BRITISH STANDARD

BS EN
14437:2004

Determination of the uplift resistance of installed clay or concrete tiles for roofing — Roof system test method

The European Standard EN 14437:2004 has the status of a British Standard

ICS 91.060.20; 91.100.25; 91.100.30

National foreword

This British Standard is the official English language version of EN 14437:2004.

The UK participation in its preparation was entrusted by Technical Committee B/542, Roofing and cladding products for discontinuous laying, to Subcommittee B/542/1, Slating and tiling, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

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English version

Determination of the uplift resistance of installed clay or concrete tiles for roofing - Roof system test method

Détermination de la résistance au soulèvement des tuiles terre cuite ou béton mises en oeuvre sur la toiture - Methode d'essai par système de toiture

Bestimmung des Abhebewiderstandes von verlegten Dachziegeln oder Dachsteinen - Prüfverfahren für Dachsysteme

This European Standard was approved by CEN on 13 September 2004.

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Contents

Foreword

This document (EN 14437:2004) has been prepared by Technical Committee CEN/TC 128 “Roof covering products for discontinuous laying and products for wall cladding”, the secretariat of which is held by IBN/BIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2005, and conflicting national standards shall be withdrawn at the latest by May 2005.

This standard is applicable where the National application standards, and/or regulations, specify a requirement for the uplift resistance of installed clay or concrete tiles for roofing.

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

Introduction

This document gives a test method and failure criteria for determining the uplift resistance of clay or concrete tiles for roofing.

NOTE The results of this test may be used to determine the uplift force which can be withstood by the fixing, e.g. to withstand wind force.

1 Scope

This document specifies a test method to establish the uplift resistance of installed clay or concrete tiles for roofing, complying with the relevant product standard, EN 490 or EN 1304, which are unfixed or mechanically fixed to the substructure.

NOTE The test method has been developed for clay or concrete tiles for roofing but may apply to other discontinuously laid small elements, such as: slates; fibre cement slates; and, stones.

The test method is applicable to mechanical fixings such as clips, hooks, screws and nails.

In case of mechanically fixed tiles, at least every third tile shall be fixed. The method is not applicable for fixed tiles with fixing patterns with less than every third tile fixed.

The test method is not applicable to under and over tiles. Examples of these tiles are given in Annex H.

2 Normative references

Not applicable.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
discontinuously laid small elements
elements to be used for roof covering and wall cladding which are installed as separate elements and collectively form the roof covering

3.2
roof pitch
pitch of the roof structure, e.g. the rafters, counter battens, panels

3.3
characteristic value
value of a material property having a prescribed probability of not being attained in a hypothetical unlimited test series. This value generally corresponds to a specified fractile of the assumed statistical distribution of the particular property of the material

3.4
roof system
comprises the structure of the battens, mechanical fixings (clips, hooks, nails and screws) as well as the laying specification for the roof covering products (clay and concrete tiles for roofing)

4 Symbols and abbreviations

d_{max} the maximum permissible displacement;

F_t force exerted on 16 tiles;

k_n a factor depending on the number of tests n;

L_h the hanging length of the tile;

L_t total length of tile;

m number of fixings on 16 roofing tiles;

n number of tests;

R_d design uplift resistance of 16 roofing tiles;

R_k characteristic uplift resistance of 16 roofing tiles;

$R_{r,i}$ uplift resistance of 16 tiles in test i;

R_t uplift resistance of 16 tiles in a trial test;

R_x mean uplift resistance of 16 roofing tiles;

s_x standard deviation of the uplift resistance of 16 roofing tiles;

W_i weight of a roofing tile;

W_k characteristic weight of a roofing tile at a roof pitch of 45^o;

W_x mean weight of a roofing tile;

α roof pitch;

γ partial safety factor for resistance, which may be defined by a national regulation.

5 Sampling

The clay or concrete tiles for roofing selected shall be representative of the intended use.

The battens selected shall be representative i.e., in line with the tile product and instructions of the clip manufacturer.

The fixings used for the test shall be representative of the manufactured product.

In selecting the number of elements, refer to 7 and 9, taking into consideration the number of fixing patterns and that in each case a trial test and at least 3 tests shall be conducted.

NOTE The specification of the battens may include a reference to a national code of practice.

6 Test conditions

Unless specified otherwise, the roofing tiles, fixings and the test frame shall be conditioned for at least 24 h in an environment of (20 ± 5) °C, and (60 ± 20) % relative humidity, prior to the test. The manner of storage shall not interfere with the free exchange of moisture from or into the materials. The test shall be conducted in the same conditions as the storage.

NOTE If in practice, the moisture content of the battens is expected to be different from the standard conditions, and if it is expected that this may influence the test results, this should be taken into account; e.g. by testing under the appropriate conditions and recording the moisture content of the battens used.

7 Test material

The test materials shall be randomly chosen from the samples.

8 Apparatus

8.1 Test rig

The test rig consists of a roof structure and auxiliary equipment to exert a force on the clay or concrete tiles for roofing. The roof structure shall have a roof pitch of (45 ± 2)°.

The test rig shall be able to exert an equal uplift force on 16 roofing tiles from a minimum distance of 1,0 m to the surface of the roof covering and at an angle of (90 ± 2) ° to the roof structure, at the start of the test.

The test rig shall have sufficient capacity and stiffness for the test as not to influence the test result. The test rig shall be capable of applying an uplift force at a rate of not more than 50 N/s.

NOTE 1 The test results obtained at 45° may be used for pitches up to 60°. For pitches greater than 60° tests at the appropriate roof pitch are advised.

NOTE 2 Annex A includes an example of the test rig.

8.2 Cables

The uplift force shall be exerted by using a cable. The cable shall be flexible, such that it minimises any overturning moment on the connection point, where the force is applied.

8.3 Force measuring device

A calibrated force measuring device shall be used to determine the total uplift force on the 16 roofing tiles (refer to 9.3), having a maximum inaccuracy in combination with the reading equipment of 1 % of the measured value or 10 N, whichever is larger.

8.4 Measuring device for displacement of the roofing tiles

A calibrated displacement measuring device shall be used to determine the displacement of the roofing tiles and shall have a maximum inaccuracy of 0,2 mm. The displacement measuring device shall not exert forces larger than 1 % of the uplift force measured on the 16 roofing tiles.

The measuring device shall ensure that any displacement or twist of the roofing tiles is taken into account.

NOTE This may be achieved by rigidly attaching a small flat plate to the measuring head, such that it always contacts the highest point on the roofing tile.

8.5 Measuring device for weight

A calibrated weighing device shall be used to determine the weight of roofing tiles with a maximum inaccuracy of 1 % of the measured value.

9 Test procedure

9.1 Measurement of the weight

Determine the individual weight W_i of at least 10 roofing tiles, where *i* indicates the number of the roofing tile weighed, after conditioning described in 6.

9.2 Installation of battens, roofing tiles and fixings

The battens shall be fitted to the test rig.

The roofing tiles shall be installed on the battens in a lay-out intended to be tested. The overlap of the roofing tiles shall be the maximum specified for the intended use in the national regulations or codes of practice or by the manufacturer.

The boundary conditions for the installed roofing tiles on the test rig shall be representative of the intended application. For roofing tiles surrounded in the intended application by at least 2 courses and 2 columns of identical roofing tiles, the test requires a set of roofing tiles, sufficient to cover at least 8 courses high and 8 columns wide, or at least 1,5 m high and 1,5 m wide, whichever is larger.

NOTE 1 For interlocking, single lap clay or concrete tiles, the lowest course on the test rig may be omitted without loss of accuracy of the test result.

The fixings shall be installed representatively of the intended use of the fixings and shall take into account the lay-out of the roofing tiles.

NOTE 2 For roofing tiles that are within 2 courses or columns distance of eaves, verge, ridge or valley or within 1 course or column distance of special tiles for eaves, verge, ridge or valley, additional guidance on the application of the test is given in Annex F.

NOTE 3 Various fixing patterns may need to be tested, refer to Annex C.

9.3 Determination of the location of the forces on the test roof

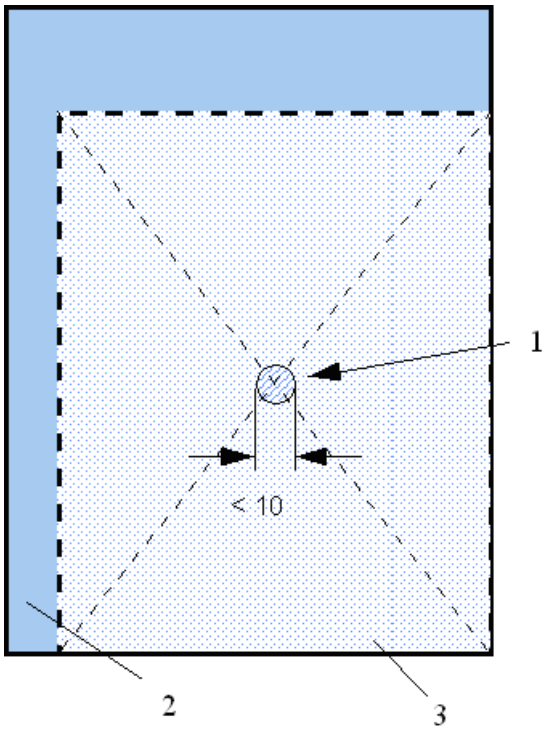
A total of 16 roofing tiles to be lifted shall be selected on the test roof. These 16 elements shall be located adjacent to each other in an area of 4 courses high and 4 columns wide, as defined in Annex B. The fixing pattern shall be chosen such that the roofing tile in the lower right corner is fixed. Annex C gives examples of suitable fixing patterns.

The connection point is within 5 mm of the centre of the projected visible area of the roofing tile, normal to the roof surface taking into account the geometric peculiarities of the tile (see Figure 1).

NOTE 1 The cable may be connected to the tile by feeding the cable through a hole to be made at the location of the connection point and locking the cable at the back-side of the roofing tile.

NOTE 2 Figure 1 shows a typical example of a tile in the centre of the roof, overlapping along its edge and head regions. Some tiles may not have a side lap e.g., double lap tiles and some single lap verge tiles.

Dimensions in millimetres



Key

1 Location of connection point within shaded area

2 Invisible (overlapped) part of tile

3 Visible part of tile

Figure 1 – Location of the forces on the test roof

9.4 Measurement of the uplift resistance

9.4.1 Calibration of the test equipment

The test equipment shall be calibrated when the equipment is commissioned. Guidance on calibration methods is given in Annex I.

9.4.2 Zero the measuring equipment

To eliminate the effect of the load application frame and cables, the load cell shall be zeroed or the weight of the load cell and the load application system shall be determined and shall be subtracted from the reading of the total force on the selected 16 roofing tiles.

9.4.3 Trial test

A trial test shall be conducted, where the total force on the 16 roofing tiles shall be increased at a rate of less than 50 N/s, until one of the events a, b, c or d (specified below in 9.4.5) occurs. The maximum total force on the 16 roofing tiles F_t shall be measured and the tile showing the largest displacement shall be identified together with the location of the largest displacement on this tile.

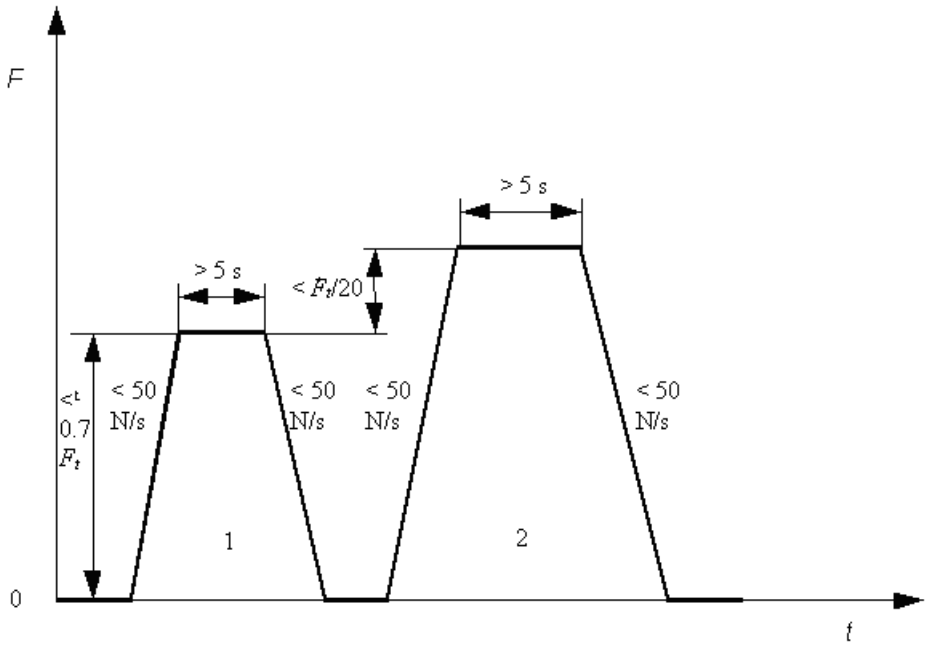
9.4.4 Test series

A series of at least 3 tests (see Clause 10) shall be conducted. The roofing tiles shall be reinstalled randomly between each test and new fixings shall be used. Any damaged roofing tiles and battens shall be replaced and, where fixings are used, the battens shall be replaced after a maximum of 6 tests. The tiles shall be installed in a manner that ensures the fixings do not coincide with previous fixing positions within 30 mm.

9.4.5 Application of the force

The total force acting on the 16 roofing tiles shall be increased in a first step of maximum 0,7 F_t and in subsequent steps of maximum 1/20 F_t, and shall be kept at the maximum level for at least 5 s. Then the force shall be released to zero. The total force shall be increased or decreased at a rate of less than 50 N/s.

At the maximum value of the force during a loading step, the displacement at the location defined in 9.4.2 shall be measured, at an angle of (90 ± 2) ° to the roof structure.



Key

1 Step

2 Step

F Force

t Time

Figure 2 – Application of the force

9.4.6 Determining the maximum uplift resistance

The maximum uplift resistance, $R_{r,i}$, where i is the number of the test, is defined as the total force on the 16 roofing tiles at the latest completed step, before one of the following events occurs:

a) breakage of the mechanical fixing from tile to batten;

b) pulling out or breakage of the connection of the mechanical fixing to the roof;

c) breakage of covering elements;

d) the maximum displacement of any roofing tile exceeds the value d_{max} (mm), given by:

$$d_{max} = 75\ l_h/400$$

where

d_{max} is the maximum permissible displacement, in mm;

l_h is the hanging length of the tile, in mm;

NOTE The hanging length of the tile is the distance between the lower (free) end of the tile to the inner surface of the hanging nib, refer to Figure E.1 in Annex E.

e) the remaining displacement of any roofing tile due to deformations of the fixings after releasing the force to zero exceeds 5 mm;

f) the tiles should not disengage from the batten.

The release of the pulling force in between various loading steps may cause a remaining displacement of the roofing tiles due to friction between the elements or between the elements and the roof substructure.

If the remaining displacement exceeds 5 mm after releasing the force to zero, the elements shall be returned to less than 5 mm by pushing at right angles to the surface of the tiles by hand. The fixings shall not be influenced when returning elements. If, after returning all the elements, a value less than 5 mm cannot be achieved, failure will be deemed to have occurred according to 9.4.6 (condition e).

10 Evaluation and expression of results

The mean value and the standard deviation of the resistance from all tests i shall be calculated by:

$$R_x = \frac{1}{n}\sum R_{r,i}$$

$$s_x^2 = \frac{1}{n-1}\sum (R_{r,i} - R_x)^2$$

where

$R_{r,i}$ is the uplift resistance from test i, from 9.4;

n the number of tests that have been carried out.

When after a series of 3 tests, the ratio s_x/R_x exceeds 0,10, two additional tests according to 9.4 shall be carried out; when the ratio s_x/R_x still exceeds 0,10 after 5 tests, two additional tests according to 9.4 shall be done.

NOTE Annex D contains information on the calculation of the characteristic value of the uplift resistance and Annex E on the calculation of the characteristic resistance of the mechanical fixing.

11 Test report

The test report shall provide the following information:

a) the title, reference number and date of publication of this document;

b) the place, date and time of sampling;

c) the identification of the roofing tile according to the relevant standard, and the commercial identification of the roofing tiles, including material specifications, surface characteristics and name of the manufacturer;

d) the head and side lap and the bonding of the installed roofing tiles;

e) the type and dimensions of the fixing and name of the manufacturer;

f) number of tiles that have been fixed and distribution of fixings (fixing patterns, refer to Annex C);

g) the species or density of the timber used for the battens, dimensions and span of the battens and the moisture content of the battens;

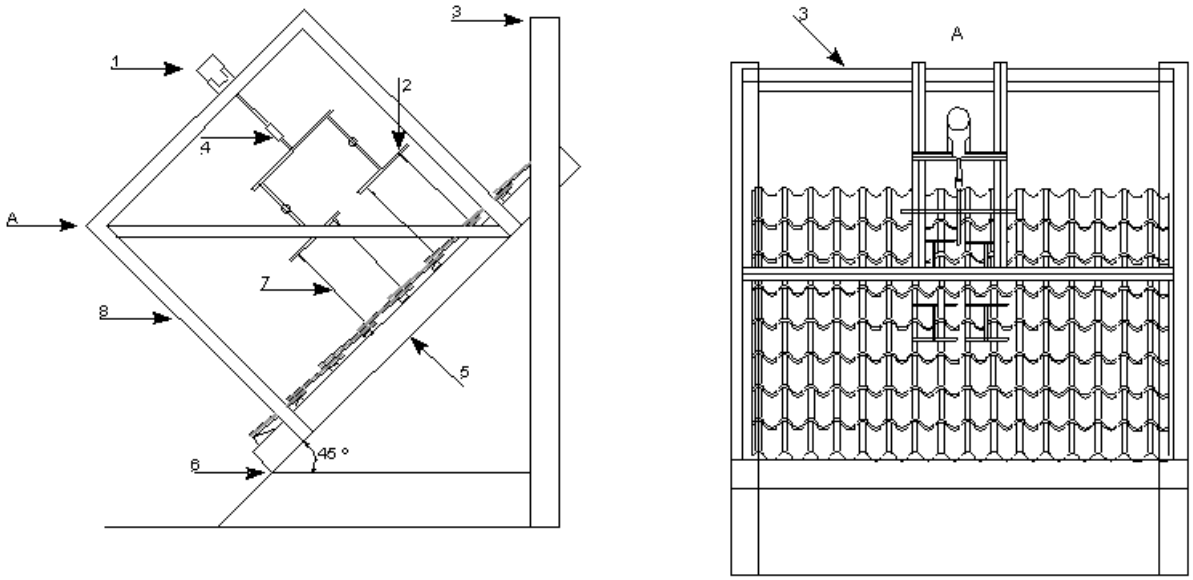
h) date of testing;

i) test results (individual values, mean and standard deviation and the modes of failure);

j) any other factor that could have influenced the result.

Annex A
(informative)

Test rig



Key

1 Hydraulic pull / push provision
2 Force application
3 Frame
4 Force measuring
5 Rafter
6 Joint
7 Cable
8 Frame

Figure A.1 – Example of the test rig

Annex B
(normative)

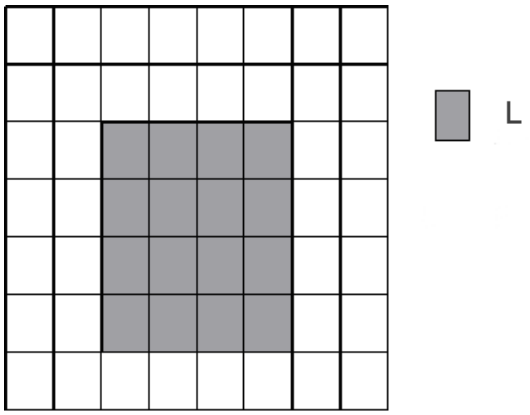
Arrangement of tiles on the test rig

B.1 General

This annex contains the specification of the arrangement of the tiles on the test rig and the arrangement of the tiles to be loaded.

B.2 Single lap interlocking tiles in straight bond

For single lap interlocking tiles laid in straight bond, the loading shall be applied to 16 tiles, laid in a rectangular shape of 4 x 4 tiles, as shown in the Figure below.



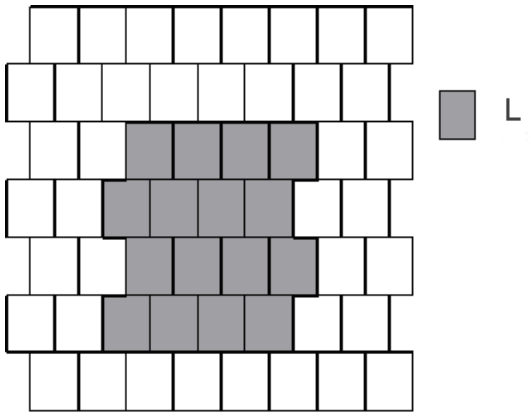
Key

L Loaded tiles

Figure B.1 - Loading pattern for single lap interlocking tiles laid in straight bond

B.3 Single lap interlocking tiles in broken bond

For single lap interlocking tiles laid in broken bond, the loading shall be applied to 16 tiles, 4 tiles per row. The loading pattern shall be similar to that shown in Figure B.2.



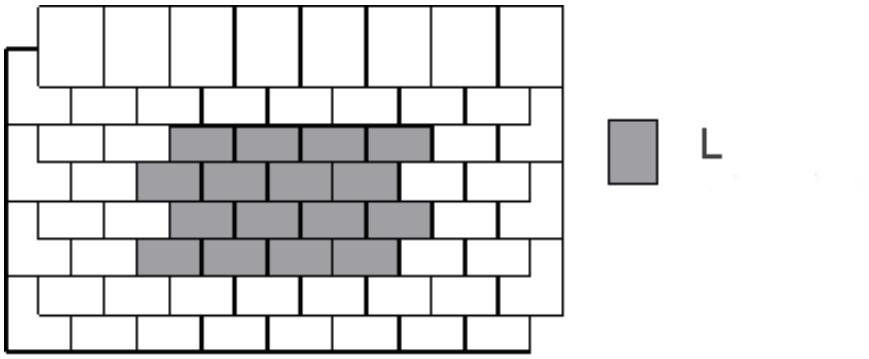
Key

L Loaded tiles

Figure B.2 - Loading pattern for single lap interlocking tiles laid in broken bond

B.4 Tiles with double-lap

For tiles with double-lap, the loading pattern is given in Figure B.3. It is similar to that of tiles laid in broken bond.



Key

L Loaded tiles

Figure B.3 - Loading pattern for tiles with double overlap

Annex C
(informative)

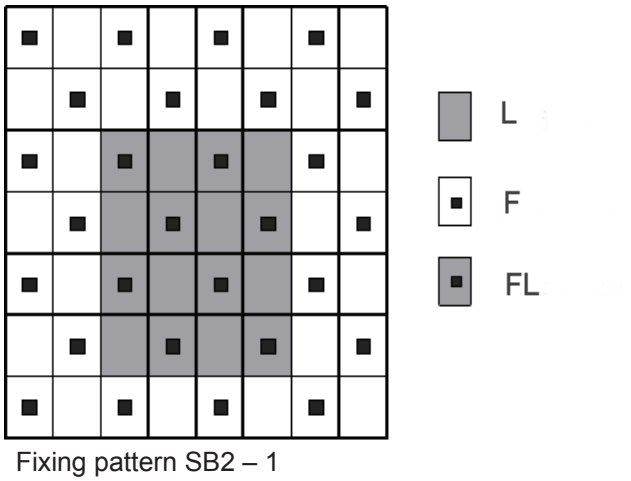
Fixing patterns to be tested

C.1 General

This annex gives examples of specifications of fixing patterns, which are possible in different configurations. The pattern used should be specified in the test report. It is recommended to include a sketch similar to the Figures C.1 to C.4 in the test report.

C.2 Single lap interlocking tiles laid in straight bond

For single lap interlocking tiles laid in straight bond and fixings applied in alternate diagonals (1:2 fixing or checkerboard) the fixing pattern shown in Figure C.1 shall be used. For single lap interlocking tiles laid in straight bond and fixings applied in alternate courses in a 1:2 fixing, the fixing pattern shown in Figure C.2 shall be used.



Fixing pattern SB2 – 1

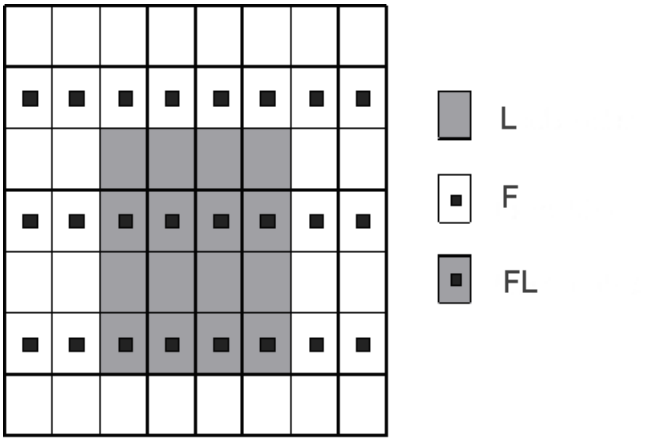
Key

L Loaded tiles

F Fixed tiles

FL Fixed loaded tiles

Figure C.1 - Alternate diagonal (1:2) fixing pattern for single lap interlocking tiles laid in straight bond



Fixing pattern SB2 - 2

Key

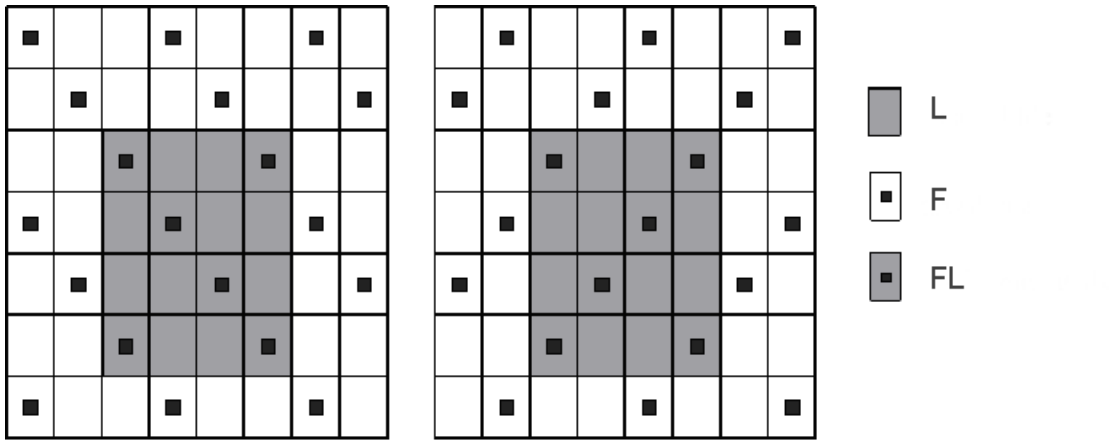
L Loaded tiles

F Fixed tiles

FL Fixed loaded tiles

Figure C.2 - Alternate course (1:2) fixing pattern for single lap interlocking tiles laid in straight bond

For single lap interlocking tiles laid in straight bond and each 3rd tile fixed (1:3 fixing), Figure C.3 shows examples of fixing patterns.



a) Fixing pattern SB3-1 b) Fixing pattern SB3-2

Key

L Loaded tiles

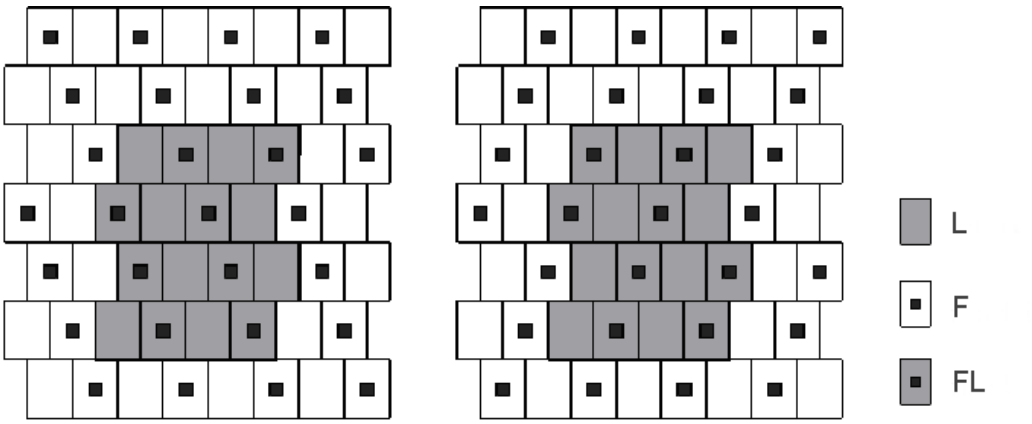
F Fixed tiles

FL Fixed loaded tiles

Figure C.3 - Fixing patterns for single lap interlocking tiles laid in straight bond in a 1:3 fixing

C.3 Single lap interlocking tiles laid in broken bond.

For single lap interlocking tiles laid in broken bond, various 1:2 fixing patterns are possible. Examples are given below in Figure C.4.



a) Fixing pattern BB2 - 1 b) Fixing pattern BB2 - 2

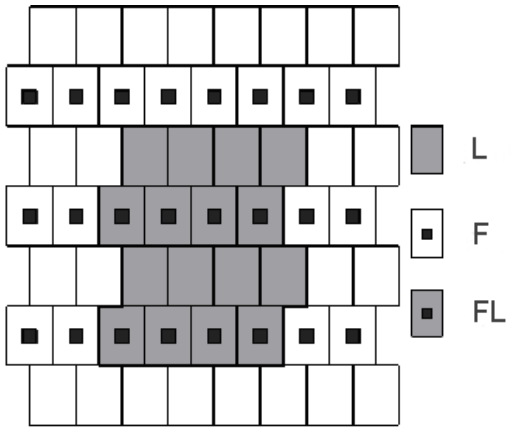
Key

L Loaded tiles

F Fixed tiles

FL Fixed loaded tiles

Figure C.4 - Fixing patterns for single lap interlocking tiles laid in broken bond in a 1:2 fixing.



Fixing pattern BB2 - 3

Key

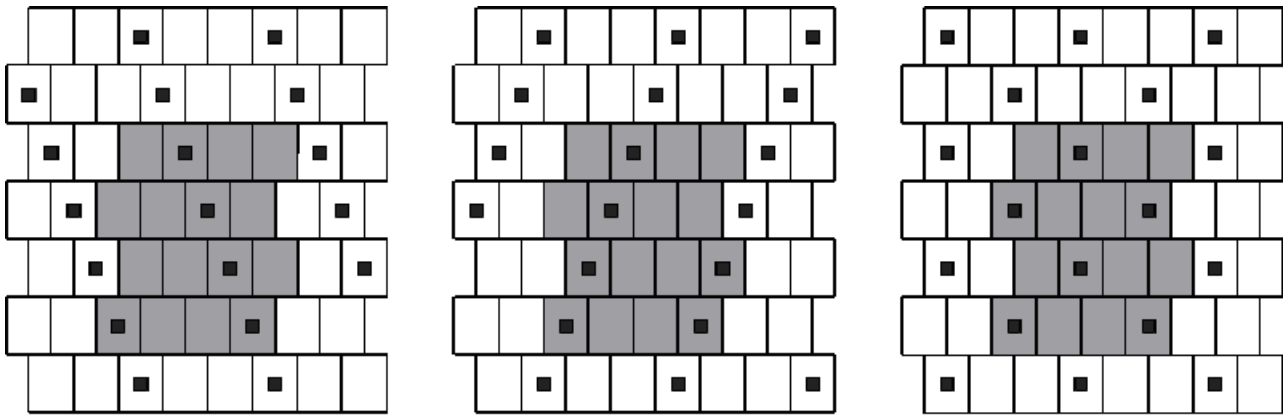
L Loaded tiles

F Fixed tiles

FL Fixed loaded tiles

Figure C.5 - Fixing pattern for single lap interlocking tiles laid in broken bond, with alternate course fixing.

For configurations with 1:3 fixing, various fixing patterns are possible. Examples are given in Figure C.6.

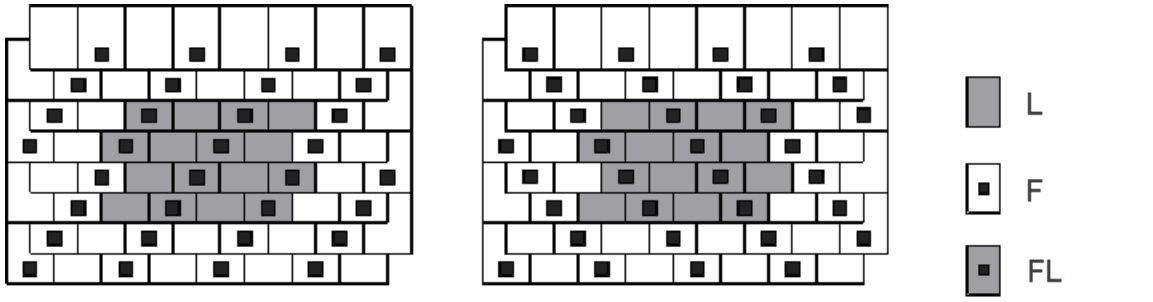


a) Fixing pattern BB3 – 1 b) Fixing pattern BB3 – 2 c) Fixing pattern BB3 - 3

Figure C.6 - Fixing patterns for single lap interlocking tiles laid in broken bond in a 1:3 fixing.

C.4 Tiles with double overlap

For tiles with double overlap, various 1:2 fixing patterns are possible. Examples are given below in Figures C.7 and C.8.



a) Fixing pattern DO2 – 1 b) Fixing pattern DO2 - 2

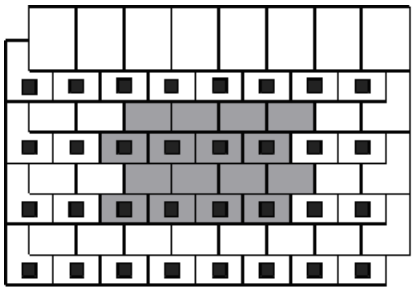
Key

L Loaded tiles

F Fixed tiles

FL Fixed loaded tiles

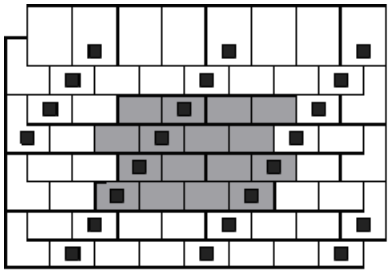
Figure C.7 - Examples of fixing patterns for tiles with double overlap in a 1:2 fixing



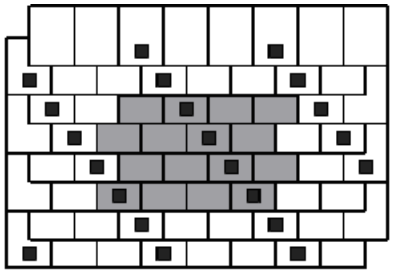
Fixing pattern DO2 - 3

Figure C.8 - Fixing patterns for tiles with double overlap in a 1:2 fixing with alternate courses

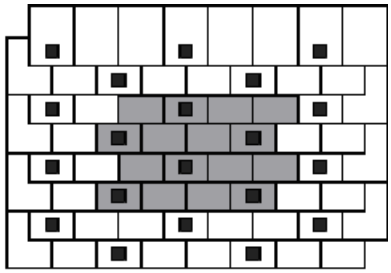
For configurations with 1:3 fixing, various fixing patterns are possible. Examples are given in Figure C.9.



a) Fixing pattern DO3 – 1



b) Fixing pattern DO3 – 2



c) Fixing pattern DO3 - 3

Figure C.9 - Examples of fixing patterns for tiles with double overlap in a 1:3 fixing

Annex D
(informative)

Calculation of characteristic values

The characteristic value of the uplift resistance of the roofing tiles may be determined based on a 5% lower bound:

$$R_k = R_x - k_n s_x$$

where

R_k is the characteristic value of the uplift resistance;

k_n is a statistical factor depending on the number of tests (n), see Table D.1;

R_x is the mean value of the uplift resistance from all tests i, as determined in Clause 10;

s_x is the standard deviation of the uplift resistance from all tests i, as determined in Clause 10.

Table D.1 - Values for the kn factor dependent on the number of tests (n)

n	3	5	7
k_n	3,37	2,33	2,08

NOTE The characteristic value of the uplift resistance may be modified into a design value by using a partial safety factor:

$$R_d = \frac{R_k}{\gamma Y}$$

where

R_d is the design uplift resistance of the roofing tiles;

γ is a partial safety factor for resistance, which may be defined by a national regulation (refer to annex G);

R_k is the characteristic uplift resistance of the roofing tiles.

EXAMPLE

Tests have been carried out on roof tiles with a mass of 4,1 kg. The visible area of the roof tiles, after installing, is 0,33 m high and 0,28 m wide, thus giving 10,82 tiles per m^2.

Three tests have been carried out on this type of tiles, using a clip on every tile. The results are:

Test 1: 800 N Test 2: 850 N Test 3: 800 N.

This gives an average value of 817 N, and a standard deviation of these test of 28,9 N. For three tests (n = 3), the value of k_n = 3,37.

This gives a characteristic value of the uplift resistance of this method of fixing and laying for this combination of tiles and fixings of: R_k = 720 N

Annex E
(informative)

Calculation of the uplift resistance of clay or concrete tiles for roofing at various roof pitches, for a tested configuration

E.1 Correction for the influence of the weight of the roofing tiles

The uplift resistance per fixing for partially or fully fixed roofing tiles for the tested configuration can be corrected for the effect of weight of the roofing tiles:

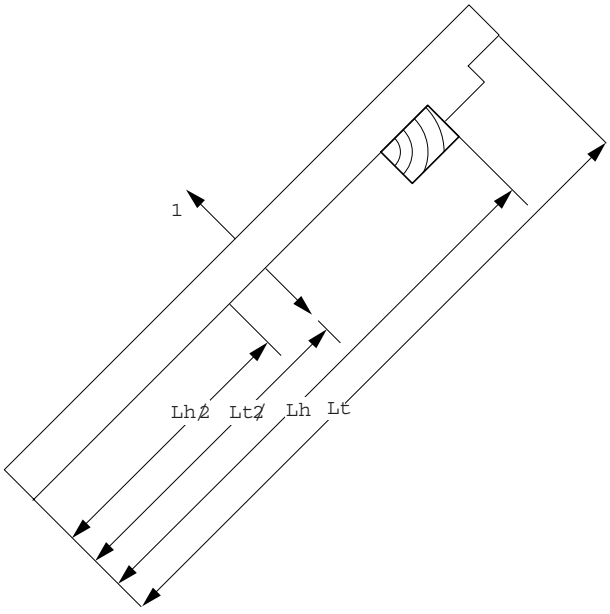
$$R_i = (R_{r,i} - 16\ W_k)/m$$

where

$R_{r,i}$ is the uplift resistance determined in test i, according to 9.4;

m is the number of tiles fixed in the area of the loaded 16 roofing tiles;

W_k is the theoretical uplift force required to lift an unfixed tile from the battens at a roof pitch of 45°.



Key

1 Uplift force

Figure E.1 - Definition of moment arms around pivot point

The theoretical uplift force required to lift the unfixed tiles at a roof pitch of 45° may be calculated from the moment around the point where the tile rotates around the batten. The weight of the tile may be assumed to

be uniformly distributed along the tile and may be taken equal to the mean weight of the tiles, determined in 9.1. This is shown using Figure E.1.

The theoretical uplift force to lift the unfixed tile may be determined by the following equation:

$$W_k = W_i \cos 45° \frac{L_h - 1/2L}{L_h - 1/2L_b}$$

where

L_h is the hanging length of the tile;

L_t is the total length of the tile;

L_b is the centre to centre distance of the battens;

W is the weight of the tile, determined according to 9.1.

E.2 Characteristic value of the strength of fixings

The characteristic value of the resistance of a mechanical fixing may be determined based on a 5 % lower bound:

$$R_{k,f} = R_{x,f} - k_n s_{x,f}$$

where

$R_{k,f}$ is the characteristic resistance of a fixing;

k_n is a factor depending on the number of tests (n), see Table D1 in Annex D;

$R_{x,f}$ is the mean resistance of a fixing from all tests i;

$s_{x,f}$ is the standard deviation of the resistance of a fixing from all tests i.

The mean value and the standard deviation of the resistance of the fixings from all tests i are given by:

$$R_{x,f} = \frac{1}{n}\sum R_i$$

$$s^2_{x,f} = \frac{1}{n-1}\sum \left(R_i - R_{x,f}\right)^2$$

where

R_i is the corrected resistance of the fixing, from test i, from E1;

n the number of tests that have been carried out.

NOTE The characteristic uplift resistance of the fixing may be modified into a design uplift resistance by using a partial safety factor:

$$R_{d,f} = \frac{R_k}{\gamma}$$

where

$R_{d,f}$ is the design resistance of the fixing;

γ is a partial safety factor for resistance, which may be defined by a national regulation (refer to Annex G);

$R_{k,f}$ is the characteristic resistance of the fixing.

E.3 Uplift resistance of partially or fully fixed roofing tiles for various roof pitches

The resistance of partially or fully fixed installed roofing tiles in the tested configuration at roof pitches different from 45° can be determined from:

$$R(\alpha) = m_{fixing} R_{k,f} + W_k \cos(\alpha)/\cos(45^o)$$

where

$R(\alpha)$ is the average resistance of partially or fully fixed roofing tiles at a roof pitch α, per tile;

m_{fixing} is the average number of fixings per roofing tile;

$R_{k,f}$ is the characteristic resistance per fixing, according to E1 in N;

W_k is the theoretical uplift force required to lift an unfixed tile from the battens at a roof pitch of 45°, according to E.1;

α is the roof pitch.

EXAMPLE

Tests have been carried out on roof tiles with a mass of 4,1 kg. The weight of a tile is 40,2 N. The length of the tile is 420 mm, the hanging length is 360 mm, and the batten distance is 330 mm. This yields a value for W_k of 21,8 N.

The visible area of the roof tiles after installing is 0,33 m high and 0,28 m wide, thus giving 10,82 tiles per m^2.

The uplift resistance for a fixing is found after correcting for the uplift resistance of the weight of the roof tiles; this correction is $16W_k$ = 350 N.

In the test, the tiles were fully fixed, which gives a value of m = 16, thus giving a value for R_i for the fixing equal to:

Test 1: (800-350)/16 = 28,1 N.

Test 2: (850-350)/16 = 31,3 N

Test 3: (800-350)/16 = 28,1 N.

This gives an average value of 29,2 N, and a standard deviation of 1,85 N. For three tests (n =3), the value of k = 3,37. The characteristic resistance of a fixing is:

$R_{k,f}$ = 29,2 - 3,37 * 1,85 = 22,9 N.

The uplift resistance of this method of fixing and laying for this combination of tiles and fixings applied at a roof pitch of 30° can now be calculated from:

$R(\alpha)$ = 1*22,9+ 21,8*cos(30°)/cos(45°) = 49,6 N (per tile)

which equals 10,82*49,6 = 537 N per square meter.

Annex F
(informative)

Determining the uplift resistance of installed clay or concrete tiles for roofing in special roof zones

When clay or concrete tiles for roofing are in the vicinity of eaves, verge, ridge or valleys, their uplift resistance may be influenced by the strength and deformation behaviour of the (special) clay or concrete tiles for roofing that are adjacent to these boundaries.

The test procedure given in this document is applicable to tiles that are surrounded by identical tiles at sufficient distance to these boundaries. This annex gives additional guidance for determining the influence of these boundaries on the test result.

a) Investigate whether or not the 16 tiles may be within two courses or two columns distance to eaves, verges, ridges or valleys or within one course of one column distance to special eaves, verge, ridge or valley tiles.

b) Investigate whether or not the deformation behaviour of the tiles to be tested will be influenced by the boundary. This will depend on the pattern of fixing, the fixing type and the interlocking and bond of the clay or concrete tiles for roofing.

NOTE 1 When special tiles for eaves, verges, ridges or valleys have been properly fixed, the standard tiles adjacent to these tiles may have a higher uplift resistance due to force redistribution through the tiles towards the special tiles.

c) When a negative influence on the uplift resistance cannot be ruled out, a test may be done where the area of 16 tiles is placed adjacent to the eaves, ridge, verge or valley or to the respective special tiles for that boundary.

d) The rules for sampling, test conditions and test material given in Clauses 5, 6 and 7 of the code also apply to the required special tiles and their fixings. The installation of the special tiles and fixings should be representative for the intended application with the tiles to be tested. The test procedure and the processing of results given in Clauses 9 and 10 is applicable.

e) Near valleys, the area of 16 tiles to be tested may need to be adjusted from an approximately rectangular array into a parallelogram shape to follow the boundary line of the valley.

NOTE 2 In some national codes requirements are given concerning the uplift resistance of special tiles and fixings adjacent to eaves, verges, ridges or valleys under a force per unit distance. For determining the uplift resistance of special tiles for eaves, verges, ridges and valleys it is recommended to install the special tiles, surrounded by at least two courses or two columns standard tiles. The rules for sampling, test conditions and test material given in Clauses 5, 6 and 7 of the code apply to the required special tiles and their fixings. Instead of applying the uplift load on 16 tiles in a rectangular array, it is advised to apply to the force in a line array on at least 4 special tiles.

Annex G
(informative)

Considerations for partial safety factors for resistance

G.1 Partial safety factors for resistance

National regulations may define partial safety factors for resistance, to be used in combination with the test results. The partial safety factors for resistance are intended to take account of unfavourable deviations from representative values, such as dimensions and strength of tiles, dimensions and strength of fixings etc. Also, inaccuracies in the structural models and systematic differences caused by the fact that the test conditions do not fully comply with the actual conditions on the roof may be accounted for in the safety factor. Finally, influences of ageing and wear may be considered in the partial safety factor for resistance.

Partial safety factors for resistance should be defined in accordance with ENV 1991-1 and should be related to the required minimum probability of failure of the fixing during the reference period.

G.2 Unfavourable deviations from representative values

When defining partial safety factors, it should be considered to what extent the test procedure will cover the effects of the randomly distributed variations, such as:

— strength of the fixing;

— strength of the tiles;

— dimensions of the fixing;

— dimensions of the tiles;

— strength of the battens;

— stiffness of the battens;

— accuracy of the laying of the tiles;

— accuracy of installation of the fixings.

In case these variations are covered adequately by the test, and none of the circumstances given in G.3 and G.4 of this annex affect the performance of the fixing, the partial factor is calculated from:

$$\gamma\gamma = \frac{R_{k,f}}{R_{x,f} - 0{,}8\beta s_{x,f}}$$

where

$R_{k,f}$ is the characteristic resistance of a fixing, refer to Annex E;

$R_{x,f}$ is the mean resistance of a fixing from all tests i, refer to Annex E;

$s_{x,f}$ is the standard deviation of the resistance of a fixing from all tests i, refer to Annex E;

β is the reliability index, corresponding to a probability of failure during the reference period.

The appropriate partial safety factors according to ENV 1991-1 combined with the 5 % characteristic value $R_{k,f}$ of the uplift resistance of the fixing and for β between 10^{-3} and 10^{-4} typically will be in the range between 1,0 and 1,2. It is advised not to use values smaller than 1,0.

The value of a partial safety factor for resistance may depend on the failure mode. In deriving partial safety factors for resistance, the failure mode should be taken into account. For failure mechanisms where the maximum displacement is the governing criterion, a partial safety factor for resistance of 1,0 is advised.

G.3 Systematic differences between test conditions and practical situations

Systematic differences compared to the tested conditions may occur in practical situations, such as:

— the use of different grades of wood for battens;

— the use of different dimensions of wood for the battens;

— the temperature (influence on the performance of the fixing);

— the relative humidity (influence on the performance of the fixing);

— the moisture content of the batten (influence on the behaviour of the batten and on the interaction of fixing and batten, for instance in case of nailed fixings).

The effects of these systematic differences may be taken into account in the partial safety factor for resistance or by performing the test for the appropriate condition.

G.4 Differences between test conditions and practical situations developing in time

Gradual changes of the properties of the fixing and/or other relevant parts in the system may cause differences compared to the tested conditions, such as:

— wear of the fixing, the interface between fixing and tile or the interface between fixing and batten due to repeated temperature, moisture and/or mechanical loading cycles;

— wear of the fixing due to UV-radiation or other types of radiation;

— corrosion of the fixing.

The effects of these systematic differences occurring in time may be taken into account in the partial safety factor for resistance or by performing additional testing to state the influence of these changes.

Annex H
(informative)

Examples of roof tiles for which the test method is not applicable

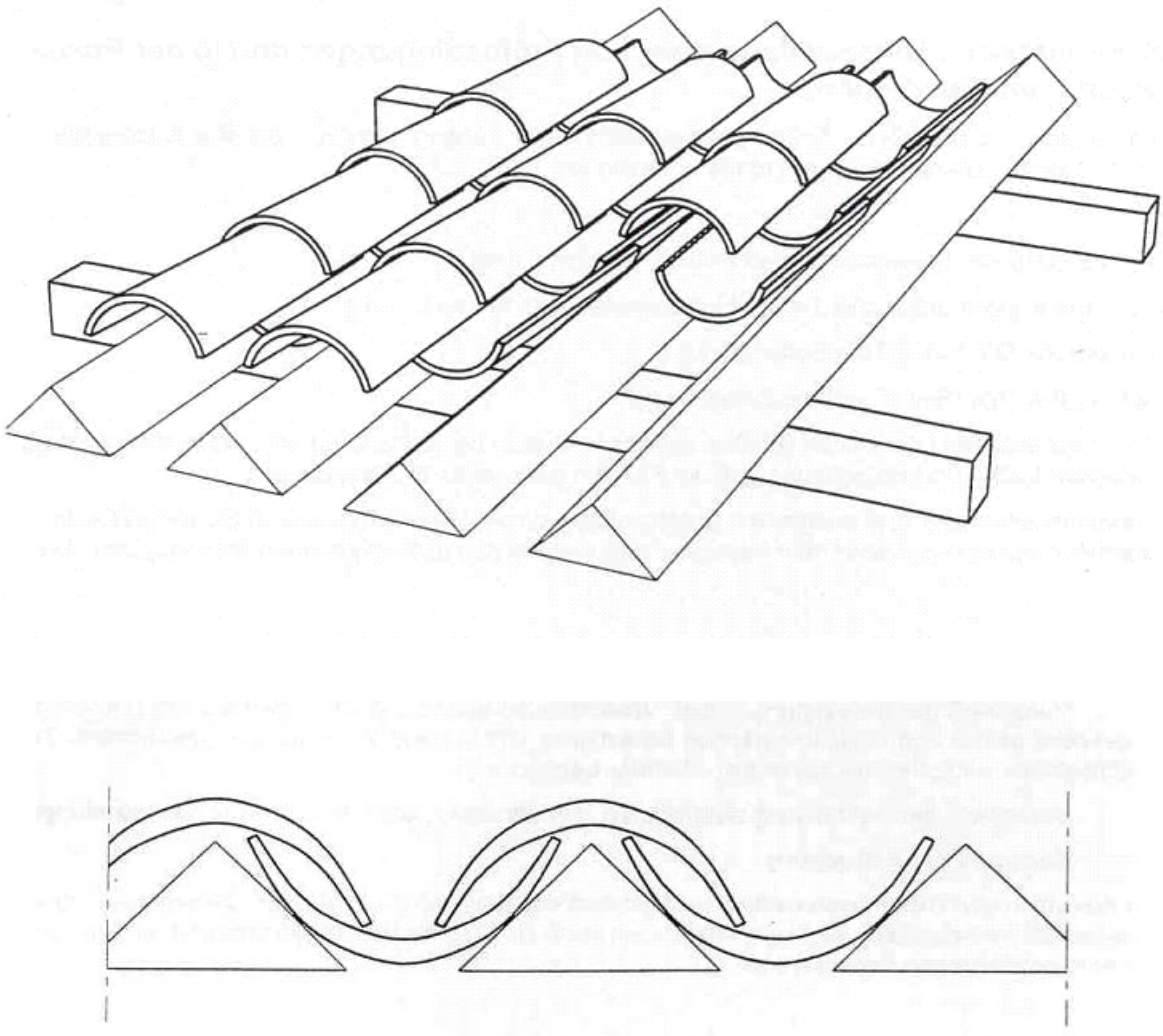


Figure H.1 – Examples

Annex I
(informative)

Test Rig Commissioning Calibrations

The following calibrations are necessary when the test facility is commissioned. These should be repeated whenever the facility is modified or moved.

a) The force applied to each of the 16 loaded tiles or slates shall be calibrated to demonstrate agreement within 5 %. This agreement shall be achieved when the loaded tiles or slates are subjected to a load characteristic of that required to lift unfixed tiles (e.g., 30 N applied to each tile).

b) The measured total load applied to the 16 tiles shall be calibrated to demonstrate that it is within 5 % of the actual value, throughout the range of tile displacements anticipated during the test.

It should be noted that for test facilities similar to that shown in Annex A:

— To demonstrate equal loads in each cable during tile loading, load cells may be placed in a minimum of two cables. One of test load cells should be moved onto the other cables in subsequent load cycles, whilst the second remains fixed as a reference. In this way all load cables ca be calibrated.

— Good agreement is likely to be reached between the loads in each cable I the loading arrangement is designed such that the load bars transferring the loads to the cables hang at the test pitch (45 º) even before any load is applied to the roof tiles. This is easily achieved using counter weights and is best checked before the cables are attached.

— A convenient method of carrying out the calibration described in items 2 above is to replace the test tiles by low friction pulleys over which cables pass. Known calibrated identical weights are attached to all the cables. The total applied load is then compared with the measured total load, over the full range of displacements anticipated during testing, taking into account the pitch of the test facility.

Bibliography

[1] EN 490, *Concrete roofing tiles and fittings - Product specifications.*

[2] EN 1304, *Clay roofing tiles for discontinuous laying - Products definitions and specifications.*

[3] ENV 1991-1, *Eurocode 1: Basis of design and actions on structures - Part 1: Basis of design.*

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