Materials and Structures/Matériaux et Constructions, Vol. **31**, October 1998, pp 513-521

RILEM TC 127-MS: TESTS FOR MASONRY MATERIALS AND STRUCTURES

RILEM TECHNICAL COMMITTEES

Recommendations

Foreward:
The texts presented hereunder are drafts for general consideration. Comments should be sent to the Chairlady:
Prof. Luigia Binda, Politecnico di Milano, Dipartimento di Ingegneria Strutturale, Piazza Leonardo da Vinci 32, I-20133 Milano, Italy. Fax: +39 2 23 99 4300; E-mail: binda@rachele.stru.polimi.it, by 1st April 1999.

TC MEMBERSHIP: Chairlady: Luigia Binda, Italy; **Secretary**: Bob de Vekey, UK; **Members**: Abderrahim Acharhabi, Morocco; Giulia Baronio, Italy; Peter Bekker, The Netherlands; Greg Borchelt, USA; Norman Bright, UK; Frieder Emrich, Switzerland; Mike Forde, UK; Hector Gallegos, Peru; Caspar Groot, The Netherlands; Ed Hedstrom, USA; Steve Lawrence, Australia; Paul Maurenbrecher, Canada; Claudio Modena, Italy; Adrian Page, Australia; Felicita Pires, Portugal; Dimitri Pumé, Czech Republic; John Roberts, UK; Pier-Paolo Rossi, Italy; Stephan Schmidt, Germany; Peter Schubert, Germany; Mike Schuller, USA; Siegfried Stöckl, Germany; Timber West, ISO-liaison representative.

MS.A.3. Unidirectional freeze-thaw test for masonry units and wallettes

CONTENTS

A.3.1 SCOPE

This recommendation specifies a method of determining the freeze/thaw resistance of masonry units and wallettes employing a uni-directional freezing system as basically described in the Dutch Standard 'NEN 2872' [1] for stony building materials, *i.e.* masonry units, tiles, composites and components, but updated to the latest state of the art. A characteristic of this method for accelerated testing is that, in odd-numbered cycles, freezing proceeds at a relatively fast rate and the temperature drops far below zero whereas, in even-numbered cycles, freezing proceeds relatively slowly and the temperature drops to just a few degrees below zero. The magnitude of the stress ratios (generated by ice formation) results from the level of water saturation of the specimen(s).

Guidance is given on the preparation of specimens, the conditioning required before testing, the apparatus, the test procedure, damage assessment and the test report.

A.3.2 SPECIMENS (size, shape, numbers)

Masonry Units:

Specimens should be normal whole units as in masonry practice. Sampling is, generally, prescribed in relevant standards, *e.g.* in a given standard for fired-clay bricks. If not, there are two methods for sampling:

1. Randomly, that is, each unit of a population (lot or batch of units) has an equal probability to be drawn. It is preferable to sample in accordance with ISO 2859 and interpret by the attributes method. The sample size will increase in inverse proportion to the -acceptable quality level (AQL), *i.e.* as AQL decreases, *e.g.* 125 units if one failure is acceptable.

2. Selective, that is, only units which are causing doubt are drawn for testing. In such cases, the sample size may be reduced to 20 units with a minimum of 5 units (*e.g.* the units may be selected on the basis of size, colour or hardness as indicating underfiring).

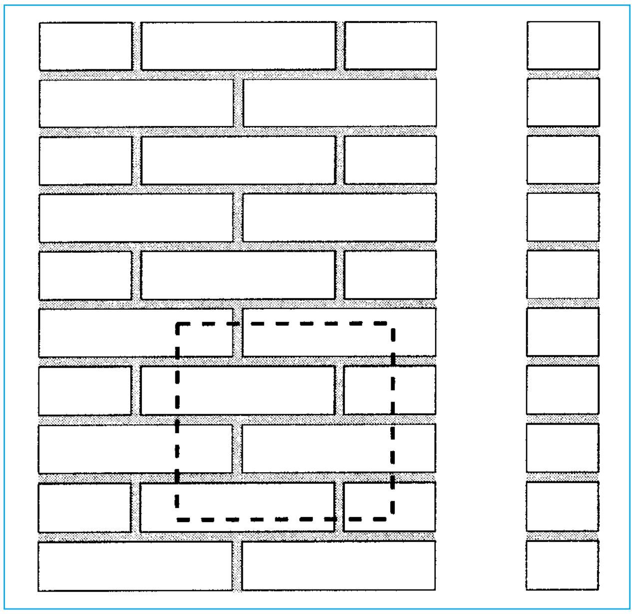

Fig.1 – Example of a wallette containing 20 units; the dotted line encloses a sub-specimen of the correct shape and minimum size.

Wallettes:

A wallette is a composite made up of masonry units and mortar joints, rendering, etc., cut out of an existing wall or purposely made in accordance with site practice. In the case of freshly made wallettes, hardening time and conditions must be specified in accordance with relevant Standards or otherwise as required for purpose. Generally, the hardening time is determined by mortar and/or rendering composition.

The total area of masonry to be tested shall be no less than 0.25m^2. This area may consist of a single specimen or several smaller specimens with a combined area of 0.25m^2. The specimens shall be square with a minimum length of one unit length. Each specimen shall contain at least two bed joints and two full-height perpend (perpendicular) joints. The dotted lines in Fig. 1 show an example of a sub-specimen which complies with these specifications.

It is noted that one wallette may be made up of units which meet different specifications or units with and without surface treatments such as water-repellent agents. The number of wallettes to be tested is often prescribed in relevant Standards or otherwise as required for purpose. If not, the following guidance is given in Table 1.

The shape of the specimens is determined by the shape of the whole units and the wallettes made of them, as in normal practice. Generally, the thickness of a wallette is determined by the width of the units. For freeze/thaw testing, a maximum thickness of 2 x unit width plus mortar joint or 1 x unit length, eventually plus rendering, is regarded as practical. Often the thickness is equal to the width of a unit, *e.g.* for testing of cavity walls.

Table 1 – Specimen formats and numbers

6 wallettes containing:	4 units per wallette
4 wallettes containing:	6 units per wallette
3 wallettes containing:	8 units per wallette
2 wallettes containing:	12 units per wallette
1 wallette containing:	20 or more units
Recommended minimum number:	3 wallettes

A.3.3 CONDITIONING OF SPECIMENS

3.3.1 Preparation

Ceramic material samples should be dried in the oven at a temperature of 105± 5°C and samples of other materials (concrete, aerated concrete, stone, etc.) at 60 ± 5°C to a constant mass. This has been reached when the difference in mass between two weighings 24 hours apart is less than 0.1%. Note the mass of each dry sample: m_d, if dried at 105 ± 5°C; m_{60}, if dried at 60 ± 5°C.

Notes:

1. After the firing process, ceramic building materials contain no water. Due to their nature, stony materials bound with cement, lime or other materials may contain pore water which remains under practical circumstances and also, it is assumed, when dried at approx. 60°C although this water will be removed by drying at approx. 105°C. This water is contained in the smallest pores and is essential to the behaviour under freezing conditions. Since it is not certain whether the water will return to the pores under the prescribed wetting conditions, it would be incorrect to subject these materials to forced drying as occurs at approximately 105°C.

2. If the question arises as to whether products still in their production phase (immediately upon or shortly afterwards, depending on the production method) can resist freezing with the water content which is in the product at that time, then drying and wetting will be inappropriate.

3.3.2 Wetting (soaking in water)

Since the magnitude of the stress ratios generated by ice forming in the pore system is predominantly determined by the level of water saturation, the following three classes are distinguished:

I. Saturation attained after 4 days complete immersion in tapwater (20 ± 5°C) at atmospheric pressure. A longer immersion period up to 7 days may be required if the rate of water absorption is low, if units are large, *e.g.* big-size blocks, or if wallettes are thicker than 200 mm.

II. Saturation attained after de-airing of the specimens at a residual pressure of 50kPa for 2 hours, followed by complete immersion in tapwater (20 ± 5°C) whilst maintaining the residual pressure specified. Evacuation and immersion procedures are given in the relevant RILEM Recommendation for the conditioning of specimens.

The so-called semi-vacuum condition may be replaced by complete immersion in tap water which is kept at a temperature of 80 ± 5°C. The standard duration of this warm immersion is three days for normal masonry units, followed by a period of 24 hours in which the units remain submerged and the water is allowed to fall to room temperature. It is noted that warm immersion may cause changes of material properties of certain types of composites of single units, mortar and/or wallettes. In such cases, warm immersion is not recommended.

III. Saturation attained after de-airing of the specimens at a residual pressure of 2.5kPa for 2 hours, followed by complete immersion in tap water (20 ± 5°C) whilst maintaining the residual pressure specified. Evacuation and immersion procedures are given in the relevant RILEM Recommendations for the conditioning of specimens. After the de-airing of dry specimens is completed they are immersed in tap water (20 ± 5°C) at a pressure of 2.5 kPA in the evacuated vessel. After complete immersion, the pressure is changed to atmospheric conditions. Then the specimens remain under water for 16 hours or longer if required for attaining the 100% level of water saturation.

The so-called full-vacuum condition may be replaced by complete immersion in boiling tap water at atmospheric pressure. This is only allowed for units of which the material properties remain unchanged by this heat treatment. Boiling of wallettes is not an option.

3.3.2 Water content

The water content relative to specimens dried at 105 ± 5°C is calculated as follows:

$$W_m = (m_n - m_d) / m_d \times 100\% \qquad \text{(Mass/Mass)}$$

$$W_v = (m_n - m_d) / (m_n - m_w) \times 100\% \qquad \text{(Volume/Volume)}$$

$$\rho_d = 1000 \,.\, m_d / (m_n - m_w) = W_v / W_m \qquad (\text{kg/m}^3)$$

Where:

W_m = water content in % (Mass/Mass)

W_v = water content in % (Volume/Volume)

m_d = mass of the dry specimen, dried at 105 ± 5°C in (0.00) kg

m_n = mass of the wet specimen in air in (0.00) kg

m_w = mass of the wet specimen in water in (0.00) kg

ρ_d = density of the dry specimen in (0.00) kg/m^3.

The water content relative to specimens dried at 60 ± 5°C is calculated as above but index d is replaced by index 60':

$$W_m = (m_{m-n} - m_{60}) / m_{60} \times 100\% \qquad \text{(Mass/Mass)}$$

$$W_v = (m_n - m_{60}) / (m_n - m_w) \times 100\% \qquad \text{(Volume/Volume)}$$

$$\rho_{60} = 1000 \,.\, m_{60} / (m_n - m_w) = W_v / W_m \qquad (\text{kg/m}^3)$$

Where additionally:

m_{60} = mass of the dry specimen dried at 60 ± 5°C in (0.00) kg

ρ_{60} = density of the specimen dried at 60 ± 5°C in (0.00) kg/m^3

Note:

The index d (dry) is generally used in relation to the drying process at a temperature of 105 ± 5°C. In this standard, the 60' index is added to the symbols used where the products should be dried at a temperature of 60 ± 5°C. The purpose of including the volumetric mass and the mass per volume unit besides the water content in % M/M and % V/V) is to verify to what degree the materials are equivalent when parts of the specimens have been subjected to different soaking methods.

3.3.3 Non-destructive measurements

After conditioning and before specimens are subjected to freeze/thaw cycles, their initial performance parameter is determined by means of a non-destructive method, *e.g.* measuring of mechanical pulse velocity MS.D.1 [2] for wallettes or ultrasonic pulse velocity MS.D.5 [3] for masonry units and small wallettes. The pulse travel times, together with a wave-pattern analysis, give information on the onset of deterioration. Pulse travel times can be measured in the X, Y and Z directions and on several spots of a specimen. More information is given in references [1] and [2], wherein the apparatus is specified.

Since uni-directional freeze/thaw cycles are generated, pulse-travel times and wave-pattern analysis in the same direction are most relevant, in particular, for masonry units.

For testing of the mortar joints, the pointing hardness testing method MS.D.7 [4] may be used. Mortar joints may also be tested by tapping and listening for hollow sounds.

Photographs or video views of the surface exposed to uni-directional freeze/thaw attacks shall be taken before the specimens are put into the apparatus. If required for the purpose, a graphical profile of the exposed surface can be made by, for example, a profilo-graphical recorder working with laser measurements.

Measuring points where mechanical and/or ultrasonic pulses are generated shall clearly be marked to ensure that successive measurements are comparative.

Finally, a visual inspection is required for recording and/or marking of cracks, fissures or other observable initial damages.

A.3.4 APPARATUS

Relevant equipment and accessories should be chosen from the following, depending on the testing method selected.

3.4.1 A drying oven, adjustable to 60 ± 5°C and 105 ± 5°C, large enough to accommodate at least one sample unit.

3.4.2 A balance suitable for weighing the samples in air and in water to an accuracy of 0.1%.

3.4.3 Soft water containing ($CaC0_3$ + $MgC0_3$) or equivalent hard water salts, at less than 400 mg/1 at a temperature of 15°C.

3.4.4 A chamois leather.

3.4.5 For testing of units placed in a tray onto a bed of gravel:

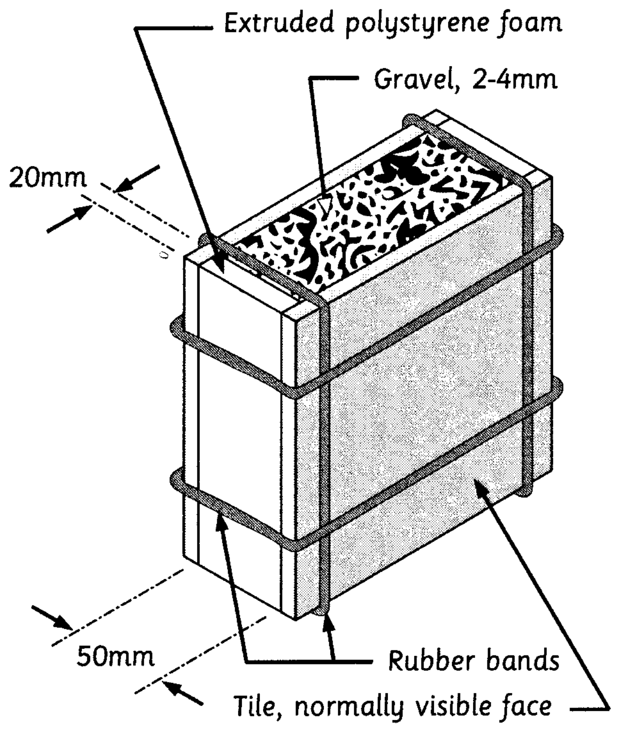

Fig. 2 – Sample holder with two plain tiles.

3.4.5a A metal container, internally insulated on five sides with a 30mm sheet of extruded polystyrene, which can at least accommodate the number of specimens of one sample. The specimens should be placed in the tray next to each other on a gravel bed, in accordance with 3.4.5, with the facing side or one of the facing sides facing upwards. The gravel bed should be 25 ± 5 mm thick. This gravel bed is laid on a coarse filter of such thickness that the exposed specimen surface is level with the top of the metal tray, or 5 mm lower at the most. The bottom of the container shall be perforated in such a way that at the start of a freezing phase only so-called 'hang' water shall be present.

3.4.5b Additional equipment for the exposure of thin-walled units:

For flat thin-walled units, *e.g.* tiles: extruded polystyrene foam sheets 20 mm thick, and wide rubber bands.

For shaped thin-walled units, *e.g.* roof tiles: a tray made out of small planks as shown by Figs. 2 and 3

3.4.5c Gravel of 2-4 mm grain size.

3.4.6 A freeze/thaw simulator equipped with a convection cooling system that is capable of extracting 300 ± 60W/m^2 and 100 ± 20W/m^2 from the exposed surface of specimens while at a temperature of 0°C. The thawing process is carried out by a system that is capable of heating frozen specimens at -15°C up to +10°C within 50% of the time which was needed for the freezing period. The thawing heat is transferred to the specimens by tap water at 15 ± 3°C.

The freeze-thaw simulator is shown in Fig. 4.

After filling with specimens, the air in the exposure chamber shall be cooled from +15°C to -15°C within two hours. The air speed shall be adjusted such that the heat extraction from a plane at 0°C is 300 ± 60W/m^2.

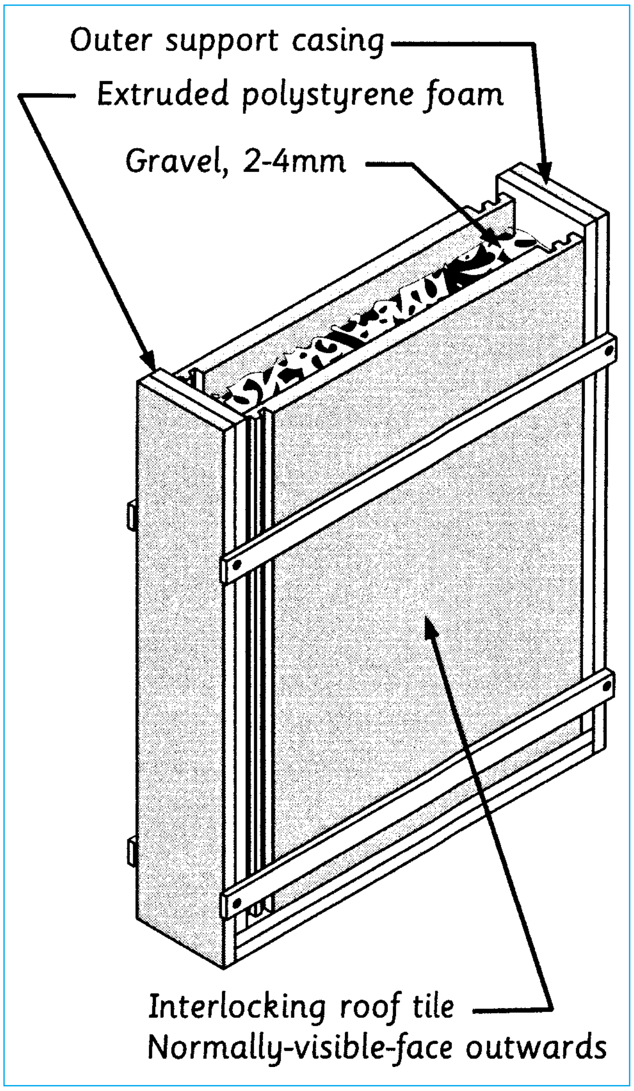

Fig. 3 – Sample holder with two interlocking tiles.

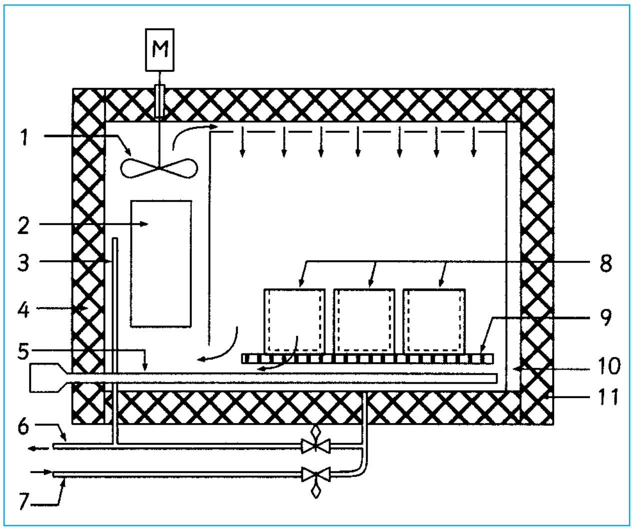

Fig. 4 – Sketch of the convection freeze-thaw simulator containing flat, thin-walled specimens.

KEY:

1 fan;	*2 air cooler;*	*3 overflow;*
4 insulation;	*5 water heater;*	*6 water overflow;*
7 water supply;	*8 samples;*	*9 grating;*
10 water barrier,	*11 door*	*M motor*

Calibration shall be carried out using an electrically heated plate with thermocouple attached to measure the temperature. Thawing takes place by complete immersion in tap water which is heated *in situ* by electric power to a temperature of 15 ± 3°C. After the thawing cycle is completed, the water is drained away.

3.4.7 The freeze-thaw simulator has measuring and controlling equipment for setting, checking and controlling the freeze/thaw cycle according to a temperature/time programme, which is shown in Fig. 5 by way of an example.

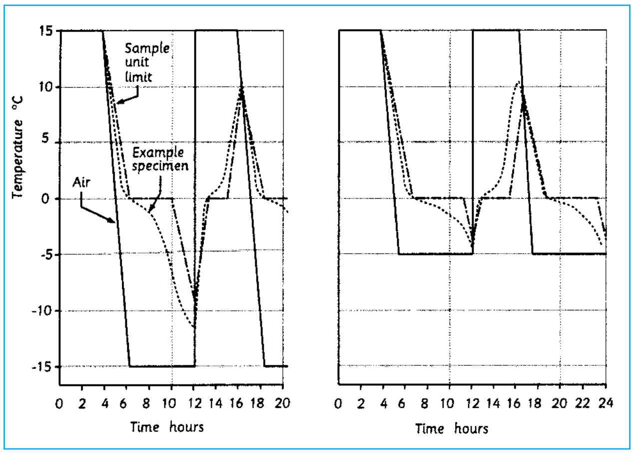

Fig. 5 – Temperature development when using the convection method and thin-walled samples.

A.3.5 PROCEDURE

3.5.1 Positioning of test units

3.5.1.1 Cylindrical or block-shaped specimens: Put the soaked specimens face up on the 25 ± 5mm thick gravel bed in the exposure chamber with the facing side horizontal or sloping slightly. The exposed surface should be level, with or no more than 5 mm below the upper plane of the tray. Fill any excess space with dummy bricks and gravel of 2-4 mm grain size.

3.5.1.2 Wallettes: Put the soaked wallette face up onto the 25 ± 5 mm thick gravel bed. The exposed surface should be level, with no more than 5 mm below the upper plane of the tray. Fill any excess space with dummy bricks and gravel of 2-4 mm grain size.

3.5.1.3 Flat thin-walled specimens: As shown in Fig. 2, using rubber bands clamp pairs of soaked specimens vertically back to back 50 ± 10 mm apart against a frame constructed of three strips, 20 mm thick, of extruded polystyrene foam. Fill the space between the trays with gravel and place the rigs vertically 50 ± 10 mm apart in the freeze-thaw simulator. Using rigs with more specimens is permitted provided that the stability of the arrangement is ensured. Fill any excess space in the cabinet with dummy specimens of the same shape and size.

3.5.1.4 Shaped thin-walled specimens: Place pairs of soaked specimens back to back in a vertical position, in a frame as shown in Fig. 3 such that the nearest distance between the specimens is 50 ± 10 mm. Then fill the space between the specimens with gravel and place the frames in the freeze-thaw simulator, such that the nearest distance between the trays is 50 ± 10 mm. Fill any excess space in the cabinet with dummy specimens of the same shape and size.

3.5.2 Test

Position the trays with the specimens in the freeze-thaw simulator such that the cooling process is equal for all of them. Start testing with a thawing phase of 8 h. During this period the specimens are completely flooded with tap water at 15 ± 3°C. Afterwards, when the water is drained off, the surface temperature of both the exposed and the opposite side of the specimens shall be no less than +10°C.

Thereafter, start the freeze-thaw process consisting of, in principle, 16 h freezing followed by 8 h thawing, *i.e.* a cycle time of 24 h. The standard test is programmed as follows:

The rate of heat withdrawal, measured at the exposed surface of the specimens, shall be 300 ± 60 W/m^2 with the surface at 0°C during the first cycle of 16 hours.

If the temperature, measured at the rear (non-exposed) surface of specimens, attains -10°C in less than 16h, the duration of the next freezing cycles may be reduced accordingly with a minimum of 8h. In such cases the thawing period shall be no shorter than 50% of the freezing period. That is, the minimum cycle time is 12 h.

In the first cycle and following odd-numbered cycles, heat extraction shall take place at a rate of 300 ± 60 W/m^2. In the 2nd cycle and following even-numbered cycles, heat extraction shall take place at a rate of 100 ± 20 W/m^2. The freezing conditions are summarised below:

Table 2 – Freezing conditions for 24 cycles

W/m^2	Cycle No	Air temperature
300 ± 60	Odd numbers Circulation Air Speed: (adjusted to cooling rate)	-15 ± 3°C
100 ± 20	Even numbers Circulation Air Speed: (adjusted to cooling rate)	-5 ± 1°C

The number of cycles is 24 as a standard; however, the test is stopped earlier as soon as any damage occurs. More than 24 cycles is also possible, particularly for research purposes.

A.3.6 DAMAGE ASSESSMENT

First, specimens must be rinsed in clean water and then carefully patted dry with absorbent material. Thereafter a visual and/or physical inspection shall be carried out.

3.6.1 Visual inspection

The following is viewed as frost damage:

Flaking: The loss of laminar material from the exposed face not exceeding 2 mm in either face dimension. This damage is not considered significant unless it causes visible alteration to the colour or texture of the unit viewed with the naked eye from a distance of 3 m.

Spalling: The loss of laminar material from the exposed face exceeding 2 mm in either face dimension.

Crumbling: The loss of particulate material from the exposed face resulting in areas of damage exceeding 10 mm in either face dimension.

Cracking: The formation of cracks readily visible to the naked eye in the exposed face.

Incipient lamination: (hollowness) Cracks forming parallel to the surface detected by tapping with a small metal rod but not visible. Such damage should be noted but only reported at the end of the test if confirmed by checking the units after removal.

Laminar cracking: Cracks in the bedding face of any unit which have formed during the test but which are only apparent after removal of the bricks or dismantling a panel.

Snapping into pieces: This is an unlikely mode of failure for specimens subjected to a unidirectional freeze-thaw test.

Damage observed, marked or recorded before testing is taken into account and recorded as initial damage which may be increased by freeze/thaw action.

All visual damage shall be marked for video or photographic recording.

3.6.2 Physical inspection (after completion of the test).

This inspection is carried out using non-destructive methods such as ultrasonic or mechanical pulse velocity measurements as given in Section 3.3.3 above. It is noted that the absolute value (pulse travel time and/or pattern) is not essential, but the change indicating that the initial condition is changed (or not) as a function of the number of test cycles (see Reference 5, sub-annex 1).

For mortar joints and pointings the recoil values by a spring-loaded hammer or pendulum hammer give adequate information with respect to loss of condition.

Specimens (units or wallettes) are qualified as "frost resistant" if no visual damage is observed and no conditional change is found in comparison with the initial condition.

A.3.7 TEST REPORT

The test report shall contain the following:

1) A reference to this method.
2) A description of the specimens including any codes, relevant specifications, name of manufacturer(s).
3) The method of sampling.
4) The properties of units, mortar and, eventually, rendering as given by the manufacturer(s), supplier(s) or resulting from testing prior to the preparation of specimens.
5) Preparation date and method.
6) Conditions of specimen(s), class of saturation (I, II or III). Table containing a record of dry mass (m_d), water content (W_m, W_v) and volumetric mass (ρ_d).
7) Photographs of initial visible condition including marked visual damages if any.
8) Initial data of the physical condition in terms of *e.g.* pulse travel times and wave patterns, recoil values, or otherwise.
9) Testing method used, *i.e.* which specimen arrangement and position was used in the freeze/thaw simulator.
10) A record of the cycles in terms of cycle time and rate of heat extraction according to Table 1.
11) A record of the inspection and/or observation results – showing the condition of the specimen(s) after the completion of each cycle or number of cycles (usually after 12 and 24 cycles).
12) Interpretation of the test results which depends on purpose:

a) Standard test consisting of 24 cycles at water saturation class I, II III.

Requirement: no failure (no loss of condition)
Classification of test results: as in Table 3

Table 3 – Classification of frost resistance

Damage generated within 24 cycles			
I: 4 days free immersion	II: semi-vacuum immersion	III: full vacuum immersion	Classification
Yes	Yes	Yes	A
No	Yes	Yes	B
No	No	Yes	C
No	No	No	D

b) Survival characteristics derived from the statistical interpretation of test results on the basis of two distinct sets of test data:

• A data table containing the number of units that failed versus the number of cycles or time. For instance, 1 unit at cycle No.3, 4 additional units of cycle No. 5, subsequently 7 units at cycle No. 6, etc. What is meant by failure (damage) must be specified. Normally it is a criterion for rejection or discarding. The observation after each cycle is, therefore: failed or not. The same table is made for mortar joints. The statistical interpretation is given by Annex 2 to test MS.A.1 [5]. This method is based on the KAPLAN-MEIER approach, resulting in a plot with the integrated hazard versus cycle No. or time in an ELog-ELog grid.

• The photographs including the description, quantification or classification of damages at each cycle or moment in time shall be interpreted by comparison with relevant references or in a comparative way (other units or masonry with other specifications). The statistical interpretation shall take place by the so-called Sign test method (equal: no sign, better: + or worse: -) derived from BINOMIAL distributed + or - data. A CHI-square test may be appropriate for the testing of frequencies associated with a qualitative range of damage.

A.3.8 REFERENCES

[1] Dutch Standard NEN 2872, Nederlands Normalisatie Instituut, Delft, Netherlands, May 1989.

[2] RILEM Recommendation MS-D.1, 'Measurement of mechanical pulse velocity for masonry', *Mater. Struct.* **29** (1996) 463-466.

[3] RILEM Recommendation MS-D.5, 'Measurement of ultrasonic pulse velocity for masonry units and wallettes', *Ibid.* 467-470.

[4] RILEM Recommendations of tests for masonry materials; MS-D.7 'Determination of pointing hardness by pendulum hammer', *Ibid.* **30** (1997) 323-328

[5] RILEM Recommendation MS.A.1 'Determination of the resistance of wallettes against sulphates and chlorides', Annex 2 'Statistical evaluation of non-parametric durability data', *Ibid.* **31** (1998) 2-11.

i. Van Der Klugt, L.J.A.R., 'Frost Testing by Uni-directional Freezing', TNO Report No. BI-84-67, TNO-Building Section, Rijswijk/Delft, Netherlands, (1984).

ii. Van Der Klugt, L.J.A.R., 'Frost Testing by Uni-directional Freezing', *Ziegel-Industrie International*, Bauverlag, Wiesbaden, Germany (2/89) (1989) 92-98.

iii. Van Der Velden, J.J., 'Weathering and Frost Testing of Structural Ceramics', *Ziegelindustrie International*, Wiesbaden, Germany, (1/83) (1983) 18-26.

iv. Bekker, P.C.F, 'Durability Testing Models and Methods for Masonry',Proceedings of the RILEM Conference at the University of Padova, Italy (Rilem Publications, June, 1995).

v. Molina, C., Garavaglia, E., Bekker, P.C.F. and Binda, L.A, 'Service Life Prediction Model', Proceedings of the 7th International Conference on the Durability of Building Materials and Components, held on May 1996 at Stockholm, Sweden, 75-84, ISBN 0-419-22130-1 (E&FN Spon, London, 1996).

MS.B.5 Determination of the damage to wallettes caused by acid rain

B.5.0 CONTENTS

B.5.1 SCOPE

This recommendation specifies a method of indicating the resistance of wallettes (representative samples of masonry) to damage caused by (acid) rain. It is an accelerated test because higher than normal rate of precipitation and, in part of the test, lower than normal pH-value, are used in order to increase the stress ratios with time. A particular pattern and magnitude of stress cycles is provided in combination with moisture dynamics. The test is proposed to detect the durability (capability to prevent deterioration with time) of masonry which is exposed to rain water.

This recommendation describes the sampling/manufacture of the specimens, the conditioning before testing, the apparatus, the method of test, how to report and evaluate the test results and, finally, the contents of the test report.

B.5.2 SPECIMENS (Size, shape and numbers)

Wallettes shall be cut from larger panels taken from existing masonry or made of masonry units and mortar as required for the purpose of testing. In the latter case, normal workmanship should be employed including pointing where specified and in respect of composition, work, finishing and hardening conditions. If the object of the test is solely to test the units and not the masonry composite, then an alternative method of preparation may be used – see Annex 1. Since the properties of the brick may affect both the initial properties of the mortar/pointing and the stress rates exerted by rain water as well as by thermal radiation, pointing mortars shall, preferably, be tested in combination with the bricks they are suitable for. If these bricks are not available for the preparation of wallettes, bricks shall be used having properties as much as possible comparable to those of the bricks which are likely to be used in practice.

Dimensions and shape

Normally, the thickness of the wallettes shall be the width of the units from which they are made. The exposed surface shall be approximately square and shall, ideally, have dimensions 500 mm × 500 mm.

Cutting to size is allowed after the wallettes are made and hardened. In that case they shall contain as many horizontal and vertical joints as possible. The four sides of the square wallettes shall be plain (no mortar or plaster on the units).

Number of specimens

In the case of prototype testing, at least three wallettes shall be tested for every variable to be studied. These wallettes shall be made with the variable considered normal, favourable and unfavourable. For instance, if the variable is compaction, the pointing mortar shall be little, normally and well compacted. If the variable is the availability of moisture during maturing, then the wallettes shall be stored in the open (however, sheltered from rain and sunshine). One wallette shall be allowed to dry, one shall be sprayed weekly with water and one shall be kept moist constantly.

In the case of selective sampling, the number of wallettes to be tested depends on the purpose of the test. Generally, it is preferable to sample in accordance with ISO 2859 and interpret by the attributes method.

B.5.3 TEST LIQUIDS (simulated rain water)

Natural rain water shall be simulated by decreasing the pH-value of potable water through intensive contact with carbon dioxide ($C0_2$) of a technical quality.

Acid rain water shall be simulated by decreasing the pH-value of imitation natural rain water further to pH 3.5 by the addition of sulphuric acid of laboratory quality.

Other pH-values or other additions may be used if required for the purpose of the test.

B.5.4 AGE AT TESTING

Pointings shall be tested at an age which shall depend on the type of the binder. The ages mentioned below shall be considered guidelines for the minimum age:
• cement based mortar : 28 days
• mixed mortar (cement-lime-sand) : 48 days
• lime based mortar : 72 days
• mortars based on pozzolanic binder : 96 days.

In addition, testing shall not commence before the pointing is completely carbonated and its hardness has reached a constant value. Hardness shall be considered constant if the difference in median value between two successive measurements at an interval of 7 days is no more than 3 points. Hardened wallettes shall not be dried artificially.

Carbonation shall be checked according to RILEM CPC 18 [2]. Hardness shall be measured according to Rilem Recommendation MS.D.7 [3].

B.5.5 APPARATUS

The apparatus used for the preparation of the test liquids shall consist of the following:
• a container capable of storing enough water for one rainy phase;
• a heating device capable of keeping the temperature of the water in the container at 25 ± 2°C.
• a carbon dioxide 'bottle' including a pressure reducing and a flow rate control valve;
• a device capable of dissolving carbon dioxide into the water in the container;
• a pH-meter capable of measuring in the range 3.0-8.5;
• a pump capable of producing the water flow rate needed in the rainy phase;
• one or more flow rate meters capable of measuring the flow rate per row of test specimens;
• a frame capable of holding the wallettes leaning backwards by 150 mm;
• one or more pipes mounted on top of the wallettes and perforated in one line, at equal distances and with such diameter that the water flows evenly in a continuous film or, in case of water repellent testing, at least evenly divided over the wallettes;
• infra red lamps 250 W;
• a frame capable of holding the IR-lamps at equal distances so as to produce a radiation density of 650 ± 50 W/m^2 at the proper surface of the wallettes;
• a radiation meter capable of measuring 250 ± 100 W/m^2;
• a basin in which the frame can be placed and which serves to collect the water dripping off from the wallettes in the rainy phase;
• lime to neutralize the collected water before it is disposed of to the sewer system;
• a dirty-water pump with water level control which serves to dispose of the water from the basin to the sewer system;
• a device to run cycles automatically night and day;
• a pointing hardness tester according to MS.D.7;
• a piercer with rounded-off tip;
• photographic equipment.

B.5.6 PROCEDURE

Place the wallettes onto the frame and make sure they lean 150 mm backwards.

Put the frame with the IR-lamps parallel to the wallettes and at such a distance that the level of radiation on the proper face of the wallettes is 650 ± 50 W/m^2.

Provide each wallette with a flow of water 25 ± 5 1/h and make sure the water forms a continuous film on the wallettes or flows at least evenly divided over the wallettes.

Run cycles consisting of 1 hour rain and 3 hour IR-radiation. First run 75 cycles with simulated natural rain water at pH 5.6 and the next 75 cycles with simulated acid rain water at pH 3.5. Start with a rainy phase.

Evaluate for possible changes every 25 cycles. Preferably start cycling on Monday morning and stop at Friday in the afternoon. Do not cycle during weekends.

B.5.7 TEST RESULTS

Evaluation shall be done according to the attributes listed below. Proceed as follows:
- visual inspection: check for
+ deposits of mortar constituents on the bricks;
+ sanding of the mortar joints;
+ occurrence of voids between brick and mortar;
+ occurrence of indents or craters in the pointing mortar;
- check for hollow sound of the mortar joints by moving a piercer along the horizontal joints;

- check for resistance to scratching and prodding using a piercer;
- measure the hardness of an uneven number of horizontal mortar joints, preferably 9, record each individual value and determine the median value;
- take pictures of every wallette, preferably using standardized lighting;
- finalize the evaluation after 150 cycles by high-pressure water blasting each wallette in order to remove all loose particles.

B.5.8 TEST REPORT

1. A reference to this method
2. A description of the wallettes.
3. The method of sampling the units.
4. The mortar composition, preparation method, working properties and maturing conditions.
5. Known properties of the units, *e.g.* ultrasonic characteristics, water absorption, IRA, porosity and technological information of manufactured ware or origin of natural ware.
6. The date of preparation of the specimens (wallettes) and the date of the commencement of the test.
7. All individual values measured during the test procedure.
8. Evaluation of the test results.
9. A statistical interpretation of two distinguished sets of test data:

– A data table containing for each wallette the number of mortar joints that failed versus the number of cycles. For instance, 1 joint after cycle No. 25, 4 joints after cycle No. 50, 7 joints after cycle No. 125, etc. What is meant by failure (damage) must be specified. Normally, it is a criterion for rejection or discarding. The observation after each cycle is, therefore, failed or not. The same table is made for the masonry units.

The statistical interpretation is given by MS.A.1: Appendix. 2 [4]. This method is based on the KAPLAN-MEIER approach, resulting in a graph with the probability of survival versus cycle number.

– The photographs including the description, quantification or classification of damages at each set of 25 cycles shall be interpreted by comparison with relevant references or in a comparative way (other masonry with other specifications). The statistical interpretation shall take place by the so-called Sign test method (equal: no sign, better: + or worse: -).

B.5.9 REFERENCES

[1] Van Der Klugt, L.J.A.R. and van Hees, R.P.J., 'The quality of masonry pointing (Annex F)', *SBR/CUR-publication* 299/93-03, Rotterdam, 1993.
[2] RILEM Recommendations CPC18
[3] R.C. de Vekey (ed), RILEM Recommendations of tests for masonry materials; MS-D.7 Determination of pointing hardness by pendulum hammer, *Mater. Struct.* **30** (1997) 323-328.
[4] RILEM Recommendation MS.A.1, 'Determination of the resistance of wallettes against sulphates and chlorides', Annex 2 'Statistical evaluation of non-parametric durability data', *Ibid.* **31** (1998) 2-11.

B.5. ANNEX 1: ALTERNATIVE MASONRY WALLETTE PREPARATION TECHNIQUE

If the wallettes are solely used for durability testing of solid units, they can be made horizontally in a mould with their faces down. On the plane bottom of that mould, a soft sheet of foam rubber, thickness 5 mm for plane unit faces and up to 10 mm if the surface is irregular, is laid. This sheet must be immersed with a mixture of water and a cement-retarder agent. Next, the pre-wetted units are put onto the bottom with their faces down into the mould and in the pattern as desired. Then the joints are filled up by pouring the mortar, followed by some seconds of vibration. This filling and vibrating cycle is repeated until the joints are full. Very good results are achieved with a Portland-cement mortar (1 cement to 3 sand by volume) The wallette must be released from the mould after sufficient curing (*e.g.* 20 hours of room conditions for ceramic units), but before the retarding process on the bottom (facing side) becomes inactive. The latter is needed for cleaning that surface by means of a brush if some mortar leakage should have taken place. The above wallette making method assures a strong bond and completely filled joints with compacted and dense mortar.