REPORT No. 060265-9-a

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PURPOSE	DETERMINATION OF UPLIFT RESISTANCE OF INSTALLED CLAY OR CONCRETE ROOF TILES ROOF SYSTEM TEST METHOD ACCORDING TO UNE-EN 14437: 2007 STANDARD
TESTED SAMPLE	POLYURETHANE FOAM REF.: "PU-TC and PU-TP ROOFING TILES"
DATE OF RECEIPT	26/09/2016
TEST DATES	30/09/2016 – 27/10/2016
DATE OF ISSUE	12/02/2019
DATE OF TRANSLATION	13/02/2019

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Firmado digitalmente por: ION OTEIZA GUERETA
Fecha y hora: 13.02.2019 11:58:13

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CHARACTERISTICS OF THE SAMPLE

To carry out the test, a test specimen was created using the following materials:

- Tiles
- Pinewood battens with 45x35 mm section
- Support structure according to figure 1
- Polyurethane.

- **A table with weight data of tested tiles is shown in annex 1**
- **Eigenvalue estimate is shown in annex II**
- **Photographs of the test conducted are shown in annex III**

Test specimen assembly

To conduct the tests, a support structure was built on which the tiles were arranged according to the layout shown in Figures 1 and 2 (drawings are carried out in a descriptive manner. The set-up can slightly vary depending on the type of tile used)

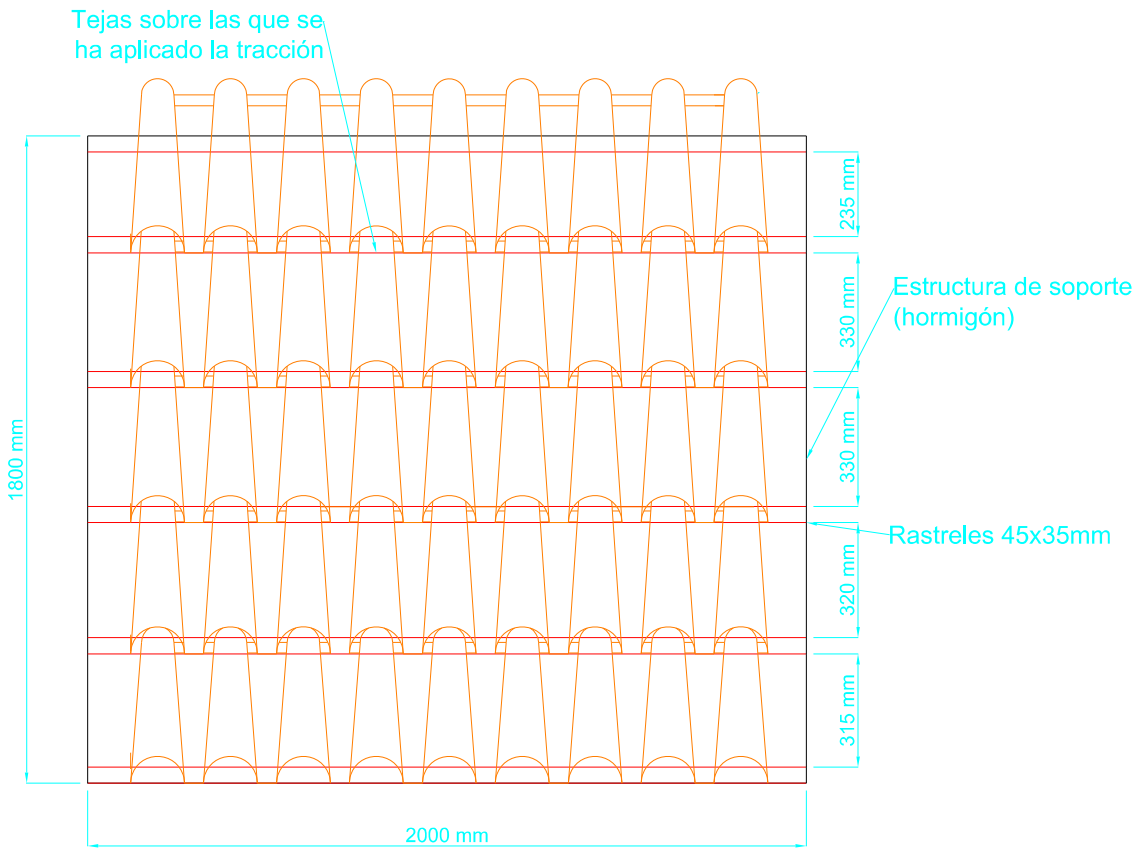

Figure 1: Plan with roof tile layout

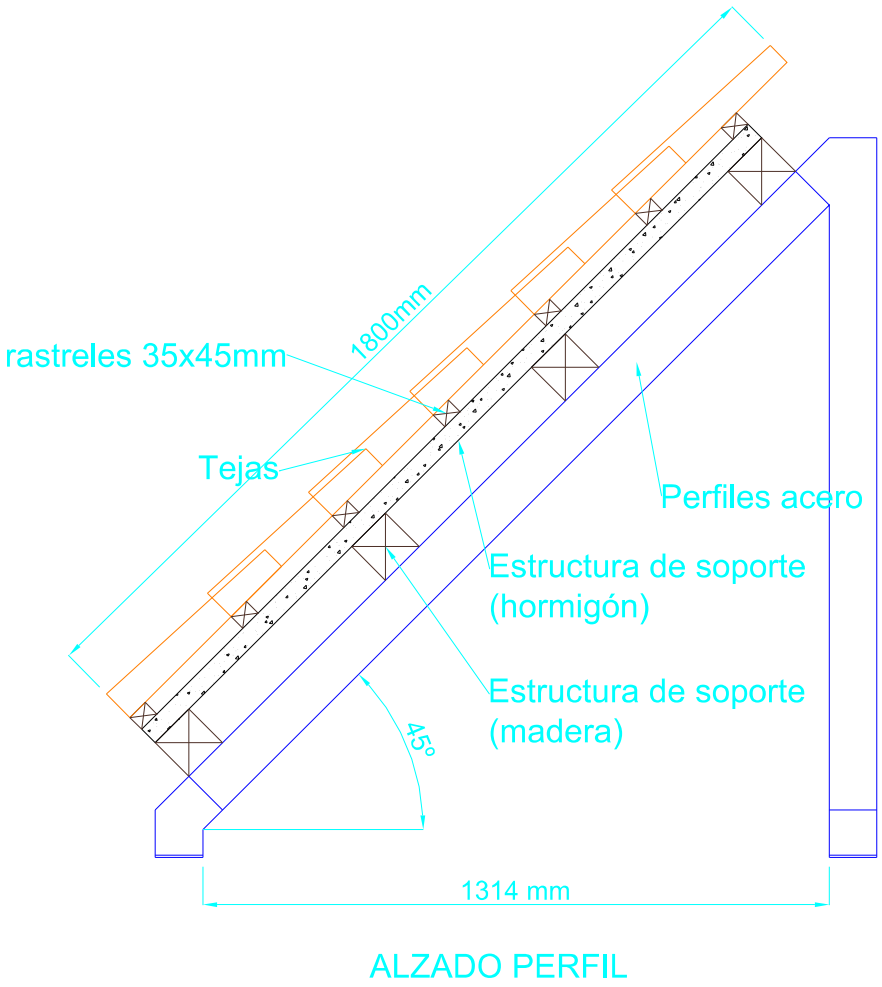

Figure 2: Profile of the support structure with tile layout

The support structure is formed by steel tubing on which 10 cm-sided wood joists have been placed. Prefabricated concrete slabs are placed on the joist to simulate the concrete on the roof. 45x35 mm-section wood battens are placed on the concrete and roof tiles are fixed over them with polyurethane FOAM.
The support structure holding the roof tiles forms a 45º angle with the horizontal plane.

TEST REQUESTED

The requested test has been the "Determination of uplift resistance of installed clay or concrete roof tiles. Test methods of the roof tile system" according to UNE-EN 14437:2007 Standard

TEST CONDUCTED

Sample conditioning

Prior to test, the sample remains at (20±5) ºC and 60±20% relative humidity for 24 hours as stated in UNE-EN 14437:2007 standard.

TEST PROCEDURE

Prior to test, the individual weight W in at least 10 tiles is determined (values are shown in annex I).

A hole (at least 10 mm in diameter) is made on each one of the tiles to place the traction cable as shown in Figures 3 and 4.

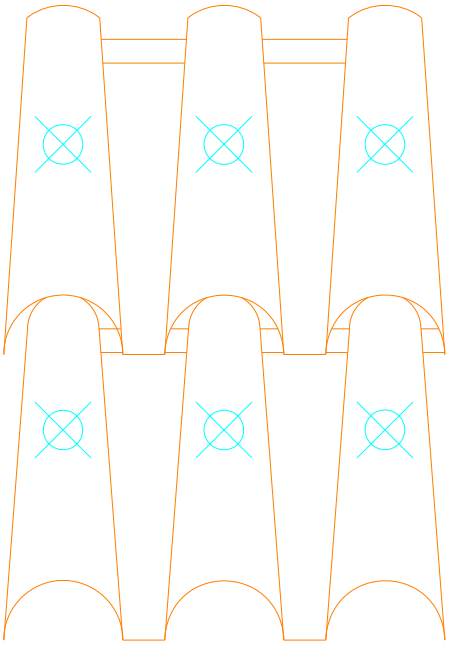

Figure 3: Hole position for placing the cables in the tiles

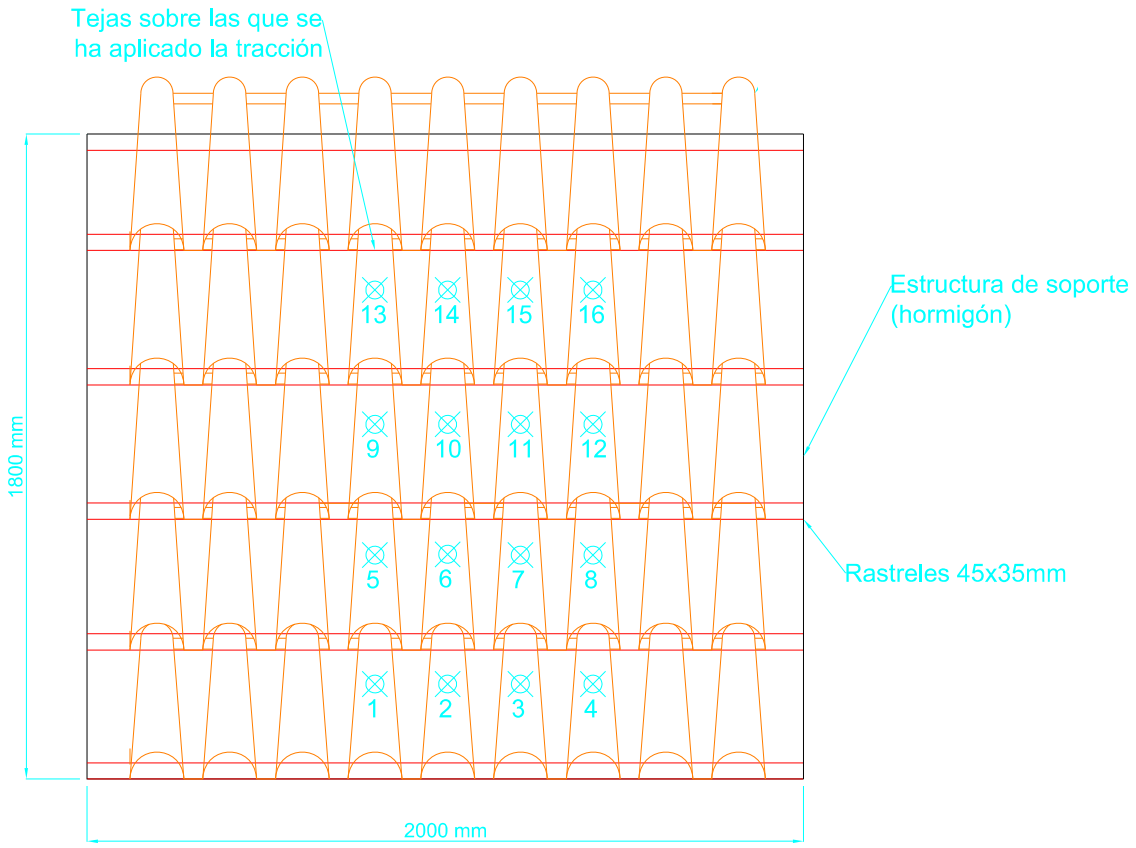

Figure 4: Position of perforations to join the traction cables to the tiles and identification of tile location.

Test trial

A test trial of 16 roof tiles arranged as shown in figures 1 and 2 was conducted. The way they were positioned should represent their true position.
The tested roof should have a minimum dimension of (1.5x1.5) m.
The force is applied perpendicular to the roof by a cable system as presented in Figure 5.

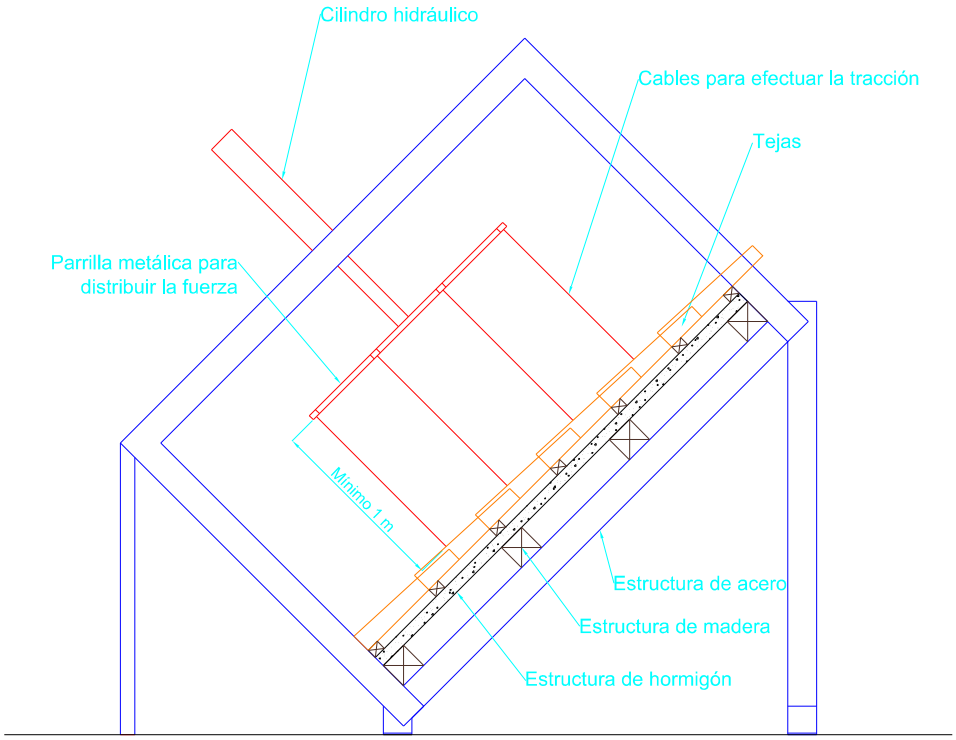

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Figure 5: Side view of the whole system

The force applied on the same should not surpass a speed of 50N/s until one of the following conditions is fulfilled:

a) Breakage of the mechanical joint between the tile and the battens (if any)
b) Breakage or detachment of the mechanical joint from the roof base
c) Breakage of roof elements
d) The maximum displacement of any of the tiles exceeds the d_{max} value (mm) given by:

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

where d_{max} is the maximum displacement permitted, in mm
where l_h is the longitudinal tile measurement, in mm

e) The tile residual displacement due to fastening deformations after reducing the force to zero exceeds 5 mm.
f) Roof tiles should not detach themselves from the battens.

The maximum force (F_t) reached by the16 tile-set is determined and the tile showing higher displacement, together with the area where it has been produced, is identified.

Series of tests

At least a series of three tests is performed.

According to the previously explained basic test criteria, firstly the force should be applied at a maximum of 0.7 $F_{t,}$ and in subsequent steps at a maximum of 1/20 F_t keeping its maximum level for at least 5 seconds. After that, it should be reduced to zero. The force should be increased and reduced at a maximum of 50 N/s.

On reaching the maximum force value, the displacement should be measured as stated in the previous section.

The force application procedure is shown in Figure 5

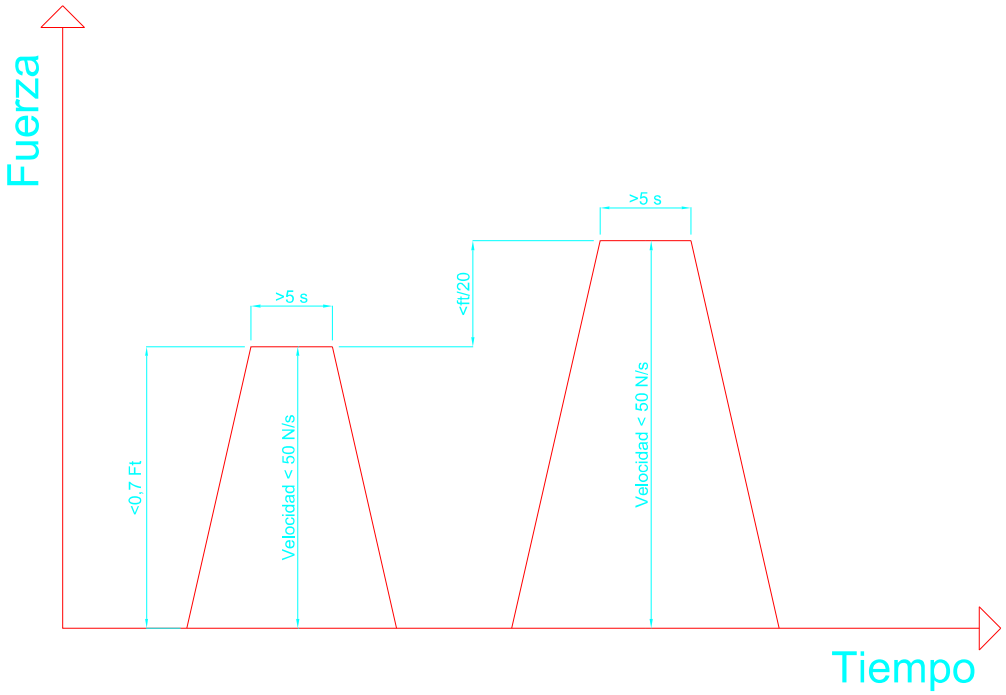


Figure 6: Force application procedure.

As for the test trial, testing is interrupted if any of the following conditions occur:

a) Breakage of the mechanical joint between the tile and the battens (if any)
b) Breakage or detachment of the mechanical joint from the roof base
c) Breakage of roof elements
d) The maximum displacement of any of the tiles exceeds the d_{max} value (mm) given by:

d_{max}= 75 l_h / 400

where d_{max} is the maximum displacement permitted, in mm
where l_h is the tile hanging length, in mm

e) The tile residual displacement due to fastening deformations after reducing the force to zero exceeds 5 mm.
f) Roof tiles should not detach themselves from the battens.

The maximum force (F_t) reached by the16 tile-set is determined and the tile showing higher displacement, together with the area where it has been produced, is identified.

Evaluation and presentation of results

The mean value and the standard deviation of the resistance in all the tests should be estimated through:

$$R_x = \frac{1}{n}\sum R_{rt}$$

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

where:

- $R_{r,i}$ is the resistance on test start-up i
- n is the number of tests conducted.

When after three series, the s_x/R_x ratio is over 0,10, two additional tests should be performed. When after 5 tests the s_x/R_x ratio still exceeds 0.10, two additional tests should be conducted.

RESULTS:

INITIAL TEST

Environmental conditions were as follows:

Temperature:	19 ºC	Relative humidity:	58%	Atmospheric Pressure:	101.2 kPa

DESCRIPTION:	Applied force (N)
MAXIMUM LOAD REACHED IN INITIAL TEST	2,904
TYPE OF FAILURE	Tile uplift
MAXIMUM DEFORMATION ZONE	
CENTRAL ZONE	

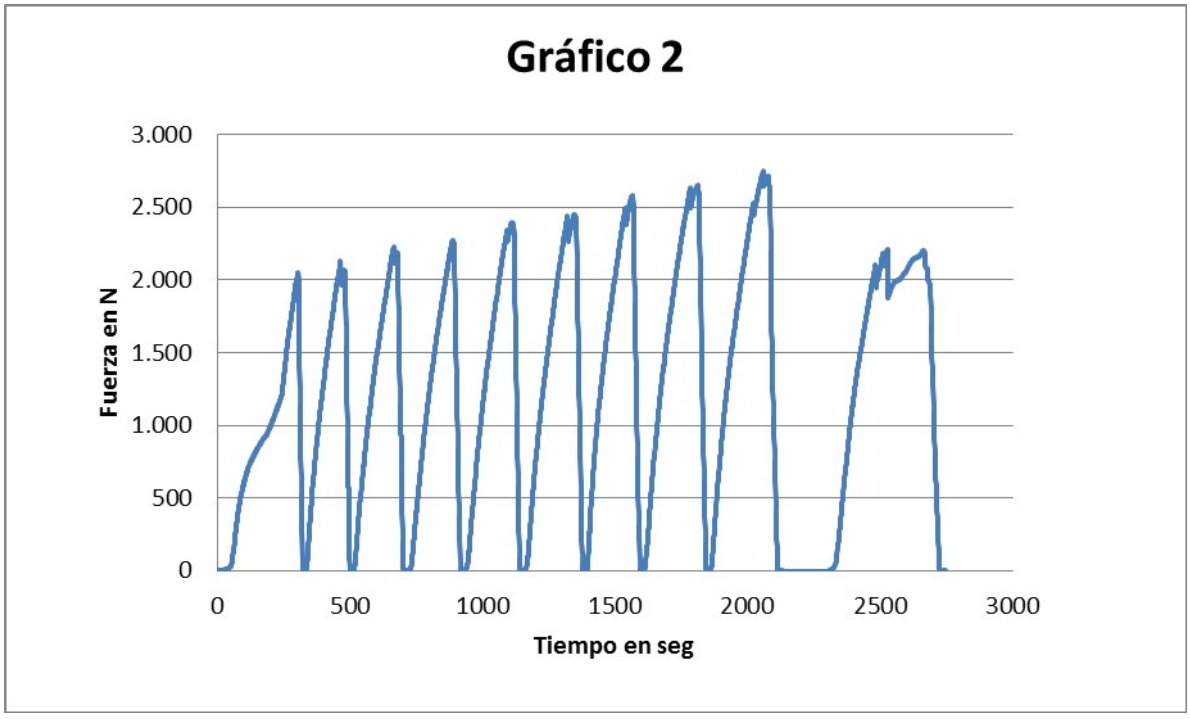
Graph 1: Load

TEST 2

Environmental conditions were as follows:

Temperature:	20 ºC	Relative humidity:	54%	Atmospheric Pressure:	101.1 kPa

DESCRIPTION:	Applied force (N)
70% OF INITIAL MAXIMUM LOAD	2,032.8
MAXIMUM LOAD $R_{r,1}$	**2,739**
TYPE OF FAILURE	Tile uplift when reaching 2,840
MAXIMUM DEFORMATION ZONE	
CENTRAL ZONE	



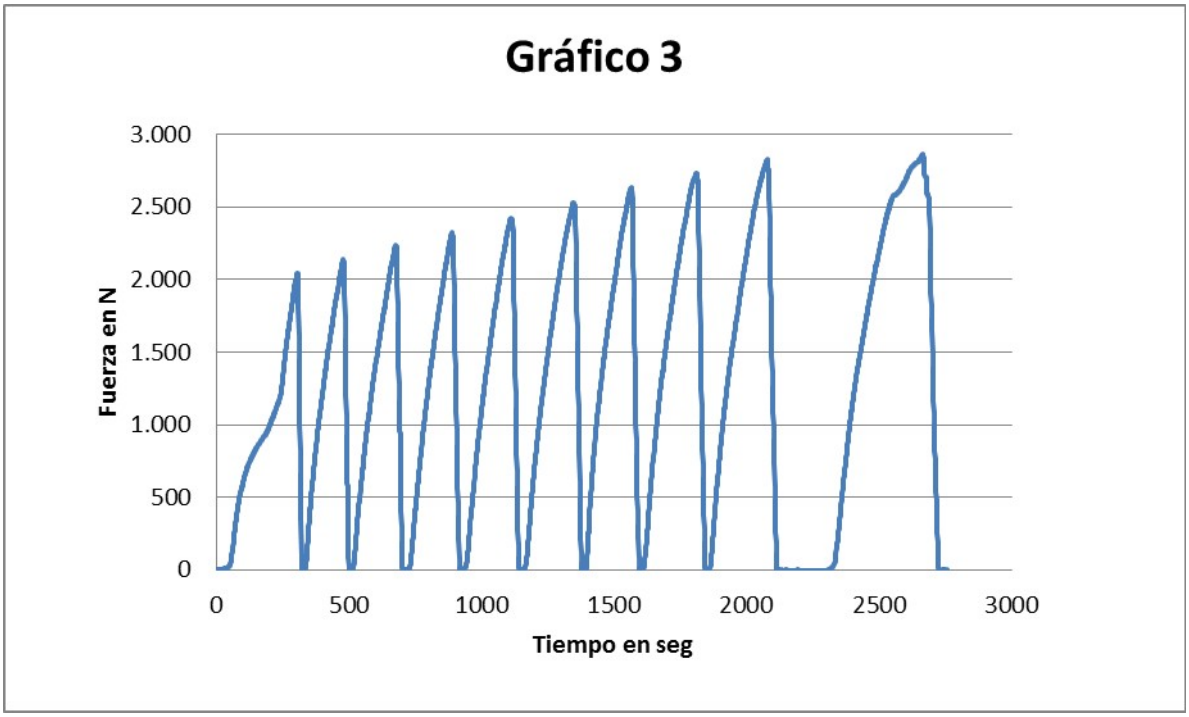
Graph 2: Load – Time in test 2

TEST 3

Environmental conditions were as follows:

Temperature:	21 ºC	Relative humidity:	53%	Atmospheric Pressure:	100.5 kPa

DESCRIPTION:	Applied force (N)
70% OF INITIAL MAXIMUM LOAD	2,032.8
MAXIMUM LOAD $R_{r,1}$	**2,840**
TYPE OF FAILURE	Tile uplift
MAXIMUM DEFORMATION ZONE	
CENTRAL ZONE	



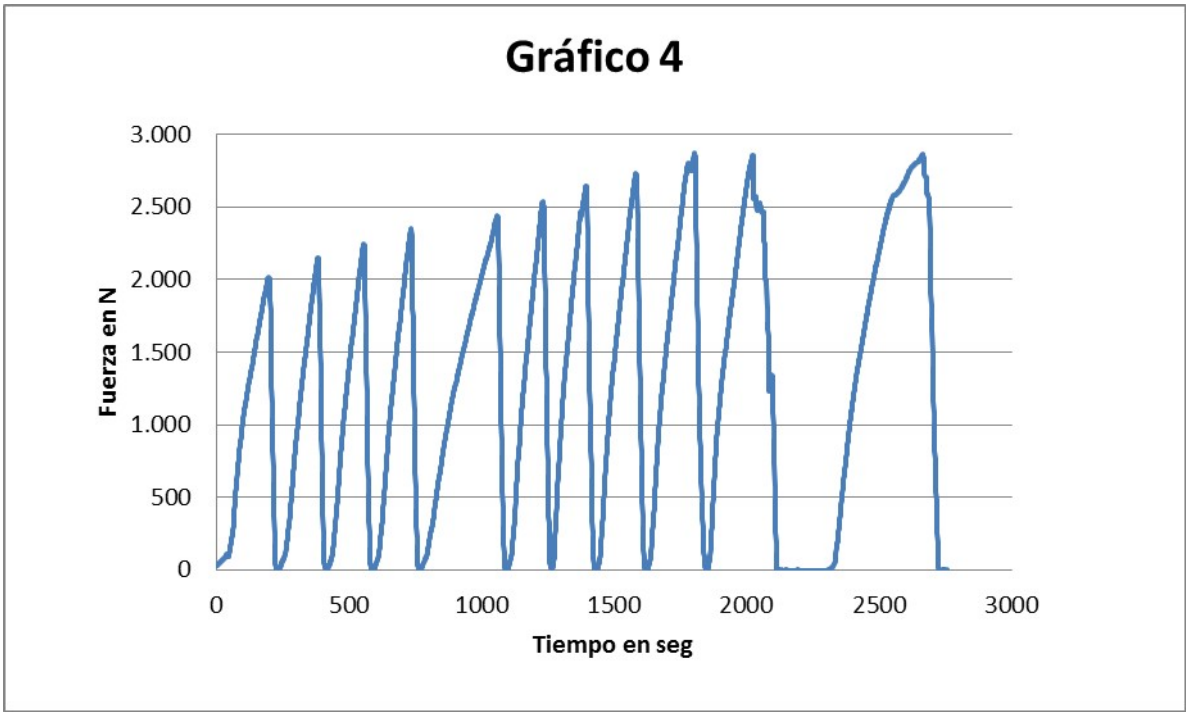
Graph 3: Load – Time in test 3

TEST 4

Environmental conditions were as follows:

Temperature:	20 ºC	Relative humidity:	50%	Atmospheric Pressure:	98.9 kPa

DESCRIPTION:	Applied force (N)
70% OF INITIAL MAXIMUM LOAD	2,032.8
MAXIMUM LOAD $R_{r,1}$	**2,840**
TYPE OF FAILURE	Tile uplift
MAXIMUM DEFORMATION ZONE	
CENTRAL ZONE	



Graph 4: Load – Time in test 4

On applying the formulas of the section "Evaluation and presentation of results" in this report, the result of the test series would be as follows:

MEAN RESISTANCE **(R_X)**	**2,806.33 N**

STANDARD DEVIATION S_X	**58.3123 N**

S_X/ R_X	**0.021**

R_k (characteristic resistance)	**2,609.82 N**

ANNEX I
DATA TABLE (w_i)

TILE NUMBER	WEIGHT (grams)
1	2429
2	2403
3	2456
4	2398
5	2464
6	2401
7	2461
8	2396
9	2463
10	2396

ANNEX II
EIGENVALUE ESTIMATE
(Information)

The resistance eigenvalue can be determined through the following formula:

$$R_k = R_x - k_n \, s_x$$

Where R_k is the eigenvalue of resistance
k_n is a statistical factor depending on the number of tests (n) (Table 1)
R_x is the mean value of the resistance in the tests
s_x is the standard deviation of the resistance

n	3	5	7
k_n	3.37	2.33	2.08

Table 1: Values of factor k_n depending on the number of tests (n)

R_x	2,806.33
s_x	58.3123
k_n (for 3 tests)	3.37

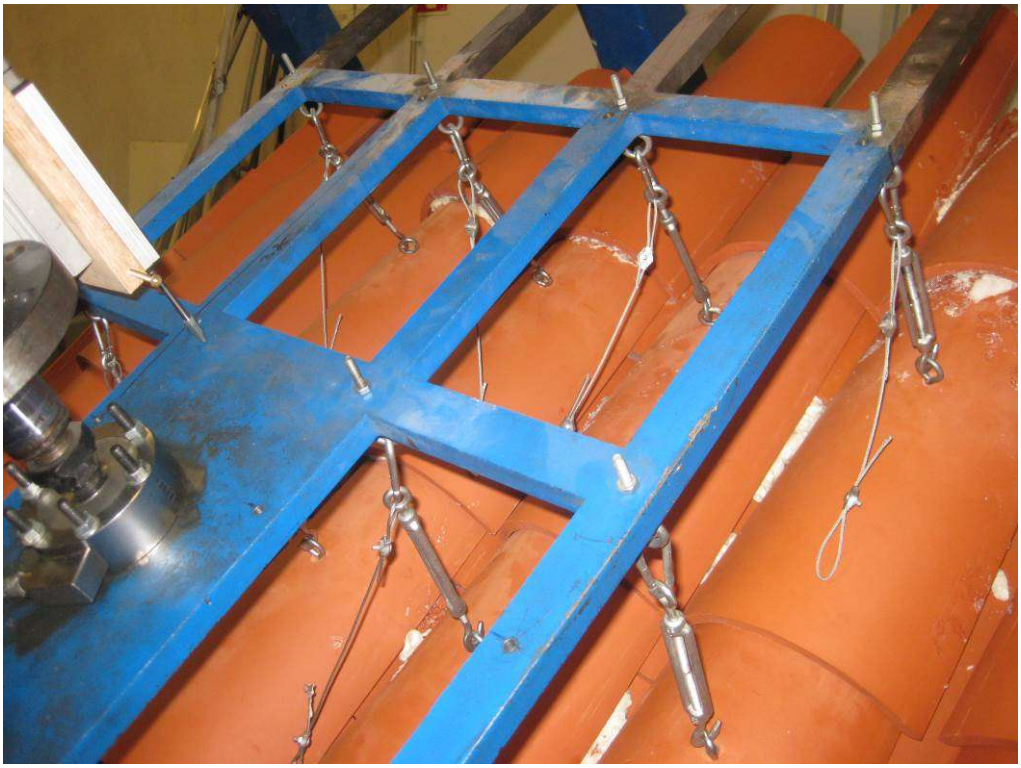
R_k	2,609.82

ANNEX III
PHOTOGRAPHS

Photograph 1

Photograph 2

Photograph 3



Photograph 4

Photograph 5