^2/min$ should be docked (wetted) or the water retentivity of the mortar should be adjusted.
Immediately after building, each prism shall be pre-compressed with dead-weights to a level of 400 Kg/m^2 (equivalent to three courses of small units laid dry).
After the required curing time for mortar joints to harden, the re-pointing should be carried out (Fig. 2b), previously wetting the existing mortar joint and following the best practice; specimens should be stored again allowing for the re-pointing mortar to harden.

C.X.4 CONDITION OF STORAGE

Laboratory specimens built with recessed joints should be stored for 28 days ± 1 day in the laboratory at a temperature of between 10 and 20°C and at a relative humidity of 60% if the mortar joints are made of hydrated lime. The humidity condition may be achieved by closely covering with a sheet material which does not permit water vapour penetration. The temperature and humidity of the laboratory and the state of the specimens should be recorded continuously. The specimens should be left undisturbed until ready for re-pointing.

Site specimens should be stored in similar conditions to that prevailing on site before and after re-pointing. In the case of cement mortars they may be tested even at seven days plus the following periods as applicable: (i) when retarded mortar has been used, the non expired period for which the mortar was retarded . (ii) the full amount of time that the air temperature eventually remains below 4°C. (iii) half the period of time that the air temperature lies between 4°C and other temperatures.

C.X.5 APPARATUS

Figure 3 illustrates the principle of the bond wrench applied to re-pointing.
A bond wrench is a lever that can be clamped to the top unit of a prism and is of such mass and proportion that the stresses imposed by the bond wrench at the start of a test do not exceed 0.1 N/mm^2 in either flexural compressive stress or flexural tensile stress. Load may be applied in a number of different ways. Four typical methods are as follows: (i) By filling a container hanging from the moment arm of the wrench with lead shot or an alternative material, delivered in a steady stream. The amount delivered should be assessed by weighing on a balance accurate to within ±25g. (ii) By driving a mass out along the moment arm at a steady rate and in such a way as not to cause shock or other disturbance. (iii) By operation of a hydraulic ram of a suitable capacity attached to a point along the moment arm via a steel wire or articulated tie. (iv) By manual application of force via a measuring device such as a load cell. Other methods of load application may also be satisfactory provided the accuracy is comparable. A method of load application was also proposed within an EC contract on repointing [Binda et al, 2001]. In fact when the re-pointing and the jointing are weak the failure of the bond can be very sudden; in that case the load rate can be kept as low as possible by substituting the lead shots with a constant water flow (Fig 4).

Additionally a clamping device (e.g. as in Figure 5) is required which can firmly clamp the unit one down from the top of the prism whilst not applying any significant bending moment to the joints below. In order to calibrate the equipment determine the mass of the wrench (m_4) to ±10g, the distance from the inside edge of the outer clamp face to the loading notch (e_3) to within ±2 mm and the distance from the inside edge of the outer clamp face to the centre of gravity of the wrench (e_4) to within ±2 mm (see Figure 6). The type with the driven mass will require the measurements to be made with the mass in the start position. Where a container is used it should be in place but empty; if a jack is used the wire should be attached to the arm but slack.

C.X.6 DISPLACEMENT MEASUREMENT

To enable the monitoring of the strength of pointing when its bond strength is very low, 4 displacement transducers can be applied on the clamping devices near the area where the highest tensile stresses are applied corresponding to the most external point of the pointing and at the end of jointing (Fig.4) so that the displacements of these two important points can be measured.

Fig.7 shows an example of the load-displacement plot obtained in one case; the couples of points 1-4 and 2-3 must have the same displacement if the test is successful.

C.X.7 PROCEDURE

(i) Position the prism leaving the re-pointing on the external side (Fig.3). (ii) Securely clamp the prism in the retaining frame such that the second from top unit has a reasonable degree of restraint against rotation but the joint to be tested is between one and three millimetres clear of the clamp. The clamp should be faced with thin layers of a resilient material such as plywood to ensure an even grip. If the mortar joints is pointed in a way which reduces the overall bonded width, the test should be set up with this face in tension. The clamp must be supported to stabilise it against the overturning moment generated during loading. (iii) Clamp the bond wrench to the top unit carefully again using plywood packing and adjust to make the moment arm horizontal. (iv) The load should be applied smoothly such as to give a rate of increase of flexural stress between 0.3 and 0.4 $N/mm^2/min$ until failure. (v) Measure the mass of the top unit and any adherent mortar (m_2) to within ±25g, the mass of the weight or container (m_3) to within ±25g, the distance of the weight from the start position (when moved) and the dimensions of the bed joint to within ± 2mm. (vi) Repeat the procedure for subsequent joints or specimens. Fig 8 shows the failure of the upper and bottom joint for a 5 course specimen.

C.X.8 TEST RESULTS

Calculate the failure stress S, in N/mm^2 as follows:

S = N/Z – W/b. d

where:

M = the bending moment at failure in Newton-mm.

Z = section modulus of joint in cubic mm = $b.d^2/6$.

W = maximum compressive load applied to the joint, expressed in Newtons.

b = the mean width of joint at the line of fracture, mm.

d = the mean depth of joint at the line of fracture, mm.

The failure stress is the value of the bond strength of re-pointing, since the highest state of tensile stress is located exactly on the most external point of the re-pointing.

Where the lead shot or jack system is used and the specimen is built from solid units laid on a full bed of mortar the expression for the failure stress is given by:

$S = g(e_4. m_4. + e_3.m_3 – (2/3).d. (m_4+ m_3 + m_2/4))/ Z$

Where additionally:

g = gravity constant = 0.98 m/sec^2.
m_4 = mass of bond wrench kg.
m_3 = mass of applied load in kg or the load applied via the jack in kg.
m_2 = mass of masonry unit and adherent mortar in kg.
e_4 = eccentricity of centre of gravity from outside face of specimens in mm.
e_3 = eccentricity of applied load from outside face of the specimen in mm.

Report the bond strength to the nearest 0.01N/mm^2 for individual specimens and to the nearest 0.05N/mm^2 for the mean result.

C.X.9 TEST REPORT

(1) A reference to this RILEM standard.
(2) A description of the specimens including their overall size and shape, bonding and joint thickness.
(3) The method of sampling of the units.
(4) A description of the units including a sketch showing the dimensions, and shape, pattern and size of holes and the properties of the units including body material, strength and, where appropriate, water absorption, IRS, density.
(5) The composition, the porosity, capillary rise coefficient, the water retention, the tensile and compressive strength of the bed mortar and of the re-pointing mortar used.
(6) The date of preparation of the specimens, of the re-pointing and the date of the test.
(7) The conditions of storage.
(8) All individual failure loads in Newtons and relevant dimensions in mm.
(9) The values of the 4 points displacement at failure and the stress-strain plot when the displacement measurement devices are applied
(10) The point of failure e.g. within mortar, at upper or lower unit/mortar interface etc.
(11) All individual values of bond strength calculated as specified.
(12) Mean bond strength, and the bond strength.
(13) Sample standard deviation and coefficient of variation (%).

C.X.10 REFERENCES

1. RILEM TC 76 LUM B.3 9/2 (1991), Bond strength of masonry using the bond wrench method.

2. Binda, L., Cardani, G., Tedeschi, C. (2001), Laboratory mechanical tests for the evaluation of the mortars for re-pointing , Final report EC Contract ENV4 CT98-706, Maintenance of pointing in historic buildings: decay and replacement.

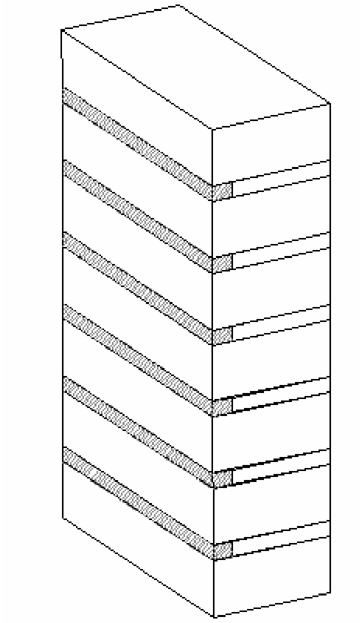


Fig.1. 7 high stack bonded specimen

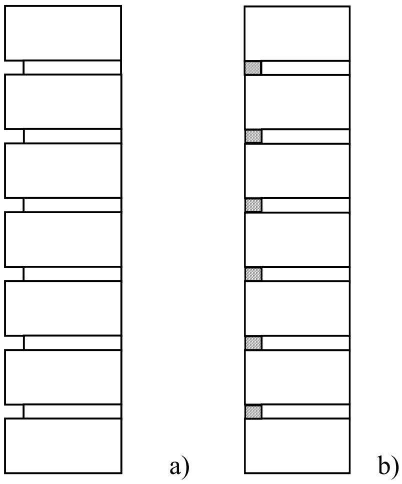


Fig.2. a) Construction of the specimen;
b) Repointing the specimen

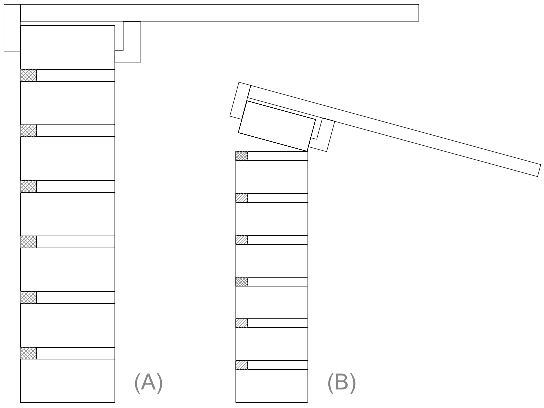


Fig. 3. Basic principle of bond wrench test (A) before and (B) after loading

Fig. 4. Loading with water flow (right bottom) and displacement measurement transducers

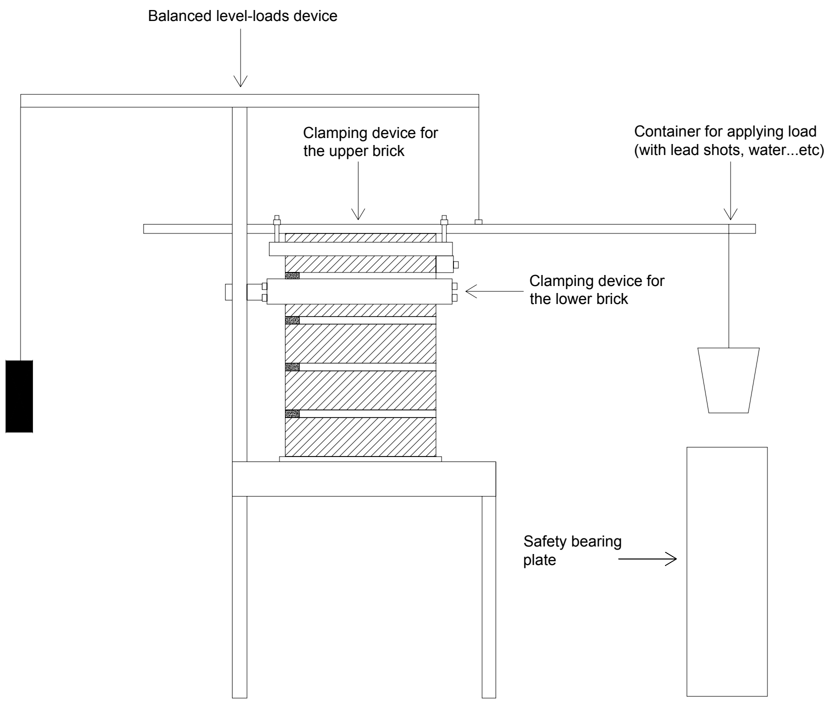


Fig 5. Testing machine for the determination of masonry flexural bond strength

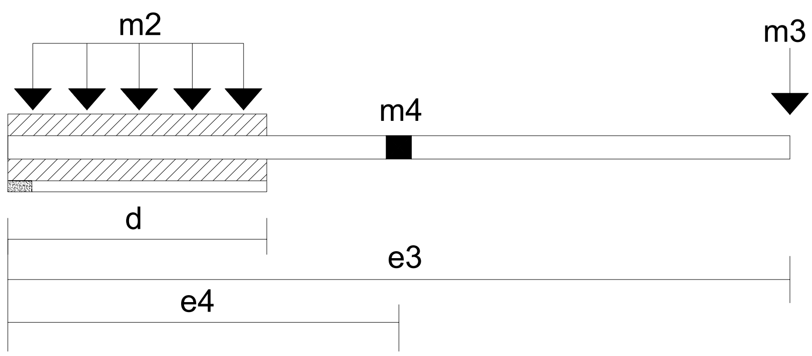
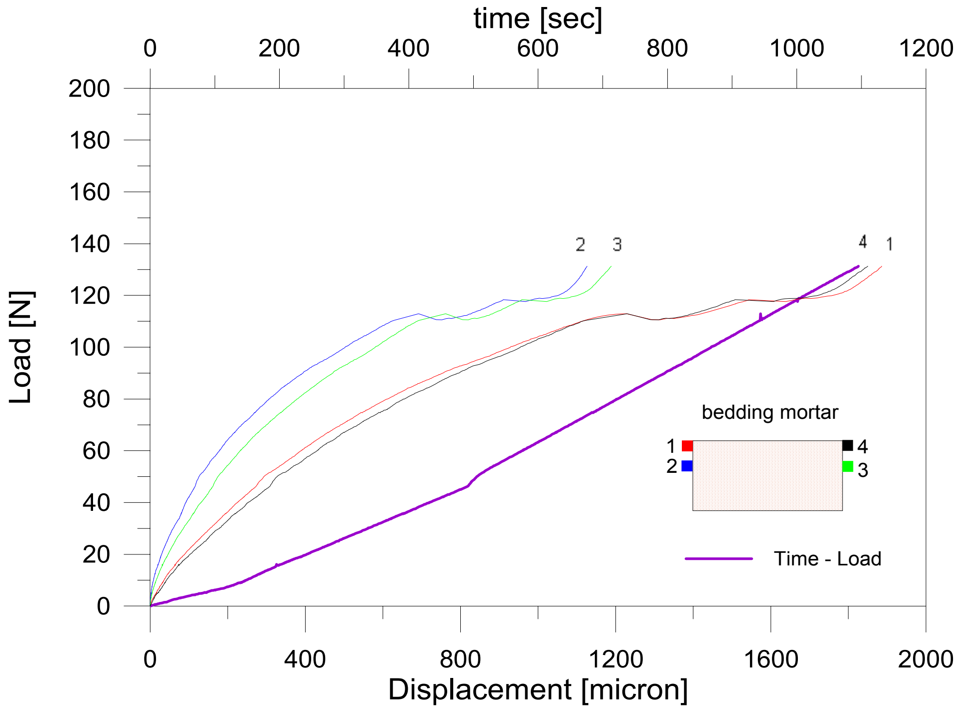


Fig 6. Load application produces an eccentric axial force



Pointing mortar (only) $\sigma = 0.292$ N/mm^2 (bed2s02b)

Fig. 7. Load/displacement plot of the four measured points and time-load plot

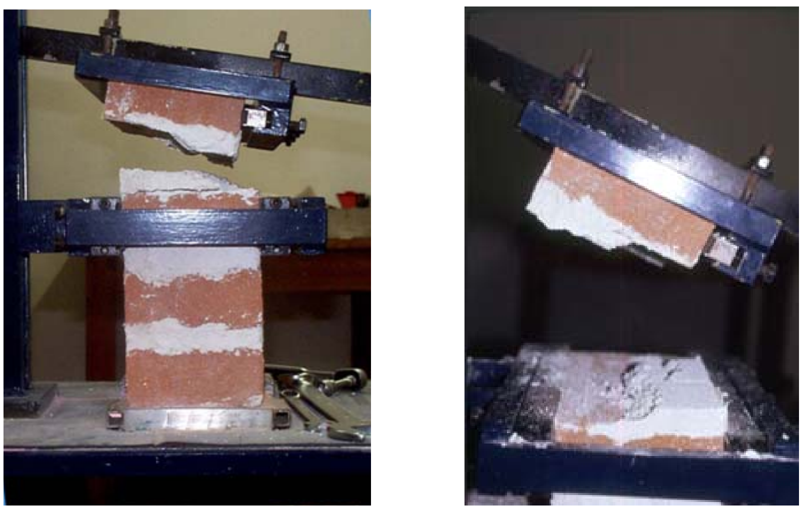


Fig. 8. Sequence of failure in a five course specimen

COMY: SPLITTING TEST FOR NEW AND ON-SITE SAMPLED MORTARS

CONTENTS

C.Y.1 PREMISES AND SCOPE

This recommendation specifies the method of determining the value of the indirect tensile strength of new and on-site sampled mortar specimens [Gonnerman and Shuman, 1928); Neville, 1963].

Due to the difficulty of carrying out direct tensile tests on porous materials and especially on very weak materials like masonry mortars, these tests are usually avoided and indirect tensile tests are preferred. The most frequently used are the flexural tensile strength test and the splitting strength test. The flexural test is carried out as shown in Fig. 1a and the splitting test in Fig.1b.

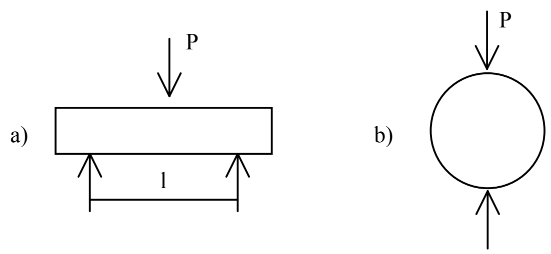


Fig1a,b. Indirect tensile tests schemes: a) flexural tensile strength test; b) splitting test.

Nevertheless it is very difficult to extract from old masonries a specimen of mortar with the right dimensions to carry out a flexural test. Therefore splitting tests are preferred because they also accept small dimensions (Fig.1b). The splitting test for cylindrical concrete specimens is described in the **ASTM** C496-96 and in the Italian UNI 6135 (where also prismatic specimens are accepted). It is convenient to adopt this test to gain an estimate of the tensile strength of the material. Usually the splitting test gives a tensile strength higher than that of the direct tensile test [Goodman, 1989, Touren and Denis, 1970]. If compared, the two types of tests (as mentioned in the literature for concrete), the flexural strength test results are more reproducible. Nevertheless in some cases (damage due to high compression stress) the splitting test failure better describes the failure mechanism. Different sizes of specimen can also be tested.

C.Y.2 SPECIMENS (size, shape and numbers)

Specimens should be cylindrical or prismatic. The minimum dimension should be a diameter of 25mm when cylindrical and a section of 20x20mm when prismatic. Sampled specimens should be in a minimum number of three.
The number of specimens prepared in laboratory should be at least 6. The size of specimens depends on the aggregate size and the minimum dimension.

C.Y.3 ON-SITE SAMPLING OF SPECIMENS

When the tensile strength of old mortars is required, samples should be taken on-site. Samples extracted from the internal part of the wall from joints with a minimum thickness compatible with the dimensions given above, or from rubble filled areas. In order to prevent damage to the specimens, coring should, if possible, be avoided. Sampling should be carried out preferably in dry conditions, so when coring the minimum amount of water should be used.

A h/d ratio of the specimen of 2/1 or less (up to 1.5) can easily be used and it is recommended (Fig.2).

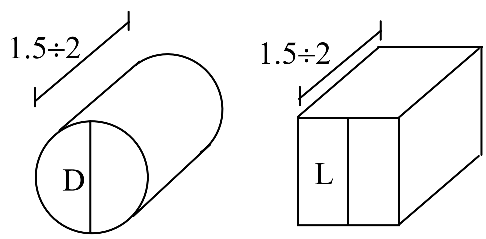


Fig. 2. Mortar cylinder and prism for the splitting tests.

C.Y.4 PREPARATION OF SPECIMENS

When the tensile strength of new mortars is required, samples should beprepared in the laboratory. Once the specimens have reached the appropriate time of curing they can be dry-cut into prisms and the prisms tested applying the splitting test.

When testing the reliability of a mortar to be used in practice, the specimens should be prepared preferably between two wet bricks/stones of the same type of the ones which will be used on-site. In order to allow that after curing, the mortar bed to be separated from the bricks, during the preparation a gauze should be put between the brick surfaces in contact with the mortar and the joint itself. The thickness of the joint should be such that the minimum dimensions of the specimen as required in C.Y.3 be respected. Care should be taken to ensure that the units are in a moisture state appropriate to the objective of the tests and that the consistence of the mortar is properly adjusted to the state of the units. When the results are to be used for design purposes the following moisture states are suggested:

- Masonry units having an initial rate of suction (IRS) of more than 1.5 $Kg/m^2/min$ should be docked (wetted) or the water retentivity of the mortar should be adjusted.

- Immediately after building, each specimen shall be pre-compressed with dead-weights to a level of 400 Kg/m^2 (equivalent to three courses of units laid dry) [*prEN 1052-3-2001 suggests to load with a mass uniformly distributed between* $2.0x10^{-3}$ N/mm^2 *and* $5.0x10^{-3}$ N/mm^2] After the required curing time for mortar joints to harden, the joint should be separated from the bricks/stones and the specimen cut in the right dimension for the test.

In any case the specimen shape should be as described in Fig.2.

C.Y.5 CONDITION OF STORAGE

The specimens should be left during the curing time between two wet bricks/stones. Laboratory specimens should be stored for 90 days in the laboratory at a temperature of between 10 and 20°C and at a relative humidity of 50 to 60% if the mortar joints are made of hydrated lime. The storage should last 28 days ± 1 day, in a controlled chamber at a temperature of 20°C±1 and at a relative humidity of 90% in the case of lime- pozzolana and hydraulic lime mortars. The moisture content must be recorded.

C.Y.6 APPARATUS

Any mechanical or hydraulic press able to carry out compression tests at the required controlled rate of loading.

C.Y.7 PROCEDURE

The specimen is centred under the machine platen located as shown in Fig.3. A strip of cardboard of the length of the specimen and 3mm thick is put on top and bottom of the specimen between machine platens and the specimen, in order to have a correct load application. In the case of cubic or prismatic specimens steel rolls should be used instead of cardboard.

A range of loading application gradient of 0.02 and 0.05 $N/mm^2 \cdot sec$ is requested. A low loading rate is preferred for weak materials. In these cases, with test time of longer than 1 minute, the effects of the initial deflection of the cardboard strip can be excluded.

The failure occurs when the specimen splits and the corresponding load is considered as the failure load. Failure must occur clearly along the loading direction the specimen (Fig. 3).

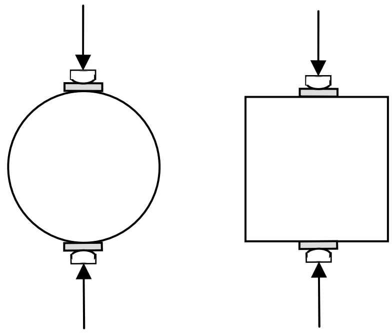


Fig.3 Testing scheme

The test reliability is considered good only if the splitting occurs along the vertical diameter following a plane surface.

C.Y.8 TEST RESULT

The tensile strength is calculated as:

$R_c = P/\pi\, r^2$ *(for cylinders)*
or P/A *(for prisms)*

where:
P is the maximum load at failure
r is D/2
A the theoretical failed section area in mm^2

C.Y.9 TEST REPORT

(1) A reference to this RILEM standard.
(2) A description of the specimens including their origin (if from site or from laboratory), overall size and shape and way of cutting if any.
(3) The method of sampling if on-site.
(4) The date of preparation of the specimens, if made in laboratory, of the re-pointing and the date of the test.
(5) The conditions of storage.
(6) The moisture content.
(7) The composition, the porosity, capillary rise coefficient, the water retention (if prepared in laboratory) of mortar.
(8) A description of the units including dimensions, and shape, and the properties of the units including body material, strength and, where appropriate, water absorption, IRS, density.
(9) All individual failure loads in Newtons and mechanism of failure.
(10) All individual values of tensile strength calculated as specified.
(11) Mean strength.
(12) Sample standard deviation and coefficient of variation (%).

C.Y.10 REFERENCES

1. Gonnerman, H., Shuman, E.C. (1928), 'Compression, flexure end tension tests of plain concrete'. *Proc. A.S.T.M.,* **28**, parte II, pp. 527-73,
2. Neville, A.M. (1963), 'Properties of Concrete', *Pitman Publishing Ltd.,* London.
3. ASTM C496-96. (2003), Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens. ASTM International, 2003
4. UNI 6135, 'Prove distributive su calcestruzzi', Prova di trazione, Settembre 1972
5. Goodman, R.E. (1989), 'Introduction to Rock Mechanics', John Wiley & Sons, New York.
6. Touren, C. and Denis, A. (1970), 'The tensile strength of rocks', *Lab the Ponts et Chaussées-Paris,* Research Report 4, 1970

COMZ: Compression test on new thin joints and on on-site sampled thin joints

CONTENTS

C.Z.1 PREMISES AND SCOPE

This recommendation specifies a method of determining the "crushing value" of new and on site sampled mortar joints. The basic set-up of this test is derived from DIN 18555-9, 1999. Due to the dimension of the specimen the value obtained is not a real compression strength.

Due to the difficulty of carrying out standardised compressive strength tests on mortar joints that are usually very thin, this test does not require the minimum specimens thickness of 40mm as required by existing mortar tests. The scope of this test is to determine the compressive strength of mortar in the joints. The only requirement is that an entire piece of joint can be sampled. The calculated strength can be used for structural analysis purposes or used for comparison with mortars for repair. However, it is important that these localised values should be representative of the whole structure.

C.Z.2 SPECIMENS (size, shape and numbers)

Specimens can be sampled on-site or prepared in laboratory. In the first case the test results give the estimation of the compressive strength of the mortar in an existing masonry, in the second case the results can be used to compare and qualify new mortars for joint repair. The size of the specimen should be full joint thickness. The length and width should be 100x200mm for new specimens, as much as possible near to these dimensions for the sampled ones.
The shape of the specimens can be prismatic or cylindrical as shown in Fig.1.

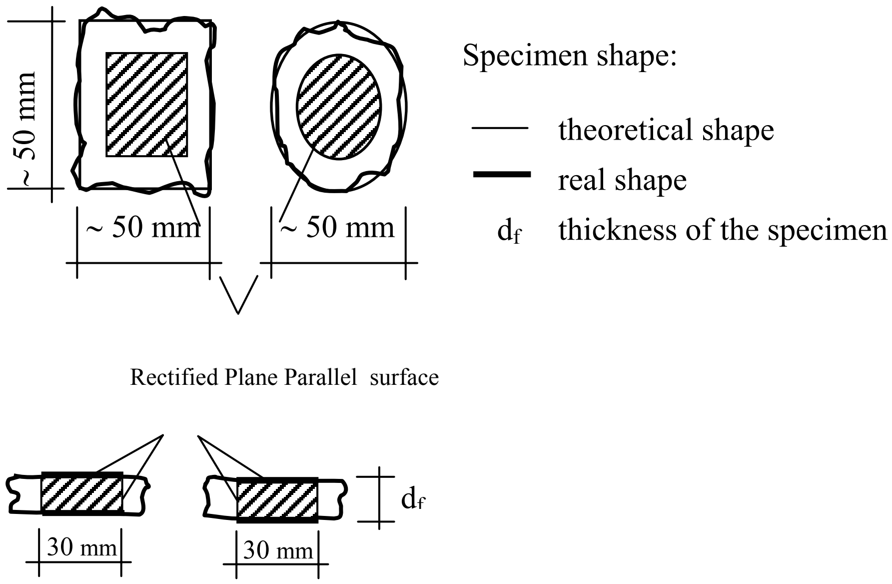


Fig. 1 Shape and dimensions of the specimens [acc.to DIN18555-9]

The number of specimens taken from masonry should be at least ten. The number of lab prepared specimens should be at least six.

C.Z.3 ON-SITE SAMPLING OF SPECIMENS

When the compressive strength of old mortars is required, samples should be cored on site. They can be cylindrical or prismatic specimens of the dimensions defined in C.Z.2 (Fig.1). Samples should be taken by extracting two bricks or stones connected with a bed joint. The joint should have a certain thickness and consistency so that the two elements can be separated without spoiling the joint.

From these cored samples, which should be cored perpendicular to the bedding, specimens with a dimension of about 80x80 mm or with a diameter of 80 mm should be obtained. Also smaller specimens can be obtained, at least 50 x 50 mm. Sampling should preferably be carried out in dry conditions. If specimens are wet, they must be dried at 40 °C until constant mass is reached, with a variation of ±0.1% of the mass, within 24 hours.

C.Z.4 PREPARATION OF SPECIMENS

When testing the reliability of a mortar to be used for repair in a real case, the specimens should be prepared, preferably between two bricks (pre-wetted if necessary) of the same type as those which will be used on site. In order to allow that after curing, the mortar bed to be separated from the bricks, during the preparation a gauze should be put between the brick surfaces in contact with the joint and the joint itself. The thickness of the joint should be such that the minimum dimensions of the specimen as required in C.Z.2 be respected. Care should be taken to ensure that the units are in a moisture state appropriate to the objective of the tests and that the consistence of the mortar is properly adjusted to the state of the units. When the results are to be used for design purposes the following aspects and procedures are suggested:

- Fire clay and stone units having an initial rate of suction of more than 1.5 Kg/m^2/min should be docked (wetted) or the water retentivity of the mortar should be adjusted.
- Immediately after building, each specimen shall be pre-compressed with dead-weights to a level of 400 Kg/m^2 (equivalent to three courses of small units laid dry).
- After the required curing time for mortar joints to harden, the joint should be separated from the bricks and the specimen cut in the right dimension for the test.
- The specimen shape should be as described in Fig.1.
- The specimen can be tested dry or water saturated up to constant mass. Before testing the upper and lower surfaces of the specimens should be made smooth and plane by polishing them carefully or eventually by adjusting two thin smooth layers of gypsum (Fig.1).

C.Z.5 CONDITION OF STORAGE

Laboratory specimens should be stored for 90 days for lime mortar, in the laboratory at a temperature of 20°C and at a relative humidity of 50 to 60% if the mortar joints are made of hydrated lime. The storage should last 28 days ± 1 day and at a relative humidity of 75% in the case of hydraulic lime mortars. In this case the humidity condition may be achieved by closely covering with a sheet material which does not permit water vapour penetration. The temperature and humidity of the laboratory should be recorded continuously. The temperature and humidity conditions of the specimens should be recorded continuously.

C.Y.6 APPARATUS

Any mechanical or hydraulic press able to carry out compression tests at controlled rate of loading.
Two special punching devices with a contact surface diameter of 40 mm for specimens of 80x80 cm or of 20 mm for specimens of 50x50 cm, as shown in Figure 2.

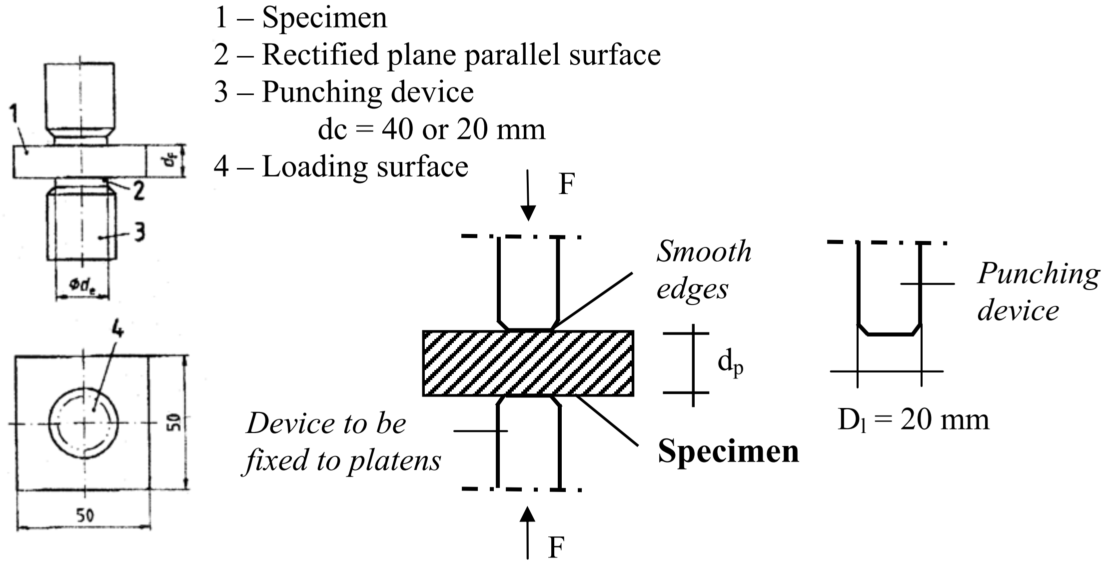


Fig.2. Testing device and procedure [acc. to DIN 18555-9]

C.Z.7 PROCEDURE

The specimen is centred under the machine platens and in the pressure device (diameter of 20mm) shown in Fig.2. The value of the failure load F max should be reached in 1 to 1.50 min.

C.Y.8 TEST RESULTS

The compressive strength of the mortar joint is calculated as a mean value of the single values. The single compressive strength is calculated as:

$R_c = P/\pi r^2 \text{ or } F_{max} / A$

where:
P is the load in N
r is the radium of the tested surface
A = loading surface, 1600 mm^2 or 314 mm^2 depending of the specimen dimension

C.Z.9 TEST REPORT

(1) Name of the Building.
(2) A reference to this RILEM standa rd.
(3) Name and description of the specimens including their origin (if from site or from laboratory), overall size and shape and way of cutting if any. (information about type of mortar, composition, ratios, etc.).
(4) The method of sampling if on site.
(5) The date of preparation of the specimens, if made in laboratory.
(6) The conditions of storage.
(7) The composition, the porosity, capillary rise coefficient, the water retention (if prepared in laboratory) of mortar.
(8) A description of the units including dimensions, and shape, and the properties of the units including body material, strength and, where appropriate, water absorption, IRS, density.
(9) Date of the test
(10) All individual failure loads in N and mechanism of failure.
(11) All individual values of tensile strength calculated as specified.
(12) Mean strength.
(13) Sample standard deviation and coefficient of variation (%).
(14) Observation if any

C.Z.10 REFERENCES

1. DIN 18555-9 - Prüfung von Mörtel mit mineralischen Bindermitteln, 1999-09