



Proposal Number: 285463 SUS-CON CP-IP

Sustainable, Innovative and Energy-Efficient Concrete, based on the Integration of All-Waste Materials

Deliverable D6.3

Tests results on prototypes

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Abstract:	This report is related to Task 6.3 (<i>Prototypes characterization</i>) and includes the results of the tests established in Task 6.2 (<i>Prototypes design and realization</i>). The performance of SUS-CON prototypes are analyzed and benchmarked.
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² PU: Public, RE: restricted to a group specified by the consortium CO: Confidential, only for members of the consortium; Commission services always included.

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1. INTRODUCTION

Main objective of WP6 is to validate the feasibility of the developed production process of the SUS-CON components and to demonstrate the real improvements in the component performances, with the aim of the subsequent industrialization. Fully-operational prototypes have to be designed and manufactured, using the SUS-CON mixtures developed in WP4 and the product design and manufacturing methods developed in WP5. The outcomes of this workpackage are prototypes for both ready-mixed and pre-cast applications, fully representative of industrial production issues and typical energy-efficiency requirements, and has been validated to show their conformities to the technical and functional statements.

More specifically Task 6.2 (Prototypes design and realization) is focused on SUS-CON prototypes production (for both testing activities and to be installed on real demo buildings), while in Task 6.3 (Prototypes characterization) the tests established in Task 6.2 were performed. The aim of the present document is to collect all the results related to the testing of SUS-CON prototypes, analyze them and compare with reference products. The characterization tests carried out to assess the performance of the prototypes were the following:

- ✓ mechanical (flexure) tests up to failure;
- ✓ thermal transmittance;
- ✓ fire behaviour;
- ✓ thermographic inspections (qualitatively thermal behaviour);
- ✓ inspections by ultrasounds (qualitative acoustic behaviour).

Specific details on the procedures followed are reported in D6.2 (Fully operational prototypes). The components (i.e. panels, blocks, slabs) used for testing were casted and prepared in Magnetti Building plants. Three partners were responsible for each scheduled tests; these are respectively Consorzio TRE for mechanical testing, Magnetti Building for thermal and fire behaviour performance evaluations and CETMA for non-destructive inspections.

2. BENDING TESTS OF FAÇADE PANELS

The involvement of Consorzio TRE in WP6 was related to mechanical testing on prototypes, more specifically flexure tests up to failure on full scale panels.

The panels, casted and prepared in Magnetti Building plant, were tested in the Official Materials Testing Laboratory in Lecco (belonging to Politecnico of Milano).

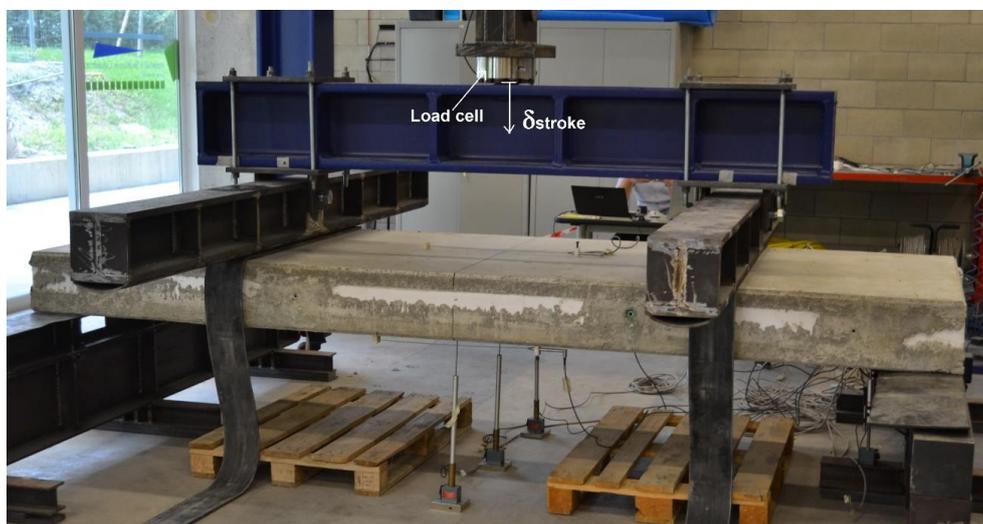
2.1. Loading scheme and instrumentation

Five panels have been tested (3 SUS-CON and 2 Reference), all with the following dimensions:

350 cm (Length) x 125 cm (Width) x 24 cm (Thickness)

The thickness of each layer, as well as the type of reinforcement, are detailed in Annex A (official report of Testing Laboratory), where the technical drawings provided by the panels producer are specified.

All the tests were performed by an electromechanical jack with the maximum loading capacity of 1000 kN, connected to a steel reacting frame. In **Figure 1** the set up and some details of the instrumentation is reported.



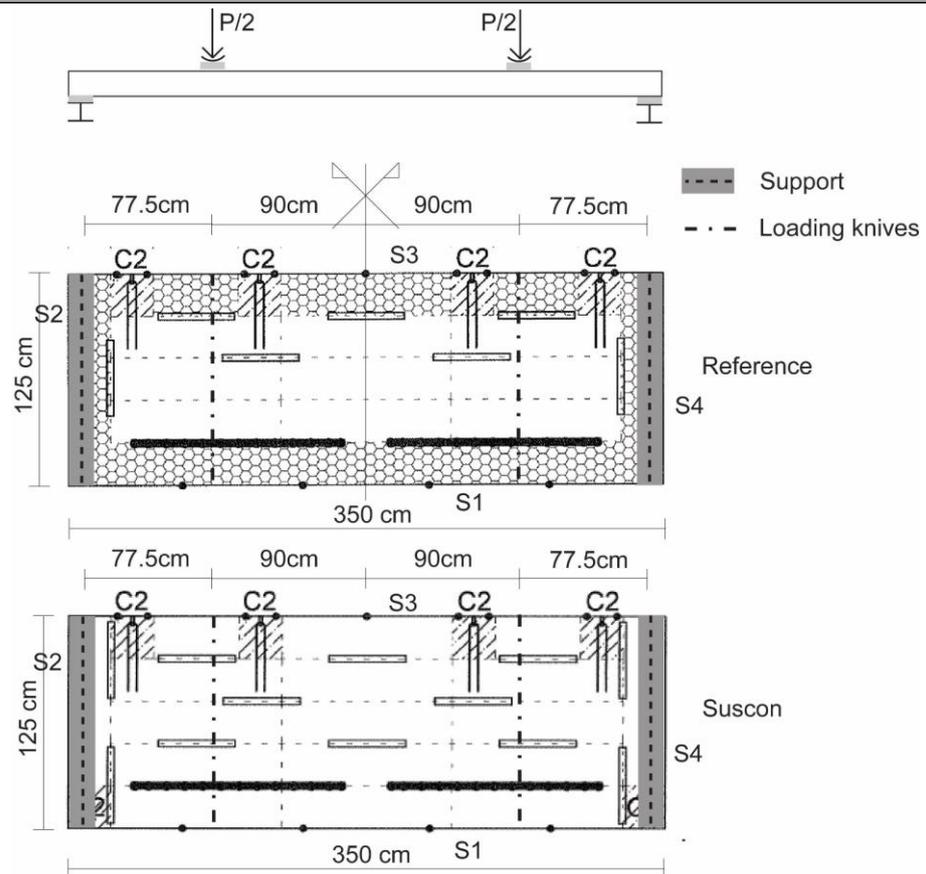


Figure 1. Test set-up and Loading scheme.

As shown in the figure, a four point bending scheme was adopted for all the tests and the detail of the support position, as well as of the load points, are available in **Figure 2**.

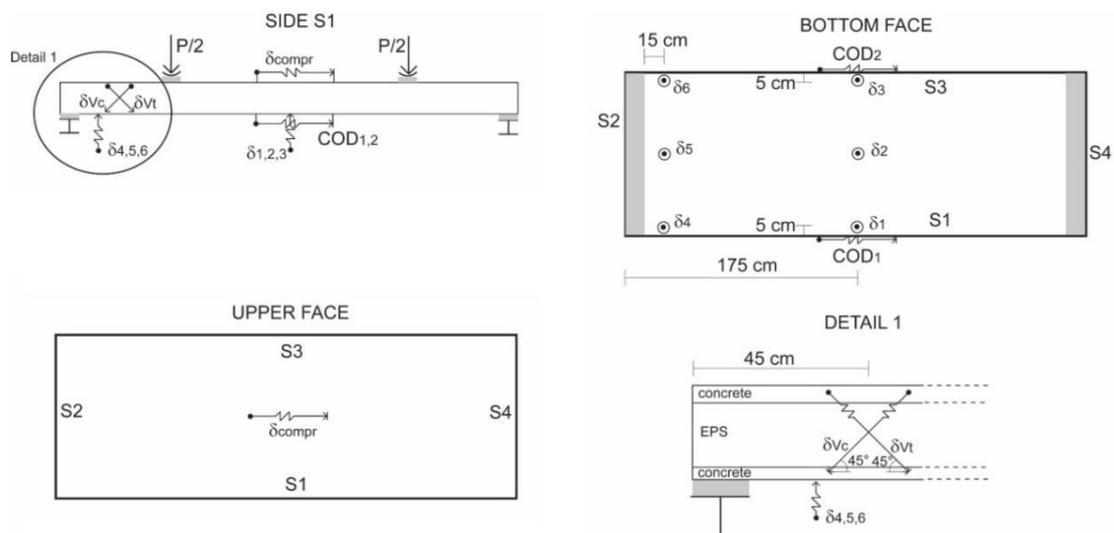


Figure 2. Instruments position.

In order to monitor the behaviour of each panel, a constant displacement (δ_{stroke}) rate was

imposed to the central point of the beam connecting the two loading knives, where also the applied force is measured by a load cell. Initial displacement rate was equal to $15 \mu\text{m/s}$ while in the final phase of each test the rate was increased up to $40 \mu\text{m/s}$. Two un-loading / re-loading cycles were performed respectively at a load corresponding to SLS and at ULS; the load at which each cycle started is reported in **Table 1**:

	Ref.1	Ref.2	SUSCON 1	SUSCON 2	SUSCON 3
Date of cast	27/07/15	9/11/15	22/07/15	24/07/15	12/11/15
Date of test	10/09/15	30/11/15	14/09/15	16/09/15	1/12/15
Concrete density at 28 days [kg/m ³]	2358 (int) 2424 (ext)	2468 (int) 2349 (ext)	1524	1495	1478
$f_{c,cube}$ at 28 days [MPa]	30.5 (int) 42.1 (ext)	32.6 (int) 41.4 (ext)	11	10.1	12.1
Concrete density at test [kg/m ³]	-	-	1521	1512	1500
$f_{c,cube}$ at test [MPa]	-	-	11.3	10.9	11.9
Panel weight [kg]	1250	1320	1090	1090	1100
Load level of SLS cycle [kN]	28.4	27	27	27	20
Load level of ULS cycle [kN]	45.2	42.5	42.6	42.6	34
Measured gauge length [mm]	L COD1	605	599	605	598
	L COD2	600	598	601	600
	L δ_{compr}	613	604	594	605
	L δ_{vt}	257	280	246	260
	L δ_{vc}	267	284	243	255

Table 1. Casting date, test date and measured gauge length of each test.

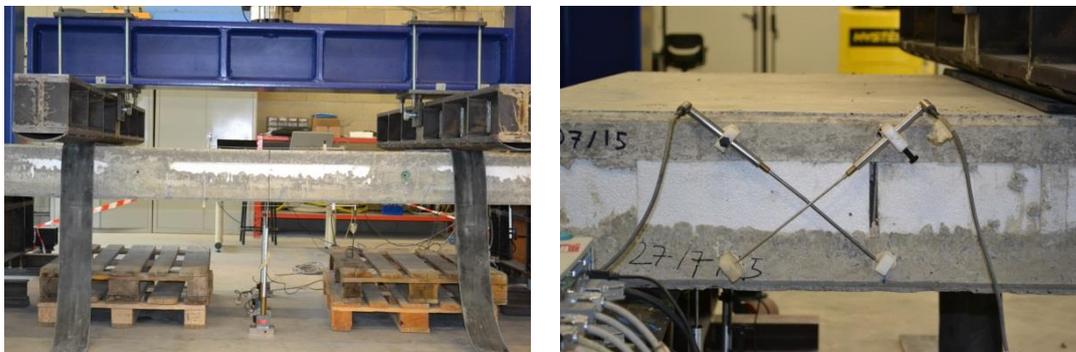


Figure 3. Details of the experimental set-up.

2.2. Comparison of the results between panels

The full results for each tested panel are shown in the attached report (see Annex A); in this section a comparison of results between traditional panels and SUS-CON panels is reported.

The tests are divided in two different groups: **Group 1** (Ref 2, Suscon 1, Suscon 2) and **Group 2** (Ref 1, Suscon 3) in order to compare panels characterized by the same longitudinal reinforcement. The following figures provide the following four diagrams:

- load vs. displacement (δ_{stroke}) used as feedback parameter;
- load vs. displacement (δ_1) used as feedback parameter;
- momentum vs curvature ϑ ;
- shear force vs shear strain γ .

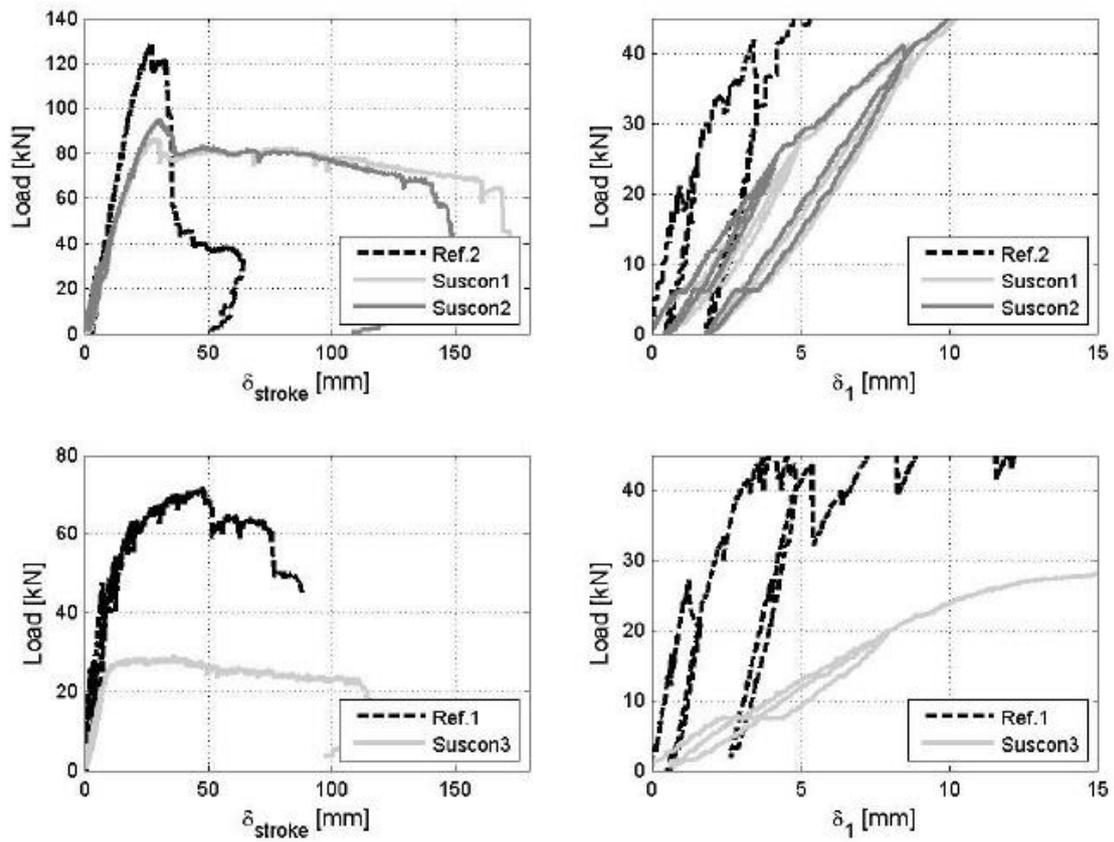


Figure 4. Comparison of experimental results: load vs δ_{stroke} and load vs δ_{stroke} .

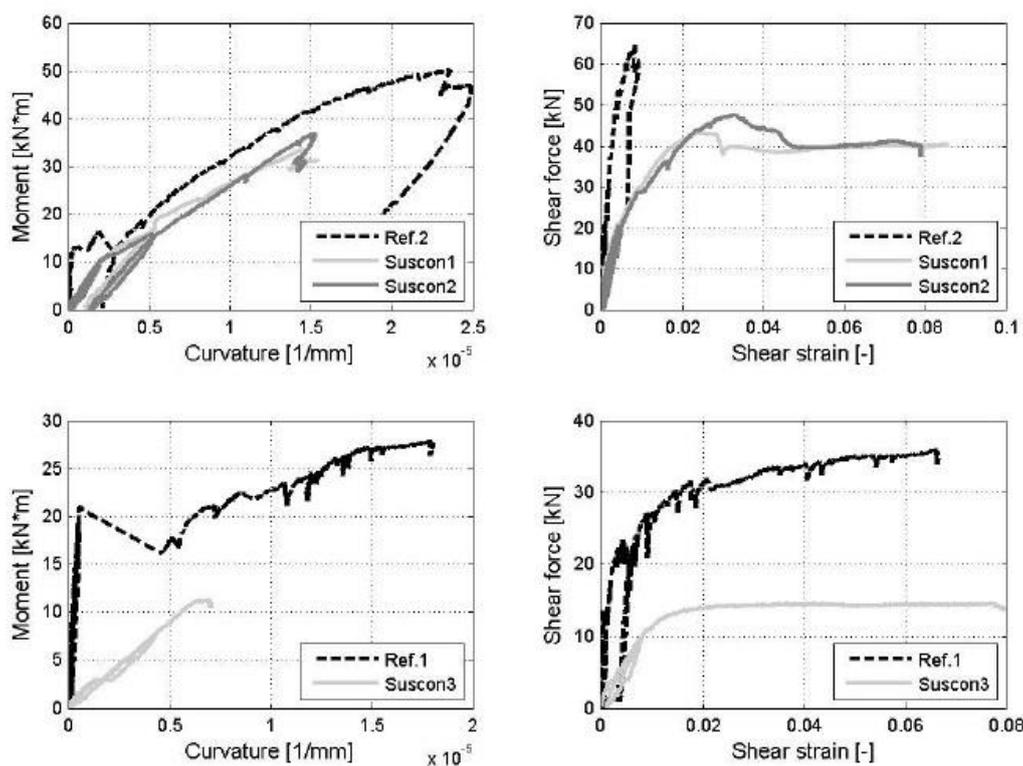


Figure 5. Comparison of experimental results: momentum vs curvature and shear force vs shear strain.

In order to compare the results of Group 2, it is important to point out that, during the test of the reference solution (Ref 1) the first crack happens outside of the gauge length; for this reason, the momentum vs curvature curve of this panel appear with a larger stiffness because it does not include the first crack but just further cracks.

The different stiffness of the panels in terms of momentum-curvature diagram is mainly related to the large difference of the elastic modulus of the two different materials.

For Group 1, the stiffness related to shear behaviour shows smaller differences because the shear stiffness is mainly governed, for both the solutions, by the steel trusses between the concrete layers. The difference observable on the load displacement curve is in between the two even if can be observed that the shear deformability seems to play a larger role mainly because of both the sandwich behaviour and the loading scheme adopted.

The full description of flexural tests can be found in Annex A.

3. THERMAL TESTS

3.1. THERMAL TESTS ON BLOCKS

The masonry blocks have a dimension about: 1200 x 1400 x 190 mm. Magnetti has casted elements for two walls made with SUS-CON blocks and one wall made with reference blocks. The elements were tested at Giordano Institute.

3.1.1. Samples description

The SUS-CON test sample (**Figure 6**) consists of two-void concrete masonry units (nominal size 392mmx192mmx190mm) based on recycled polyurethane foam and PFA/GGBS (SUS-CON concrete PU30, with density about 770 kg/m³).



Figure 6. SUS-CON masonry unit and wall built for testing.

The REFERENCE test sample (**Figure 7**) consists of two-void concrete masonry units (nominal size 392 mm x 192 mm x 190 mm) based on traditional concrete (density about 2.150 kg/m³).



Figure 7. REFERENCE masonry unit and wall built for testing.

The blocks were used to build masonry sections with the following characteristics:

- concrete masonry units;
- horizontal and vertical masonry mortar (MAPETHERM AR1 GG for SUS-CON blocks and MALTOMIX MB10 for traditional blocks, respectively), thickness 10 mm, discontinued at the void;
- outside rendering mortar: none;
- inside rendering mortar: none.

3.1.2. Normative references

The test was carried out in accordance with the requirements of standard UNI EN ISO 8990:1999 dated 30/06/1999 “Thermal insulation. Determination of steady-state thermal transmission properties. Calibrated and guarded hot box”.

3.1.3. Test apparatus

The test was performed using a guarded hot box of metering area size 1,52m × 1,52m and surfaces with emissivity of 0,93 meeting the requirements of standard UNI EN ISO 8990.

3.1.4. Conditioning of the masonry

Before the testing, the masonry was cured under laboratory conditions (temperature (23 ± 5) °C and relative humidity (50 ± 20) %) for a period of 28 days and then dried at a temperature of:

- 65 °C for 3 days for SUSCON test n. 1;
- 65 °C for 7 days for SUSCON test n. 2;
- 105 °C for 6 days for REFERENCE test.

3.1.5. Test method

The test was performed in accordance with the requirements of standard UNI EN ISO 8990 with guarded hot box and specimen area less than the metering area.

The masonry was installed in the test apparatus in an upright position inside a rectangular opening made in an expanded polystyrene (EPS) surround panel.

Heat exchange in the cold box occurs by forced convection with flow in an upwards direction and parallel to the surface of the masonry, whilst in the metering box it occurs by forced convection with flow in a downwards direction and parallel to the surface of the masonry.

In order to record the temperature, the following sensors were fitted to each side of the apparatus (**Figure 8**):

- 9 sensors to measure air temperature;
- 9 sensors on the surface of the baffle;
- 21 sensors inside the metering area, of which:
 - 4 on the surfaces at the centre of the masonry units;
 - 8 on the surfaces of the masonry units at the void;
 - 2 at the horizontal masonry mortar;
 - 2 at the vertical masonry mortar;
 - 5 on the surface of the surround panel.

Data processing was carried out in accordance with the requirements of standard UNI EN ISO 8990 using the method for homogeneous specimens given under clause 3.6.1, measuring thermal resistance during testing.



Figure 8. Test setup: hot side and cold side.

3.1.6. Results

The measured thermal transmittance “U” were:

SUS-CON BLOCKS (test n. 1)	$U = (1,41 \pm 0,06) \text{ W}/(\text{m}^2 \cdot \text{K})$
SUS-CON BLOCKS (test n. 2)	$U = (1,26 \pm 0,06) \text{ W}/(\text{m}^2 \cdot \text{K})$
TRADITIONAL BLOCKS	$U = (2,59 \pm 0,10) \text{ W}/(\text{m}^2 \cdot \text{K})$

It is worth to mention that concrete density has effected the final result of the tests. The full description of thermal tests on blocks can be found in Annex B.

3.2. THERMAL TESTS ON PANELS

The panels have a dimension of 1500 x 1000 x 240 mm. Magnetti has casted two panels made with SUS-CON concrete and one panel made with reference concrete. The elements were tested at Giordano Institute.

In the panels design (**Figure 9**), the same values of thermal transmittance and weight both for SUS-CON and reference elements were maintained:

- $U = 0,30 \text{ W}/(\text{m}^2 \cdot \text{K})$;
- density $\sim 235 \text{ kg}/\text{m}^3$.

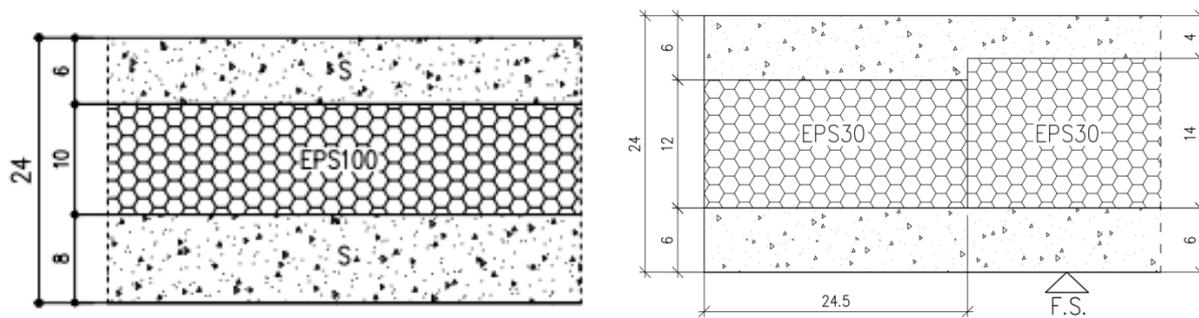


Figure 9. Stratigraphy of SUS-CON (left) and REFERENCE panel (right).

3.2.1. Samples description

The SUS-CON test sample (**Figure 10**) consists of a façade panel, with thickness of 240 mm, insulated with a layer of expanded polystyrene interposed between two layers made with reinforced concrete (see the drawings in Annex C for more details). The concrete used for this panel is based on Remix (mixed plastic) and PFA (SUS-CON concrete RX4, with density about $1500 \text{ kg}/\text{m}^3$).



Figure 10. SUS-CON panel: internal and external side.

The REFERENCE test sample (**Figure 11**) consists of a façade panel, with thickness of 240 mm, insulated with a layer of expanded polystyrene interposed between two layers made of reinforced concrete (see the drawings in Annex C for more details). The mix used for the traditional panel (with density about $2400 \text{ kg}/\text{m}^3$) has the following performances:

- compressive strength: C25/30 internal side, C30/37 external side;

- workability: S5;
- maximum aggregate diameter: 15 mm;
- environmental exposure class: XC1 internal side, XC4 external side.



Figure 11. REFERENCE panel: internal and external side.

3.2.2. Normative references

The test was carried out in accordance with the requirements of standard UNI EN ISO 8990:1999 dated 30/06/1999 “Thermal insulation. Determination of steady-state thermal transmission properties. Calibrated and guarded hot box”.

3.2.3. Test apparatus

The test was performed using a guarded hot box of metering area size 1,52 m × 1,52 m and surfaces with emissivity of 0,93 meeting the requirements of standard UNI EN ISO 8990.

3.2.4. Sample conditioning

Before the testing, the sample was dried at a temperature of:

- 65 °C for 8 days for SUS-CON test n. 1;
- 65 °C for 20 days for SUS-CON test n. 2;
- 105 °C for 26 days for REFERENCE test.

3.2.5. Test method

The test was performed in accordance with the requirements of standard UNI EN ISO 8990 with guarded hot box and specimen area less than the metering area.

The sample was installed in the test apparatus in an upright position inside a rectangular opening made in an expanded polystyrene (EPS) surround panel.

Heat exchange in the cold box occurs by forced convection with flow in an upwards direction and parallel to the surface of the sample, whilst in the metering box it occurs by forced convection with flow in a downwards direction and parallel to the surface of the sample.

In order to record temperature, the following sensors were fitted to each side of the apparatus (**Figure 12**):

- 9 sensors to measure air temperature;
- 9 sensors on the surface of the baffle;
- 21 sensors inside the metering area, of which:
 - 15 on the sample surface;
 - 5 on the surround panel surface.

Data processing was carried out in accordance with the requirements of standard UNI EN ISO 8990 using the method for homogeneous specimens given under clause 3.6.1, measuring thermal resistance during testing.

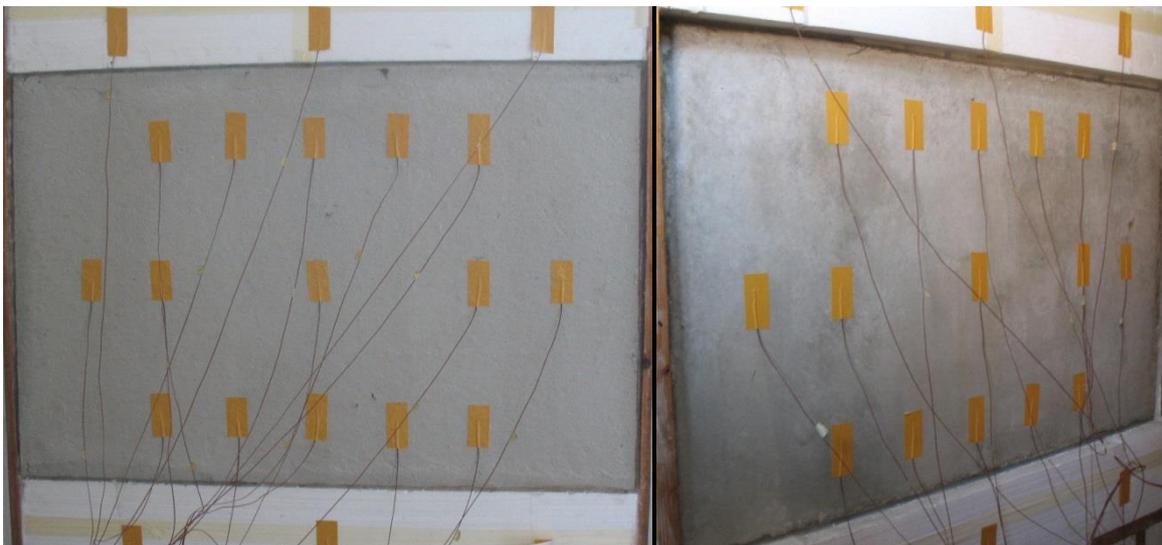


Figure 12. Test setup: hot side and cold side.

3.2.6. Results

The measured thermal transmittance “U” were:

SUS-CON PANEL (test n. 1)	$U = (0,537 \pm 0,024) \text{ W}/(\text{m}^2 \cdot \text{K})$
SUS-CON PANEL (test n. 2)	$U = (0,553 \pm 0,025) \text{ W}/(\text{m}^2 \cdot \text{K})$
TRADITIONAL PANEL	$U = (0,92 \pm 0,05) \text{ W}/(\text{m}^2 \cdot \text{K})$

In general, the small size of the panel justifies the great difference of the experimental U value compared to the theoretical value. It is worth to highlight that the result on reference panel could be affected by:

- a higher incidence of the full concrete zones with respect to the SUS-CON panels;
- the change of polystyrene section on the perimeter.

The full description of thermal tests on panels can be found in Annex C.

3.3. FEM analysis: calculation of theoretical U value

For the panels, it was decided to do further FEM (Finite Elements Method) analysis for the calculation of thermal transmittance, starting from thickness and thermal conductivity (λ) of materials, and checking the impact of single discontinuity points inside the panel: full concrete zones, steel connectors, change of polystyrene section in the reference panel. This analysis was done in the Giordano Institute.

3.3.1. Sample description

The panels have dimension of 1500 x 1000 x 240 mm.

The SUS-CON test sample is a façade panel, with thickness of 240 mm, insulated with a layer of expanded polystyrene interposed between two layers made of reinforced concrete (see the drawings in Annex D for more details). SUS-CON concrete (RX4) - density about 1500 kg/m³ - has been used for this panel.

The REFERENCE test sample is a façade panel, with thickness of 240 mm, insulated with a layer of expanded polystyrene interposed between two layers made of reinforced concrete (see the drawings in Annex D for more details). The traditional concrete - density about 2400 kg/m³ - has been used for this panel.

3.3.2. Normative references

The test was carried out in accordance with the requirements of standard UNI EN ISO 6946:2008 dated 17/07/2008 “Components and building elements - Thermal resistance and thermal transmittance - Calculation method “ and UNI EN ISO 10211:2008 dated 10/07/2008 “Thermal bridges in building - Heat flows and surface temperatures - Detailed calculations”.

3.3.3. Results

SUS-CON panel

Thermal transmittance of the panel components

The thermal transmittance value of the homogeneous insulated part of the panel is: $U = 0,293 \text{ W}/(\text{m}^2 \cdot \text{K})$.

The punctual thermal transmittance values of thermal bridges due to fixings and the hooks pass through the insulating layer, calculated according to the UNI EN ISO 10211, are:

Fixing	Single punctual thermal transmittance	Number of fixing	Total contribution on the panel
	[W/K]	[n.]	[W/m ² · K]
Pin	0,00600	6	0,024
Connector	0,0534	5	0,178
Hook	0,0402	2	0,054

Thermal transmittance of the panel

Using the above data it was calculated the thermal transmittance of the panel: $U = 0,55 \text{ W}/(\text{m}^2 \cdot \text{K})$. In **Figure 13**, **Figure 14**, **Figure 15** and **Figure 16** the schematization and isotherms of the representative module of the SUS-CON panel are showed.

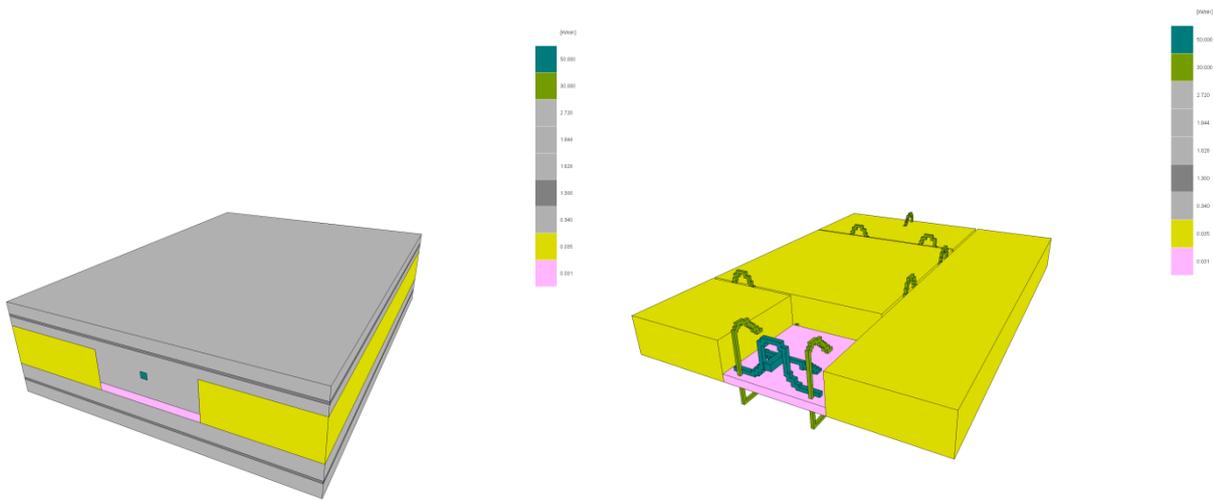


Figure 13. Schematization of the representative module of the SUSCON panel.

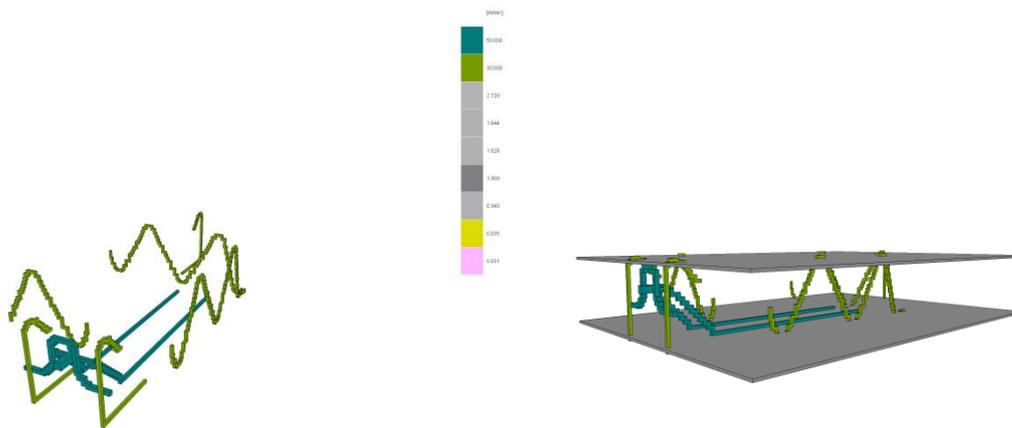


Figure 14. Schematization of the representative module of the SUS-CON panel.

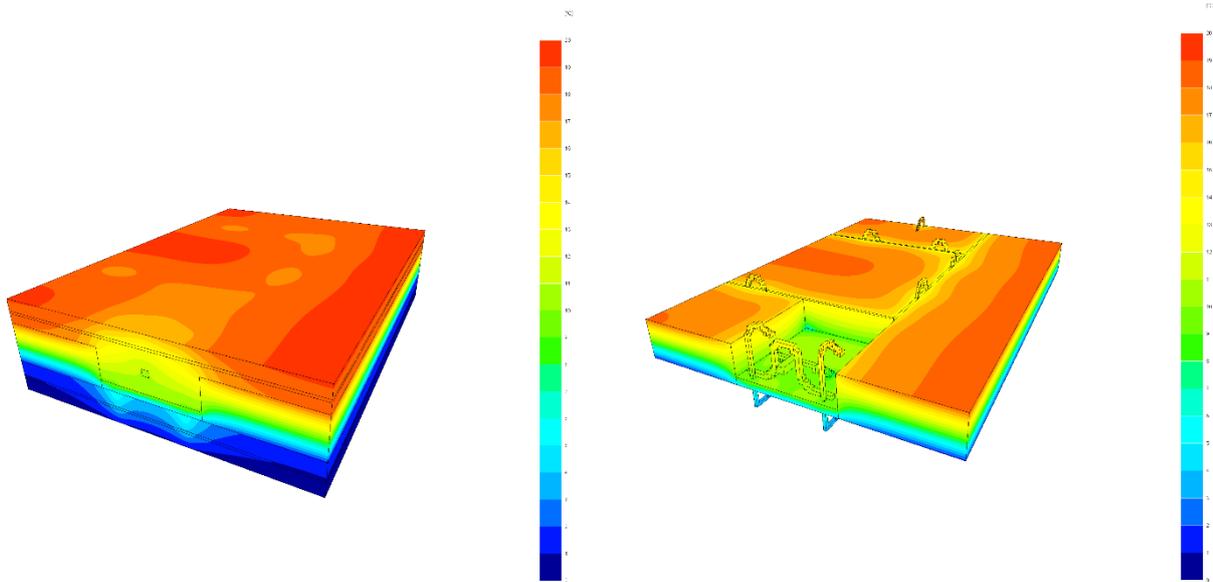


Figure 15. Isotherms of the representative module of the SUS-CON panel.

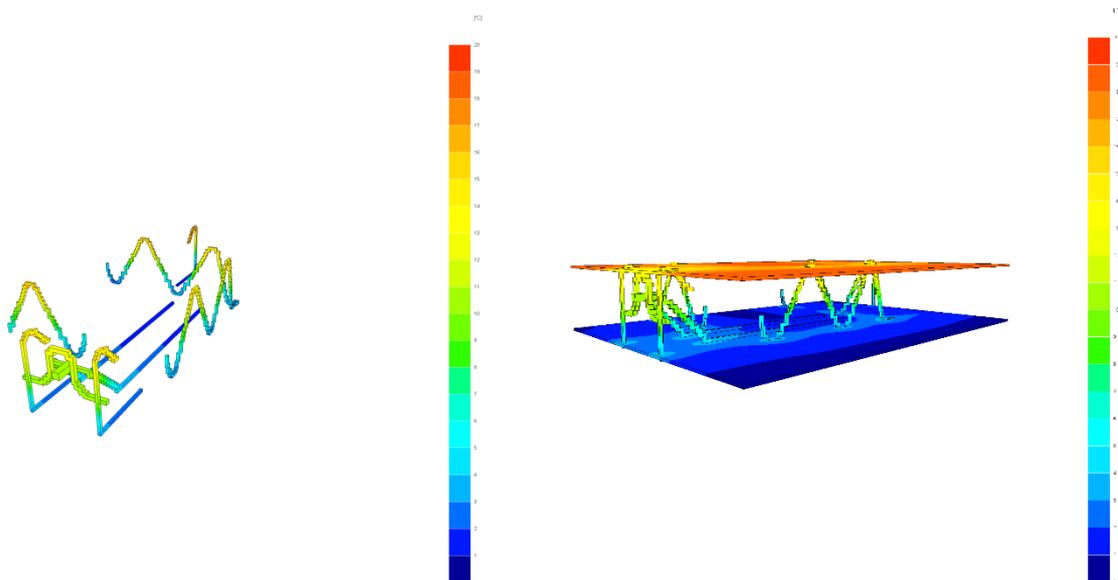


Figure 16. Isotherms of the representative module of the SUSCON panel.

REFERENCE panel

Thermal transmittance of the panel components

The thermal transmittance value of the homogeneous insulated part of the panel is: $U =$

0,307 W / (m² · K).

The linear thermal transmittance value of thermal bridge present in correspondence of the edge, calculated according to the standard UNI EN ISO 10211, is:

Section	Linear thermal transmittance	Total contribution on the panel
	[W/(m · K)]	[W/m ² · K]
Edge	0,0122	0,041

The punctual thermal transmittance values of thermal bridges due to fixings and the hooks pass through the insulating layer, calculated according to the UNI EN ISO 10211, are:

Fixing	Single punctual thermal transmittance	Number of fixing	Total contribution on the panel
	[W/K]	[n.]	[W/m ² · K]
Pin	0,00730	6	0,029
Connector	0,0834	5	0,278
Hook	0,116	2	0,154

Thermal transmittance of the panel

Using the above data it was calculated the thermal transmittance of the panel: $U = 0,81$ W/(m² · K). In **Figure 17**, **Figure 18**, **Figure 19** and **Figure 20** the schematization and isotherms of the representative module of the REFERENCE panel.

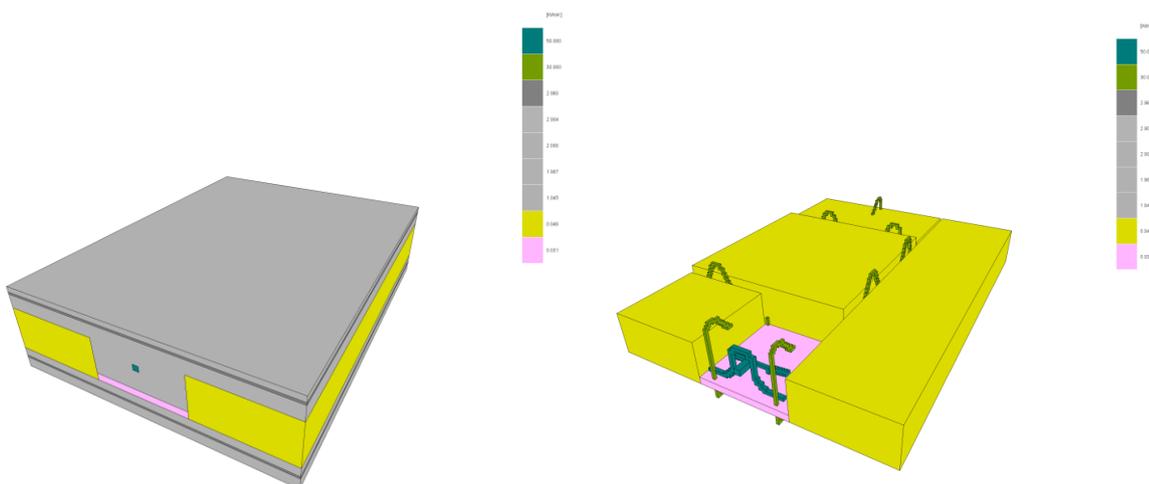


Figure 17. Schematization of the representative module of the REFERENCE panel.

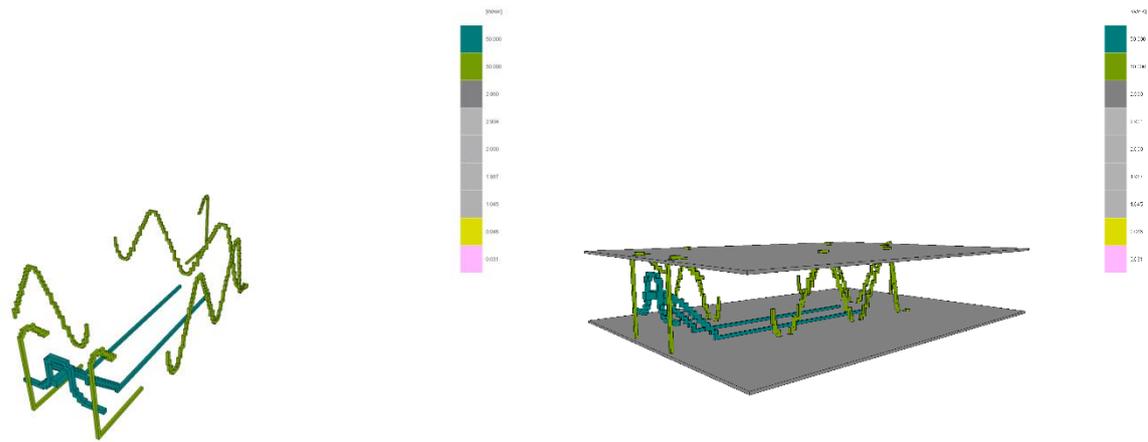


Figure 18. Schematization of the representative module of the REFERENCE panel.

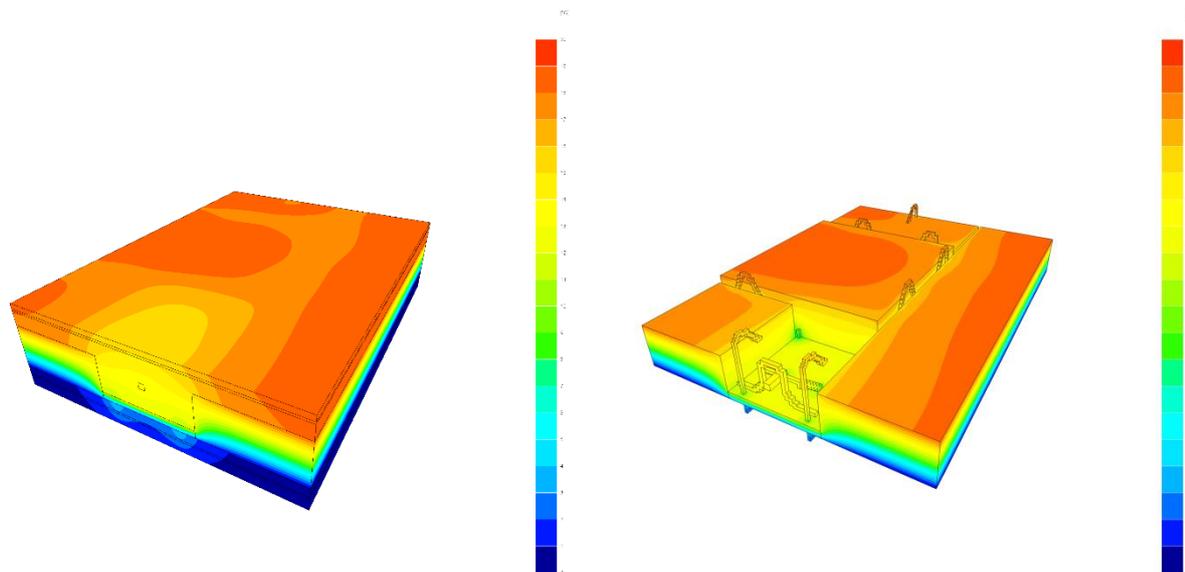


Figure 19. Isotherms of the representative module of the REFERENCE panel.

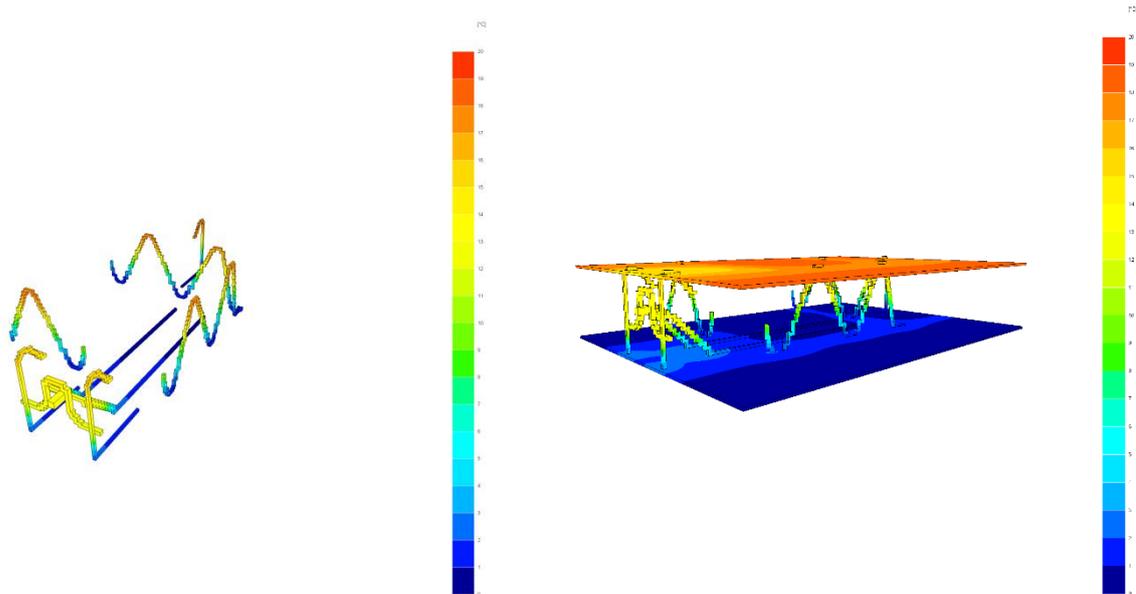


Figure 20. Isotherms of the representative module of the REFERENCE panel.

The U value from Finite Elements Method is similar to experimental tests for both solutions (SUS-CON and REFERENCE).

The full description of FEM analysis on panels can be found in Annex D.

4. FIRE BEHAVIOUR TESTS

4.1. FIRE BEHAVIOR OF BLOCKS

In accordance with the provisions of standards UNI EN 1363-1:2012 and UNI EN 1364-1:2002, a test was performed in the test furnace of Giordano Institute's Fire Resistance Laboratory on a non-loadbearing wall called REFERENCE and SUS-CON.

4.1.1. Description of specimens

The test specimens are a non-loadbearing wall called REFERENCE and SUS-CON with the following dimensions:

- nominal width: 3000 mm;
- nominal height: 3000 mm;
- nominal thickness: 190 mm.



More specifically, the specimens are unplastered and manufactured with building blocks called REFERENCE and SUS-CON, laid with the voids pointing in the vertical plane and bonded together with straight horizontal and vertical M5 standard cement-mortar joints.

The REFERENCE building blocks are cast from concrete, nominal density 2.150 kg/m^3 , and formed by 2 exposed faces of size $390\text{mm} \times 190 \text{ mm}$, measured minimum thickness 31 mm, feature shaped vertical edges and 2 perforations arranged in a single lengthways row and have the physical characteristics specified in the following table:

	Nominal value stated by the Customer	Value measured by Istituto Giordano
Thickness (mm)	192	190
Height (mm)	190	190
Length (mm)	392	390
Weight (kg)	15,5	15,6

The SUS-CON building blocks are cast from concrete PU30, nominal density 770 kg/m^3 , and formed by 2 exposed faces of size $390 \text{ mm} \times 190 \text{ mm}$, measured minimum thickness 31 mm, feature shaped vertical edges and 2 perforations arranged in a single lengthways row and have the physical characteristics specified in the following table:

	Nominal value stated by the Customer	Value measured by Istituto Giordano
Thickness (mm)	192	190
Height (mm)	190	190
Length (mm)	392	390
Weight (kg)	5,5	6,1

Hereafter a schematic drawing of the clay block used to build the test specimen and a schematic drawing of the specimen itself (**Figure 21** and **Figure 22**).

Supporting construction

The specimen was mounted in a warp-resistant reinforced-concrete perimeter test frame, nominal density 2.300 kg/m^3 , without the need for a supporting construction.

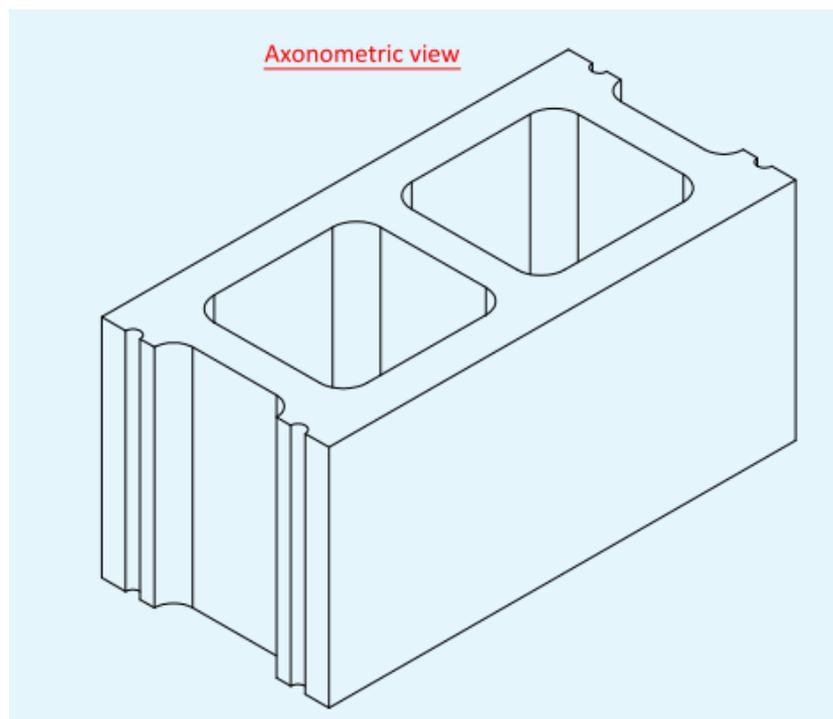
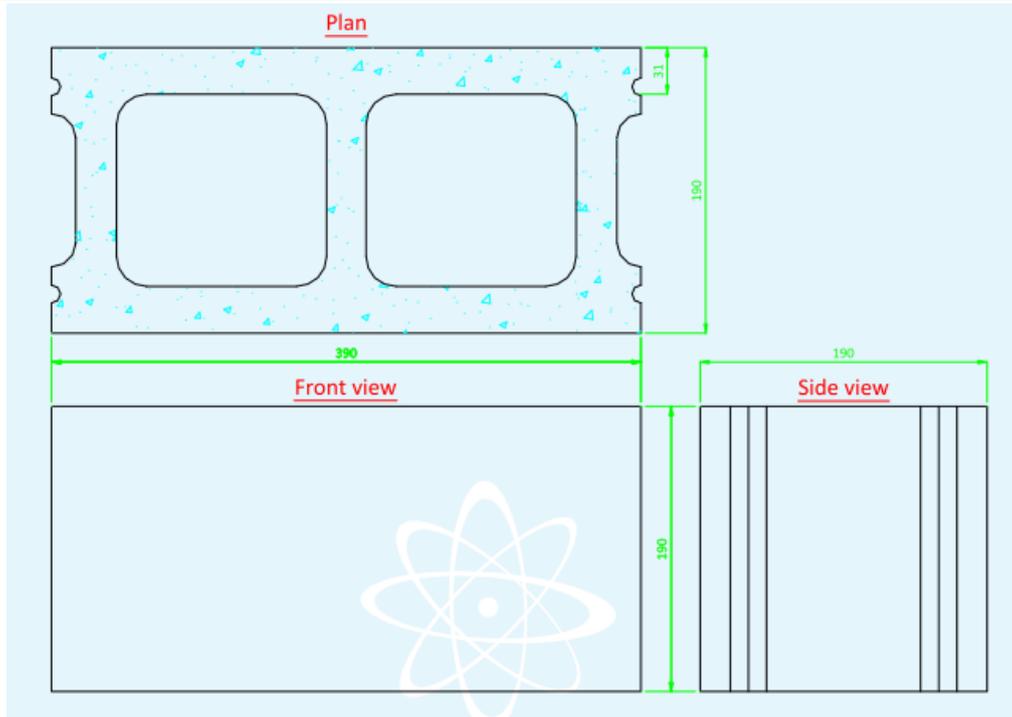


Figure 21. Schematic drawing of building block.

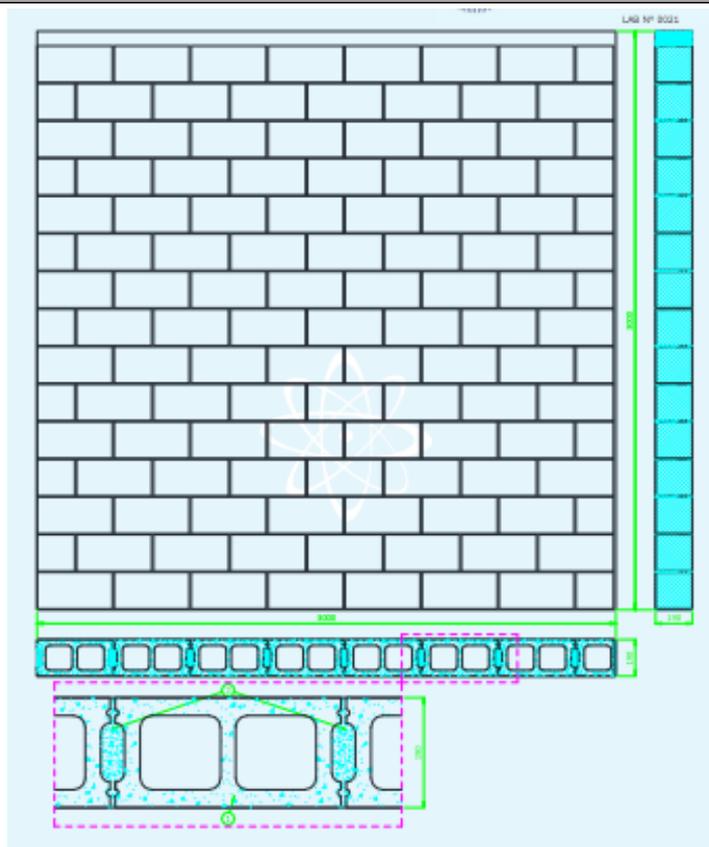


Figure 22. Schematic drawing of the specimen.

Normative References

The test was performed in accordance with the requirements of the following standards:

- UNI EN 1363-1:2012 dated 11/12/2012 “Fire resistance tests - Part 1: General requirements”;
- UNI EN 1364-1:2002 dated 01/04/2002 “Fire resistance tests for non-loadbearing elements - Walls”.

Conditioning

Before the testing, the specimen was stored in the laboratory for 63 days until reaching an equilibrium.

4.1.2. Test method

Description of test furnace

A test furnace was used having an opening on the vertical face, internal height 3200 mm,

internal width 3200 mm and internal depth 1200 mm, ceramic-fiber lining and fitted with:

- 8 twin-flame, light-oil-fired burners, equally spaced over the vertical side walls;
- 2 separate chimneys with electronically-controlled valves for varying outlet area;
- pressure measurement system comprising:
 - 2 pressure measuring devices situated 500 mm and $\frac{2}{3}$ up the furnace opening, connected to an automatic recording system;
 - manual pressure reading system situated on one of the furnace walls close to the opening;
- temperature measurement system comprising:
 - control units situated on the vertical sides of the furnace for measuring temperatures inside the furnace;
 - type “K” thermocouples connected to a mobile control unit, in turn connected to a reader that transforms the potential difference of the thermocouples themselves into temperature;
- data acquisition system connected to an electronic calculator with management software.

The test specimen is symmetrical, therefore just one of the two faces was exposed to fire.

Temperature and deflection measurement points

The temperature measuring points on the test specimen's unexposed face (position of thermocouples on the unexposed face) and within the test specimen (position of internal thermocouples) and the specimen deflection measuring points (position of displacement transducers) are shown in the schematic drawing on the attached reports.

Pressure measuring

Pressure was measured using a T-shaped pressure sensor positioned inside the test furnace 500 mm above the base of the specimen and 100 mm from the supporting element.

4.1.3. Test results of REFERENCE blocks

The behavior of REFERENCE blocks is below reported:

- 30min: slight traces of steam start to escape from the perimeter edges on the specimen's unexposed face.

- 40min: small patches of condensation start to form on the specimen's unexposed face at several cement-mortar joints between building blocks.
- 99min: test halted as specimen suffers thermal insulation failure due to mean temperature rise over initial ambient temperature exceeding 140°C as recorded by the five thermocouples fitted at the center and along the diagonals of the specimen.

Repeated checks carried out on the specimen face not exposed to fire in accordance with standard UNI EN 1363-1:2012 at no time recorded specimen integrity failure.

This classification has been carried out in accordance with clause 7.5.2 of standard UNI EN 13501-2:2009. The vertical non-loadbearing element called REFERENCE is classified according to the following combinations of performance parameters and classes:

EI 90

The following sheets show photos (**Figure 23**, **Figure 24**, **Figure 25**, **Figure 26** and **Figure 27**) of specimen before and after the test.

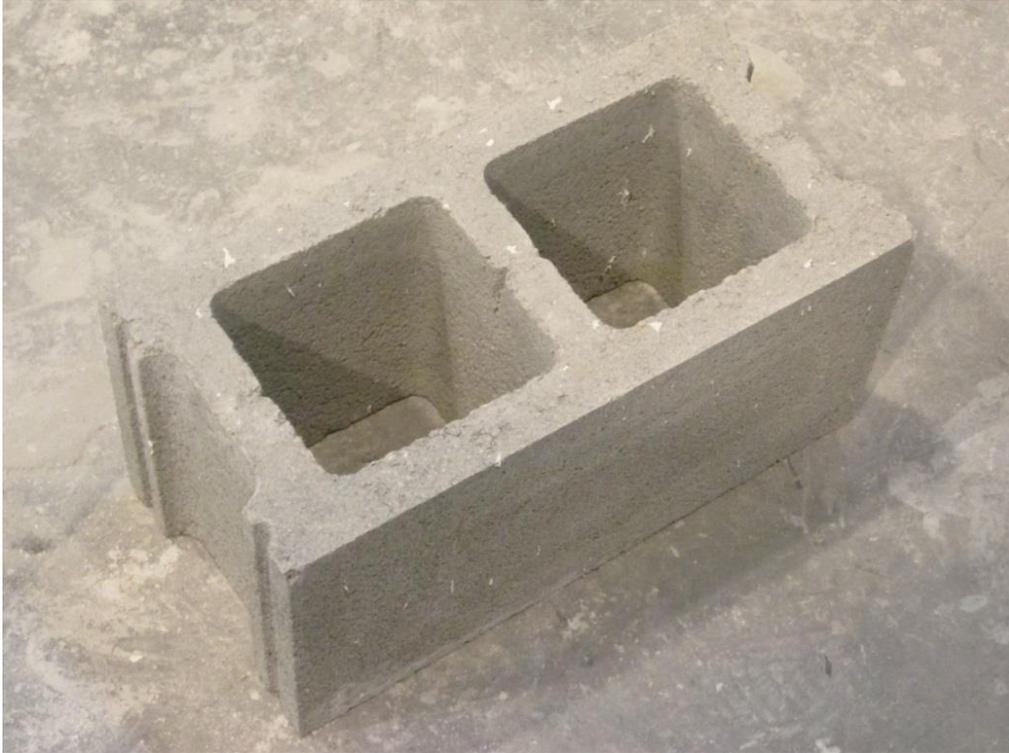


Figure 23. Block used to build specimen.



Figure 24. Pre-test photo of the specimen's fire-exposed face.



Figure 25. Pre-test photo of the specimen's unexposed face.



Figure 26. After-test photo of the specimen's fire-exposed face.



Figure 27. After-test photo of the specimen's unexposed face.

4.1.4. Test results of SUS-CON blocks

The behaviour of SUS-CON blocks is below reported:

- 3min: thick smoke is produced inside the test furnace; this phenomenon dies out over the next few minutes;
- 30min: traces of yellowish cold smoke start to escape from the top horizontal edge on the specimen's unexposed face;
- 75min: specimen suffers thermal insulation failure due to temperature rise over initial ambient temperature exceeding 180 °C as recorded by thermocouple 7 fitted 15 mm in from the specimen's top edge;
- 94min: blackening begins of the specimen's unexposed face with patches forming at the building block voids; this phenomenon continues right until the end of the test;
- 102min: test halted without any significant additional phenomena being noted.

Repeated checks carried out on the specimen face not exposed to fire in accordance with standard UNI EN 1363-1:2012 at no time recorded specimen integrity failure.

During cooling, the specimen almost totally collapsed.

This classification has been carried out in accordance with clause 7.5.2 of standard UNI EN 13501-2:2009. The vertical non-loadbearing element called SUSCON is classified according to the following combinations of performance parameters and classes:

EI 60

E 90

The following sheets show photos (**Figure 28**, **Figure 29**, **Figure 30** and **Figure 31**) of specimen before and after the test.



Figure 28. Photo of block used to build specimen.



Figure 29. Pre-test photo of the specimen's fire-exposed face.



Figure 30. Pre-test photo of the specimen's unexposed face.



Figure 31. After-test photo of the specimen's unexposed face.

The full description of fire test of blocks walls can be found in Annex E.

4.2. FIRE BEHAVIOUR OF PANELS

In accordance with the provisions of standards UNI EN 1363-1:2012 and UNI EN 1364-1:2002, a test was performed in the test furnace of Giordano Institute's Fire Resistance Laboratory on a non-loadbearing wall called REFERENCE and SUS-CON.

4.2.1. Description of specimens

The vertical non-loadbearing element called REFERENCE and SUS-CON are a non-loadbearing wall having the following dimensions:

Modular panel nominal length	3000 mm
Modular panel nominal height	1500 mm
Modular panel nominal thickness	240 mm
Specimen nominal width	3000 mm
Specimen nominal height	3005 mm
Specimen nominal thickness	240 mm

In particular in first case, the specimen is a wall formed by assembling 2 REFERENCE

modular panels each comprising:

- exterior C25/30 concrete layer placed on the fire-exposed face, maximum nominal thickness 60 mm at the edges and minimum nominal thickness 40 mm in the center;
- exterior layer placed on the fire-unexposed face, nominal thickness 60 mm, made from an exposed layer of C30/37 concrete, nominal thickness 30 mm, coupled with an underlying layer of C25/30 concrete, nominal thickness 30 mm;
- intermediate void forming layer comprising expanded polystyrene foam slab, minimum nominal thickness 120 mm at the edges, maximum nominal thickness 140 mm in the center and nominal density 10 kg/m³.

In 4 areas of the modular panel, nominal size 250 mm × 250 mm each, along the top longitudinal edge, the void forming layer of expanded polystyrene foam is replaced by a layer of NEOPOR expanded polystyrene foam containing graphite, nominal thickness 20 mm and nominal density 18 kg/m³, placed on the unexposed face, and C25/30 concrete, nominal thickness 100 mm, placed on the fire-exposed face.

In the second case, the specimen is a wall formed by assembling 2 SUS-CON modular panels each comprising:

- 2 exterior layers, nominal thickness 80 mm for that placed on the unexposed face and 60 mm for that placed on the fire-exposed face, cast from RX4 concrete;
- intermediate void forming layer comprising expanded polystyrene foam slab, nominal thickness 100 mm and nominal density 20 kg/m³.

In 6 areas of the modular panel, nominal size 250 mm × 250 mm each, arranged four along the top longitudinal edge and two at the bottom corners, the void forming layer of expanded polystyrene foam is replaced by a layer of NEOPOR expanded polystyrene foam containing graphite, nominal thickness 20 mm and nominal density 18 kg/m³, placed on the unexposed face, and concrete incorporating SUS-CON cast using recipe "RX4, nominal thickness 80 mm, placed on the fire-exposed face.

In both cases the internal reinforcement was formed by:

- 2 arc-welded square B450A steel meshes, nominal wire diameter 5 mm and nominal mesh aperture 250 mm × 250 mm, placed at the exterior concrete layers;

- 4 B450C steel bars, nominal length 2900 mm and nominal diameter 10 mm each (REFERENCE) or nominal diameter 14 mm each (SUS-CON), placed at the exterior concrete layers near to the longitudinal edges of the modular panel;
- 4 B450C steel bars, suitably bent at the ends, nominal length 2400 mm and nominal diameter 8 mm each, placed at the exterior concrete layers near to the vertical edges of the modular panel;
- stainless steel coil, nominal length 1250 mm, nominal height 210 mm (REFERENCE) or nominal height 190 mm (SUS-CON) and nominal diameter 8 mm, placed horizontally at the center of the modular panel;
- 9 stainless steel coils, nominal length 450 mm, nominal height 210 mm and nominal diameter 8 mm, spread about the modular panel (REFERENCE) and 13 stainless steel coils, nominal length 450 mm, nominal height 190 mm and nominal diameter 8 mm, spread about the modular panel (SUS-CON);
- 12 stainless steel hairpin, nominal diameter 8 mm, placed close to the longitudinal edges of the modular panel;
- 4 B450C steel bushes with safety bar, nominal diameter 8 mm, and B450C steel U-bolt, nominal diameter 10 mm, placed in the four areas with a different layer configuration along the top longitudinal edge.

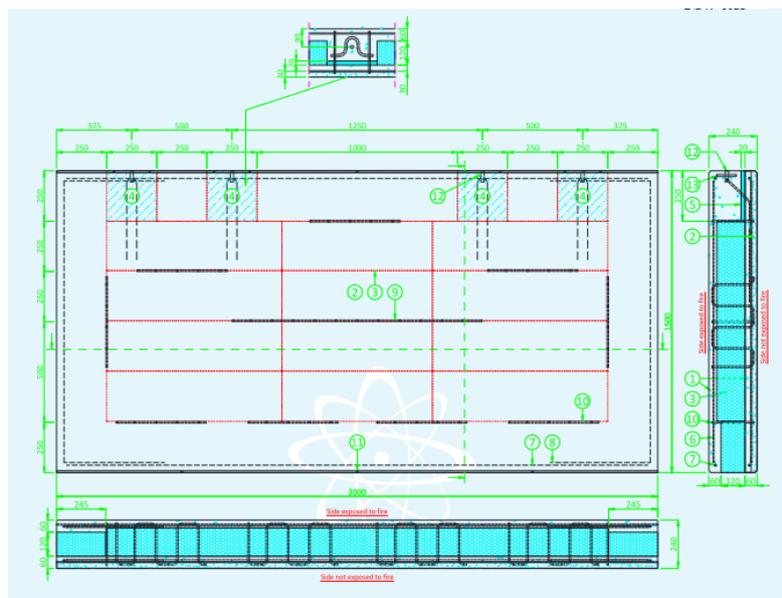


Figure 32. Schematic drawing of panel.

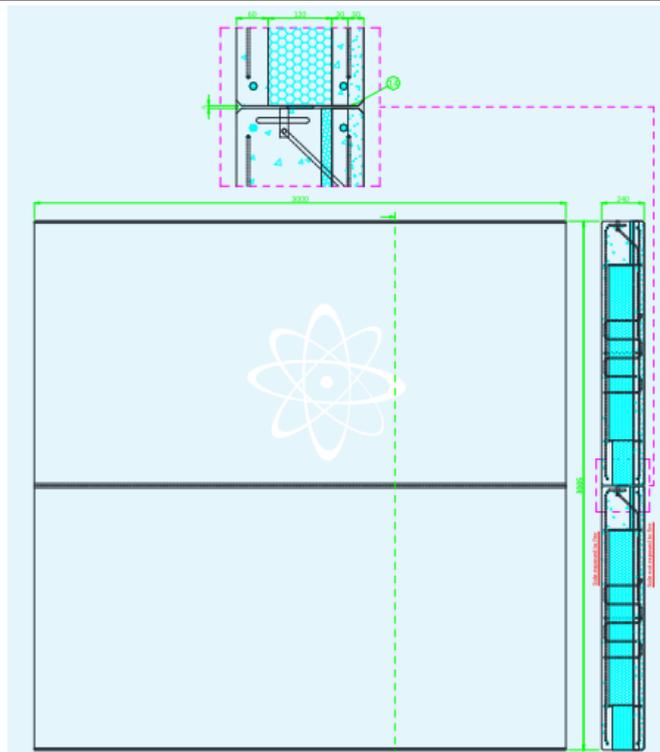


Figure 33. Schematic drawing of specimen.

Supporting construction

The specimen was mounted in a warp-resistant reinforced-concrete perimeter test frame, nominal density 2.300 kg/m³, without the need for a supporting construction.

The specimen was installed in the test frame by securing the modular panels using standard cement-mortar joints, nominal density 1.450 kg/m³.

Normative References

The test was performed in accordance with the requirements of the following standards:

- UNI EN 1363-1:2012 dated 11/12/2012 “Fire resistance tests - Part 1: General requirements”;
- UNI EN 1364-1:2002 dated 01/04/2002 “Fire resistance tests for non-loadbearing elements - Walls”.

Conditioning

Before the testing, the specimen was stored in the laboratory for 83 days until reaching an equilibrium (REFERENCE).

Before the testing, the specimen was stored in the laboratory for 101 days until reaching an equilibrium (SUS-CON).

4.2.2. Test method

A test furnace was used having an opening on the vertical face, internal height 3200 mm, internal width 3200 mm and internal depth 1200 mm, ceramic-fiber lining and fitted with:

- 8 twin-flame, light-oil-fired burners, equally spaced over the vertical side walls;
- 2 separate chimneys with electronically-controlled valves for varying outlet area;
- pressure measurement system comprising:
 - 2 pressure measuring devices situated 500 mm and $\frac{2}{3}$ up the furnace opening, connected to an automatic recording system;
 - manual pressure reading system situated on one of the furnace walls close to the opening;
- temperature measurement system comprising:
 - control units situated on the vertical sides of the furnace for measuring temperatures inside the furnace;
 - type “K” thermocouples connected to a mobile control unit, in turn connected to a reader that transforms the potential difference of the thermocouples themselves into temperature;
- data acquisition system connected to an electronic calculator with management software.

The test specimen is not symmetrical and just the face with exterior concrete layer of lesser thickness was exposed to fire.

Temperature and deflection measurement points

The temperature measuring points on the test specimen's unexposed face (position of thermocouples on the unexposed face) and the specimen deflection measuring points (position of displacement transducers) are shown in the diagram on the attached reports.

Pressure measuring

Pressure was measured using a T-shaped pressure sensor positioned inside the test furnace 500 mm above the base of the specimen and 100 mm from the supporting element.

4.2.3. Test results of REFERENCE panels

The behaviour of REFERENCE panels is below reported:

-
- 8 min: slight traces of steam start to escape from the perimeter edges on the specimen's unexposed face.
 - 13 min: beginning of explosions originating from inside the modular panels. This phenomenon continues to a varying degree until minute 35 of the test.
 - 30 min: small non-penetrating cracks begin to form on the specimen's unexposed face along with patches of condensation on the same face.
 - 80 min: resumption of explosions originating from inside the modular panels; this phenomenon continues right until the end of the test.
 - 85 min: test halted following specimen integrity failure confirmed by the passage of the 25 mm gap gauge through a penetrating hole that has formed in the center/top section of the lower modular panel.

This classification has been carried out in accordance with clause 7.5.2 of standard UNI EN 13501-2:2009. The vertical non-loadbearing element called REFERENCE is classified according to the following combinations of performance parameters and classes:

EI 60

The following sheets show photos (**Figure 34**, **Figure 35**, **Figure 36** and **Figure 37**) of specimen before and after the test.

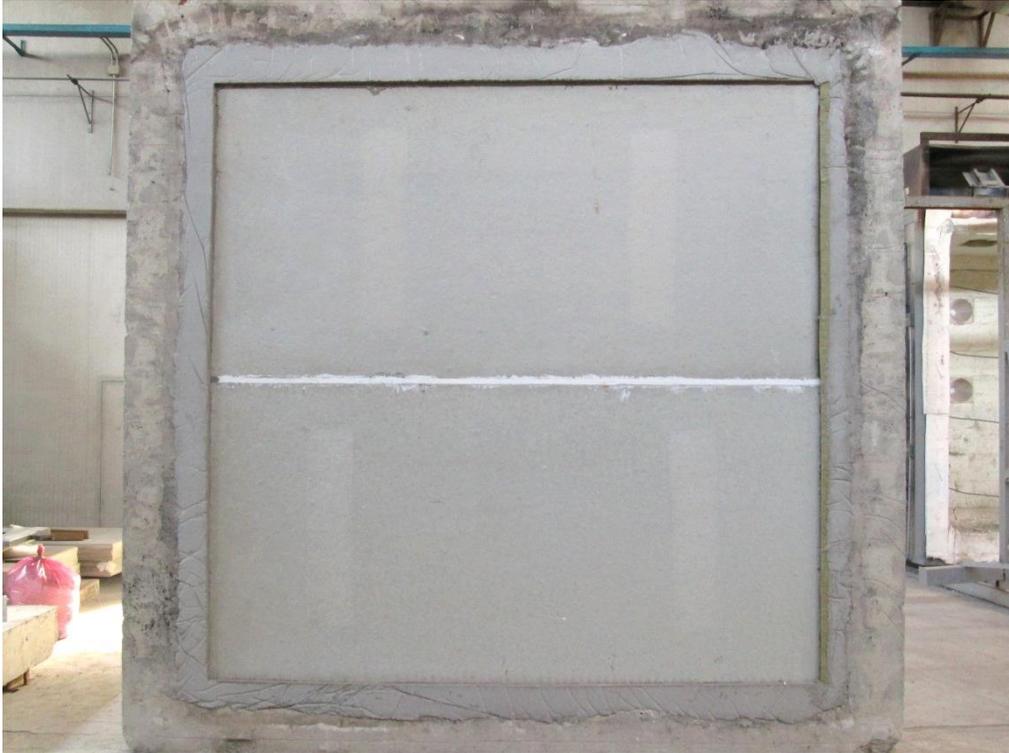


Figure 34. Pre-test photo of the specimen's fire-exposed face.

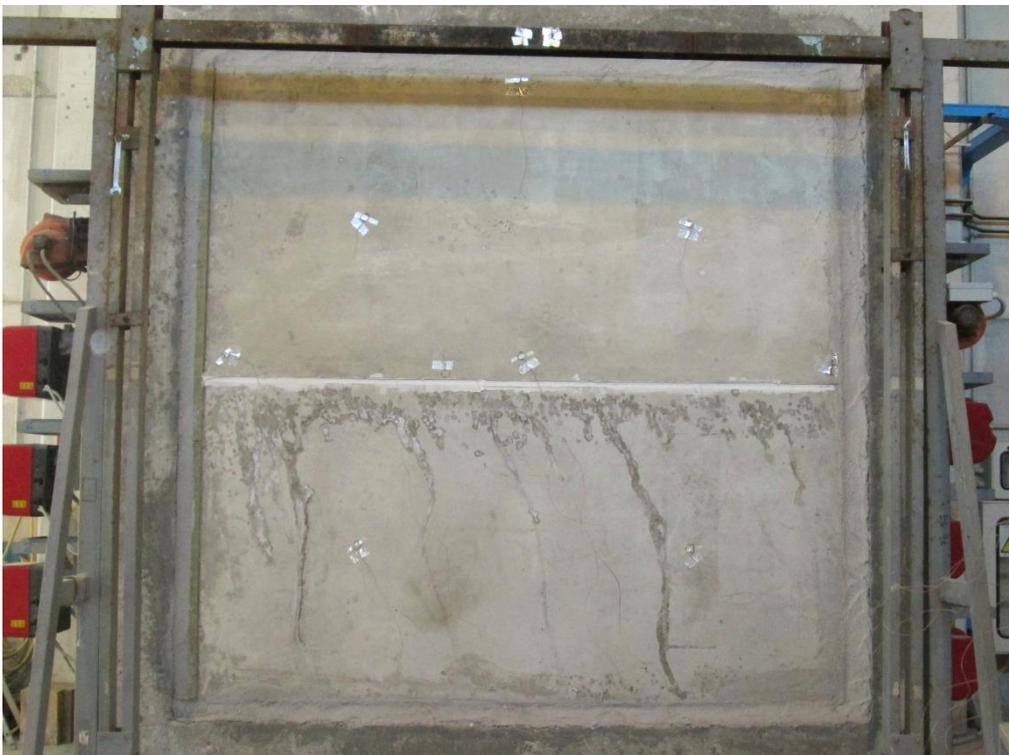


Figure 35. Pre-test photo of the specimen's unexposed face.



Figure 36. After-test photo of the specimen's fire-exposed face.

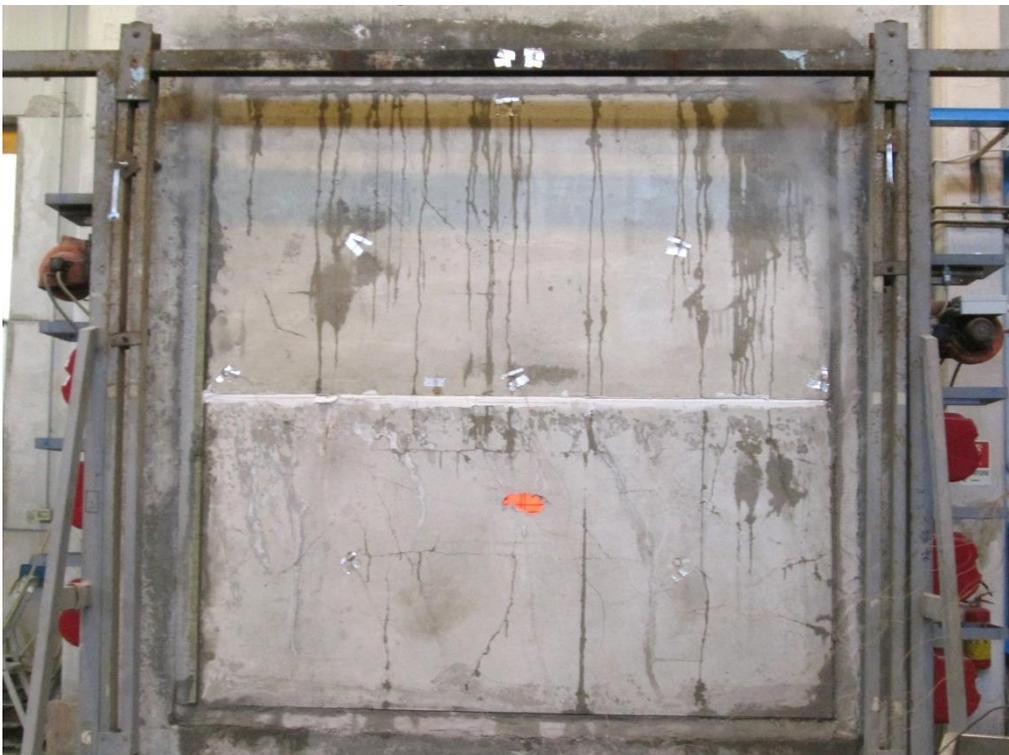


Figure 37. Photo of specimen's unexposed face upon halting the test.

4.2.4. Test results of SUS-CON panels

The behaviour of SUS-CON panels is below reported:

- 4 min: large amounts of steam and cold smoke start to escape from the perimeter edges of the modular panels on the specimen's unexposed face. This phenomenon gradually dies down although continuing right until the end of the test.
- 65 min: patches of condensation start to form on the horizontal joint between the two modular panels. This phenomenon continues, also extending to the specimen's top horizontal edge as of minute 85 of test.
- 245 min: test halted without any significant additional phenomena being noted.

This classification has been carried out in accordance with clause 7.5.2 of standard UNI EN 13501-2:2009. The vertical non-loadbearing element called SUSCON is classified according to the following combinations of performance parameters and classes:

EI 240

The following sheets show photos (**Figure 38**, **Figure 39**, **Figure 40** and **Figure 41**) of specimen before and after the test.

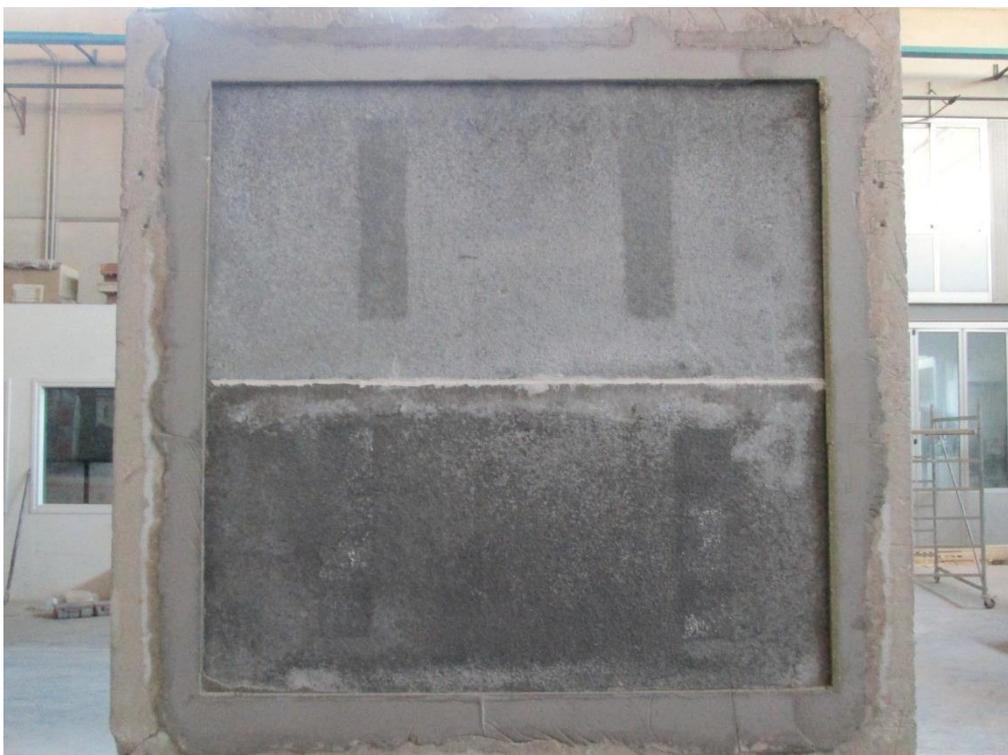


Figure 38. Pre-test photo of the specimen's fire-exposed face.



Figure 39. Pre-test photo of the specimen's unexposed face.



Figure 40. After-test photo of the specimen's fire-exposed face.



Figure 41. After-test photo of the specimen's unexposed face.

The full description of fire test of panels walls can be found in Annex F.

5. NON-DESTRUCTIVE INSPECTIONS

SUS-CON and traditional concrete components (blocks and slabs), produced by MAGNETTI, were provided to CETMA in order to perform the following non-destructive inspections (NDI):

- inspections by using an infrared (IR) thermo-camera, which aim was a qualitative analysis and comparison of thermal insulation behaviour;
- inspections by using ultrasounds (UPV tests), which aim was a qualitative analysis and comparison of acoustic insulation behaviour.

Two typologies of blocks were manufactured by the producer with the same geometry (19x19x39 cm) but different composition. The first typology based on SUS-CON recipe PU30 - 100% polyurethane aggregate combined with PFA/GGBS binder - and the second one, for comparison reasons, based on traditional concrete. The blocks have a content of voids of 48% and, being based on different formulations, have in turn different densities (around 430 kg/m³ and 1070 kg/m³, respectively). These blocks were selected to build mock-ups in Spain - Acciona demo-park (D6.4) and, to perform the lab tests, were assembled in two walls with dimensions approximately 120x100 cm. A traditional mortar was used to place traditional blocks while a thermal mortar for SUS-CON blocks (as for mock-ups installed in Spain). Moreover, to perform the tests in similar conditions, the same mortar was applied on the surface of both walls. The above described walls were inspected by the infrared thermo-camera and by ultrasounds.

Two concrete slabs were manufactured by the producer with the same geometry (50x50x5.5 cm) but different composition. The first typology based on SUS-CON recipe RX4 - 70% Remix (mixed plastic) aggregates combined with PFA binders - and the second one, for comparison reasons, based on traditional concrete. The slabs, being based on different formulations, have in turn different densities (around 2070 kg/m³ and 1450 kg/m³). The concrete used to cast the slabs for lab tests were also selected for manufacturing the panels installed on mock-ups in Spain - Acciona demo-park (D6.4). The panels actually consist in three different layers, two external in concrete and the inner one made with EPS. Being not possible to cast panels, with similar structure, on small scale for lab testing it was decided to use slabs, made only with concrete, being at least representative of the panel composition. The above presented slabs and blocks were inspected by ultrasounds.

5.1. THERMOGRAPHIC TESTS ON BLOCKS

The infrared thermography (IRT) is used in many sectors to evaluate the surface temperature distribution and to monitor the evolution of the temperature during heating or cooling thermal transients. Differences in conductivity, transmittance, geometry, materials etc. may affect the distribution of surface temperature and can be evaluated using an infrared camera.

Thermography can be classified as qualitative or quantitative, and passive or active. Qualitative thermography usually does not require an accurate temperature measurement. It only evaluates temperature differences between specific components, between different spots on the same object or between the measured object and the background. In contrast, the goal of quantitative thermography is an accurate temperature measurement of inspected objects. Knowledge of thermo-optical properties of the measured objects is essential in this case. Important applications of quantitative thermography include temperature monitoring during thermal processing or determination of thermal boundary conditions for numerical simulations of thermal processes. Both the qualitative and quantitative approaches can be applied in terms of passive (if the object temperature is not artificially affected during its measuring) or active (if an artificial excitation using an external source is applied on the measured object) thermography. The external excitation causes temperature contrasts associated with material inhomogeneities or defects occurrence or it can be used for material properties identification.

To test the effectiveness of innovative SUS-CON blocks a series of thermographic tests on in scale elements have been carried out. The structural elements made with the innovative mixtures were blocks with size 19x19x39 cm.

The IRT survey conducted was qualitative with active approach. Even if the thermo-optical properties of the objects have been measured with accuracy, the temperature distribution and the evolution during the time was recorded only to compare the thermal performances of the two materials. At the laboratory of the CETMA Consortium, two different walls with the same size and construction techniques were built: the first named W-SRB (wall with SUS-CON Reference Block) with traditional concrete blocks, the second named W-SIB (wall with SUS-CON Innovative Block) with innovative blocks.



Figure 42. SUS-CON Innovative block (left) and SUS-CON Reference block during assembly (right).

The thermographic test was carried out in controlled laboratory conditions with the setup shown in **Figure 43**; the camera was placed at a distance of 3.3 m from the two walls on the perpendicular axis from the separation zone between the two walls.

The test has been designed to minimize the environmental variables such as temperature during the test, incidence angle of the lamps, warming up and cooling down time, etc. The arrangement of walls and lamp against the size of the laboratory have been set symmetrically, the type and the radiating power of the lamps is the same in both cases with times of heating and cooling identical for the two materials.

The two walls were subjected to a warming up cycle of 30 minutes and a subsequent cooling down of 60 minutes; considering the power of the lamps and the arrangement of the two walls in this time intervals, a stationary state of heating and cooling can be reached starting from room temperature.

Thermographic sequences recorded during the test, with a frequency equal to 1 Hz, have been processed in order to export the trend of the surface temperature representative of the two materials; for both walls two rectangular ROIs (Region Of Interest) with same dimension (in pixel) were selected, than the value of the average temperature has been exported. The size and position of the two ROI has been selected so as to eliminate the edge effects that occur on the outer parts of the two walls.

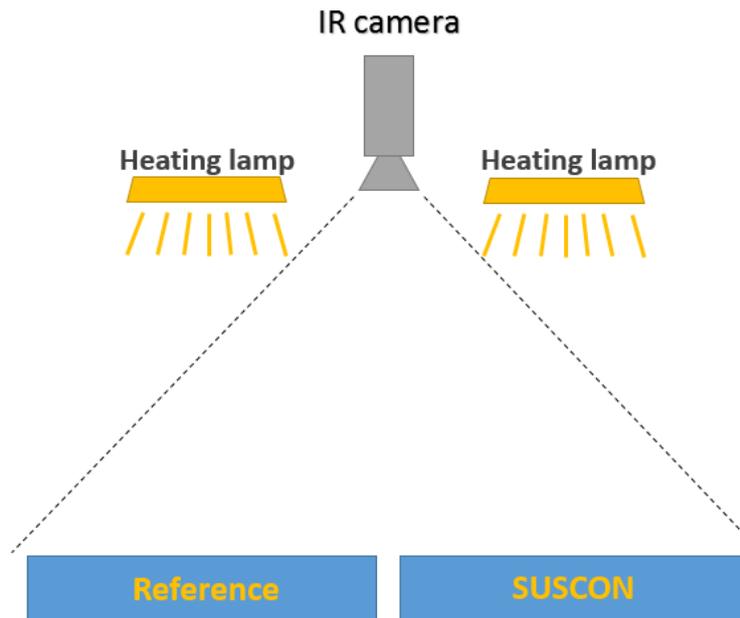


Figure 43. Thermographic setup used during active test.

In **Figure 44** the walls (W-SIB on the left and W-SRB on the right) before the tuning on of the two 1300 W lamps can be seen; in **Figure 45** the thermographic equipment with the software used for the post-processing of the data recorded during the test is shown.



Figure 44. W-SIB (left) and W-SRB (right) walls before the thermographic test.



Figure 45. Thermographic equipment and software used during the test.

Thermographic analysis was carried out using a thermocamera SC 640, a commercial microbolometric FLIR System with a 640 x 480 Focal Plane Array, with spectral range from 7.5 to 13 μm and a standard $24^\circ \times 18^\circ$ lens (38 mm). Measurements were carried out simultaneously on the two specimens.

The tests were carried out in a reflection mode: the specimens were in front both the IR lamps, settled to the maximum power of 1300 W, and the thermographic camera that, being sensitive to infrared radiation emitted from the specimen analyzed, is able to record a temperature map of its surface. To ensure that correct values of temperature were obtained, prior to test, the material emissivity was evaluated by direct comparison to a material with known emissivity. For all specimens analyzed an emissivity of 0.95 was measured (traditional plaster).

The lamps were used to give a preferred way to the heat flux to speed up the specimen heating and finally to simulate the final application of the insulating structure, in which the heat radiation only comes from the outside of the building.

In the following some thermograms extracts from the thermographic sequence recorded during the test are shown; these thermograms were extracted during the heating and the cooling phases at intervals of 10 minutes. Both in the heating and in cooling phases a starting thermogram showing the initial conditions has been acquired: in the warming up phase both of the walls are at room temperature and in thermal equilibrium, in the cooling down phase the initial thermogram is taken a moment before switching off of the lamps. In each thermogram the W-SRB specimen is on the left and W-SIB one on the right.

Warming up phase

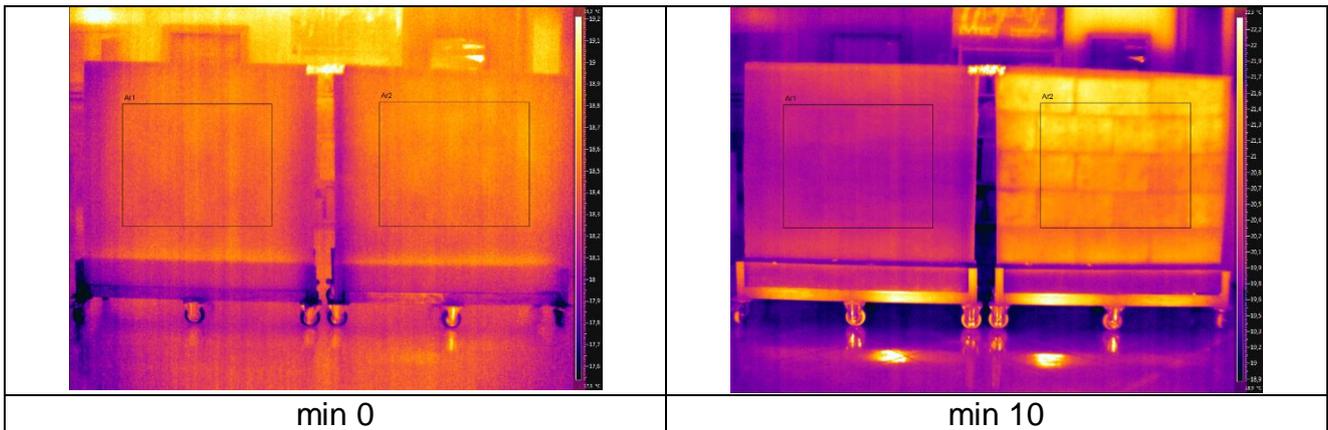


Figure 46. Temperature maps during warming up phase at min. 0 and min. 10.

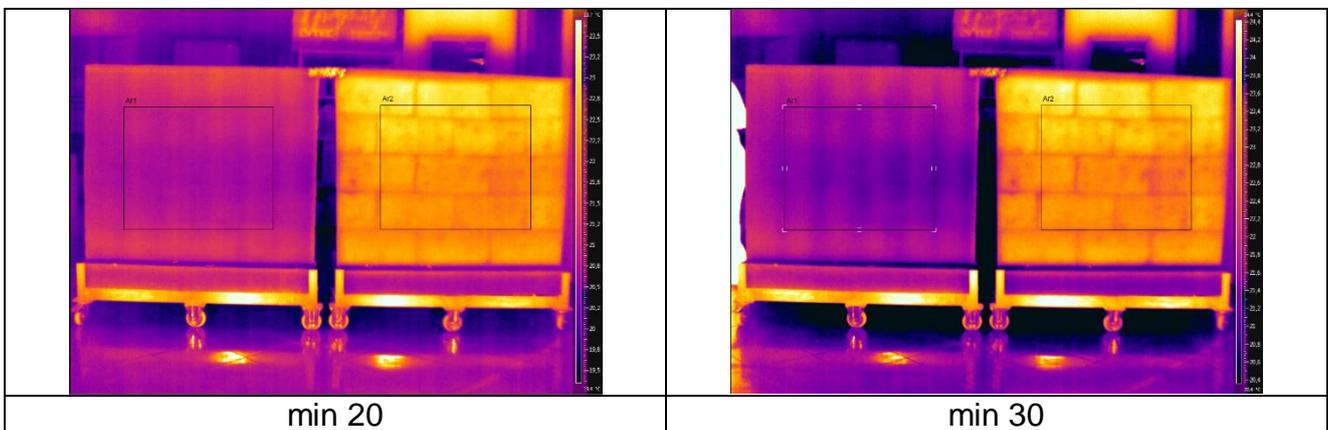


Figure 47. Temperature maps during warming up phase at min. 20 and min. 30.

As can be seen in the following graph (**Figure 48**), in which the delta T between current and starting temperature versus time are reported, the W-SIB increases the surface temperature of a value equal to 4,77 °C in comparison with W-SRB that reaches a temperature increase of 3,06°C.

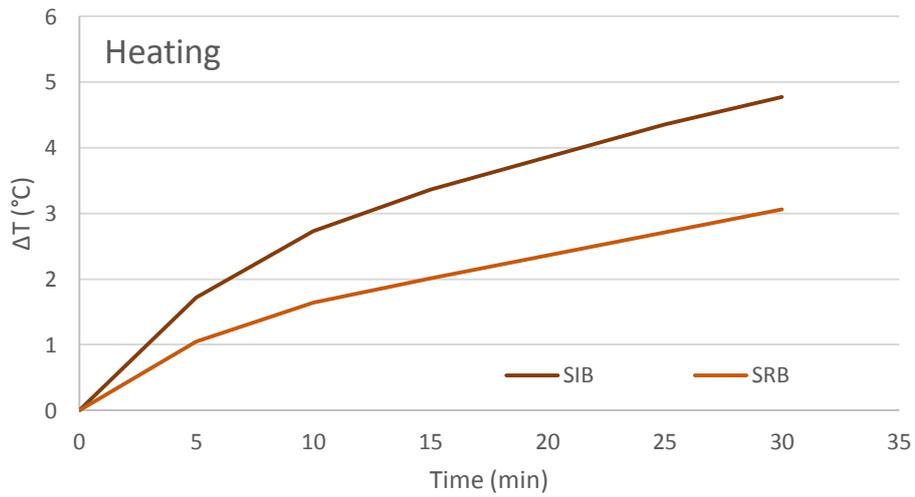


Figure 48. ΔT versus time during the warming up phase for W-SIB and W-SRB specimens.

Cooling down phase

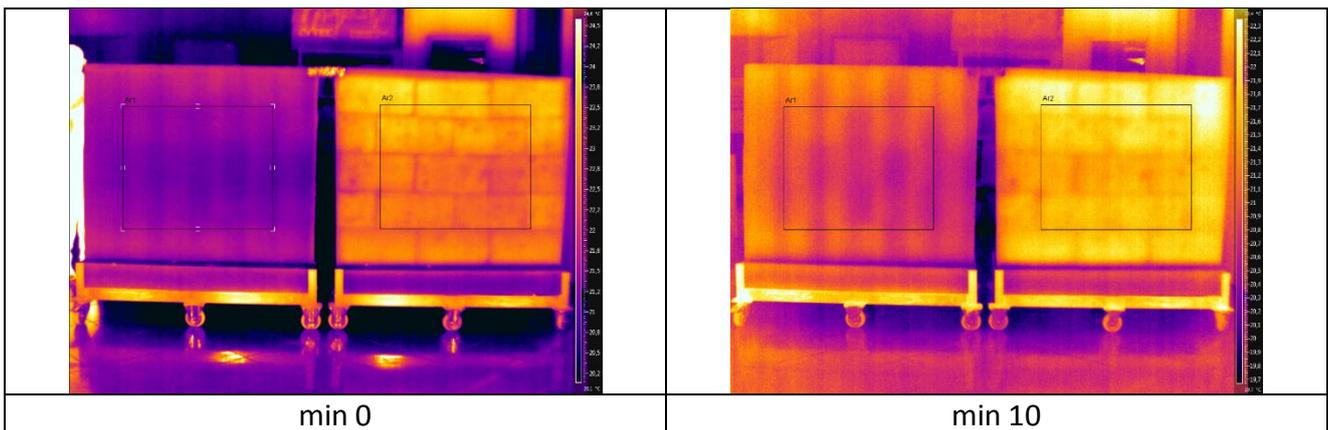


Figure 49. Temperature maps during cooling down phase at min. 0 and min. 10.

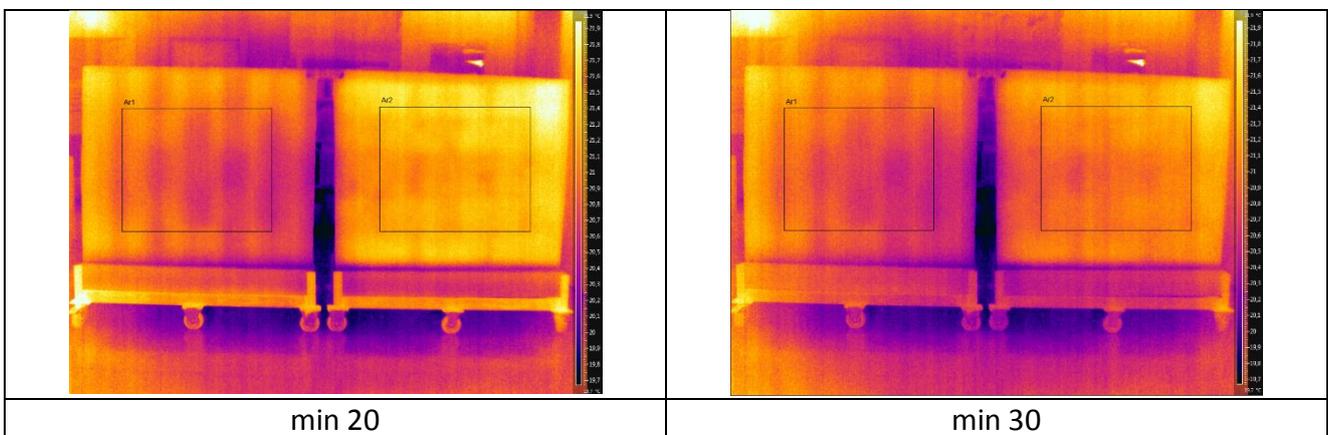


Figure 50. Temperature maps during cooling down phase at min. 20 and min. 30.

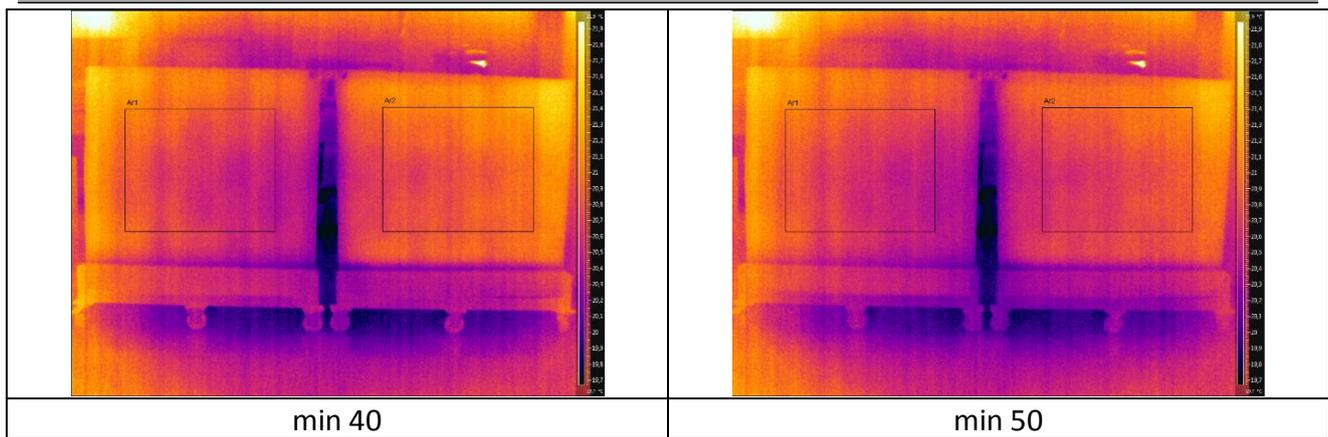


Figure 51. Temperature maps during cooling down phase at min. 40 and min. 50.

As shown in the following graph (**Figure 52**), in 60 minutes the W-SIB decreases the surface temperature of a value equal to 2,50 °C in comparison with W-SRB that reaches a temperature decrease of 0,90 °C in the same time.

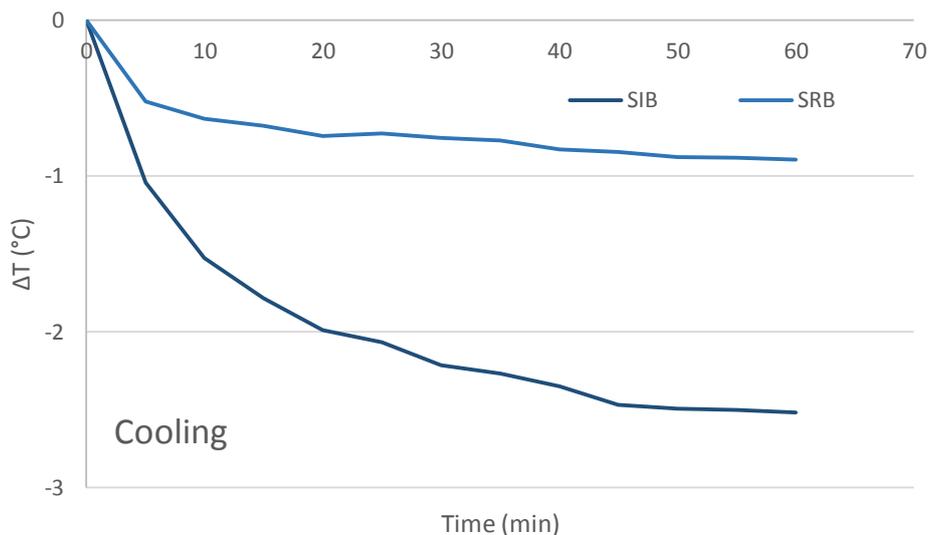


Figure 52. ΔT versus time during the cooling down phase for W-SIB and W-SRB specimens.

The results of the whole test are shown in **Figure 53** in which the trend of the average surface temperatures as a function of time are shown; in the first section (heating) an increasing trend of paraboloid shape can be noticed until an equilibrium value, from that point, in the cooling phase, a similar trend but with opposite concavity can be noticed.

The initial surface temperature of all the specimens is about 18,5 °C, during the test the temperature increases until a kind of plateau, due to the equilibrium between heating source and thermal dissipation of the specimens; when the IR lamps are switched off the

temperatures decrease in different way according to the thermal properties of the constituent materials.

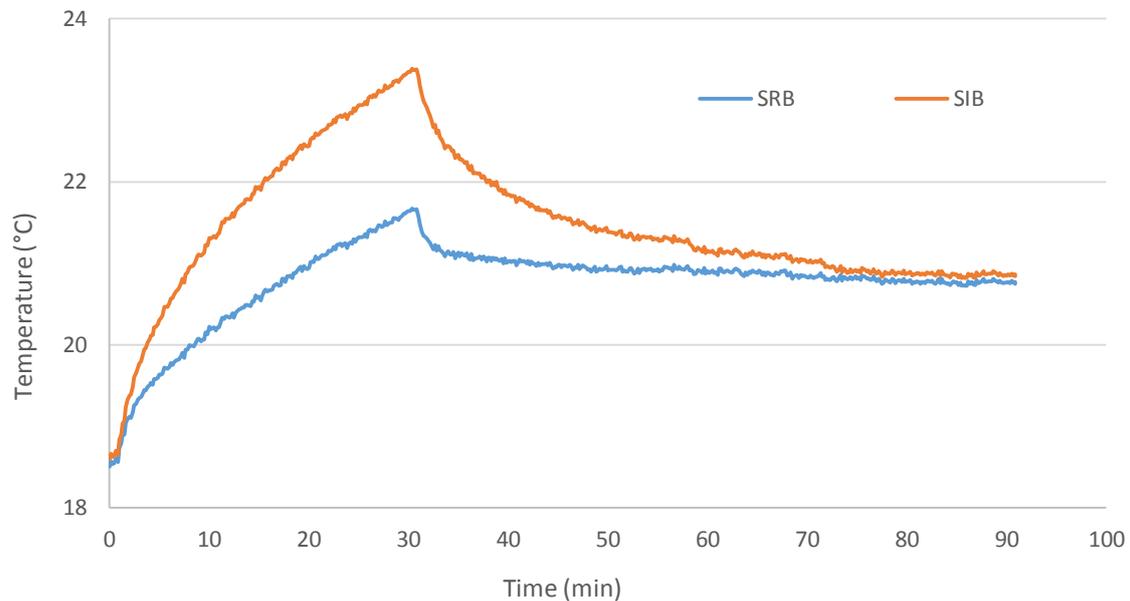


Figure 53. Time vs Temperature for SRB and SIB walls during the test.

By comparing the two trends some main differences can be noticed:

- the W-SIB specimen reaches higher temperatures more quickly than the W-SRB one with a gap at the end of the heating of about 1.7 °C;
- in the SIB wall are clearly visible in the wall the mortar joints between the blocks, in the wall SRB is difficult to distinguish the texture of walls;
- during the cooling phase the SIB wall dissipates 1,60 °C more than the SRB wall in the same amount of time, reaching the same final temperature.

During the heating phase, with lamps turned on, the heat generated by the lamps tends to accumulate on the surface of the W-SIB specimen increasing the temperature more quickly than on W-SRB specimen surface. This is caused by higher insulating properties of the structure that composes the W-SIB specimen with respect to the W-SRB specimen; in fact, the less insulating material allows the passage of heat from the surface irradiated by the heating sources to the opposite surface which would represent the inside of a home; the more insulating material slows this process by ensuring lower temperatures on the other side. This takes place in the summer but is equivalent in the winter period where the heat flow is reversed, from the inner comfort temperature (20÷22° C) to the much lower environmental one.

In the cooling phase, despite the different initial temperatures, in a short time the same temperature is reached, avoiding the temperature increase on the other side of the wall.

The data above reported confirm that the thermographic analysis is a suitable technique for monitoring the dynamic thermal behavior of real scale construction elements with the purpose to evaluate thermal properties in a qualitative way. On the basis of the test conducted on the specimens it is clear that the W-SIB one has increased thermal insulating properties in comparison with reference one (W-SRB). Moreover the good insulating properties of SUS-CON blocks based on recycled PU has been also confirmed by a study reported in D5.5 - *Modelling SUS-CON products design (Part B)*. In such study, among other properties, the thermal behaviour of SUS-CON components exposed to realistic conditions was numerically simulated. According to these evaluations the thermal insulation of a wall composed by one layer of PU based blocks has up to 8 fold higher thermal insulation than normal concrete. The thermal behaviour of the wall over time was also assessed, the walls made with PU30 blocks showed the best thermal behaviour thus resulting in higher savings in terms of energy consumption.

5.2. ULTRASONIC PULSE VELOCITY (UPV) TESTS ON SLABS AND BLOCKS

Ultrasonic pulse velocity (UPV) test is a non-destructive method to measure the speed of ultrasonic pulses passing through a material. The basic principle of this test consists in the properties of ultrasound waves to propagate in a solid and to reflect or refract when its physical-mechanical characteristics change. Therefore, the alteration of measurable parameters of a material (i.e. transit time) can be correlated with variations of its properties (i.e. density, homogeneity or structure). The practical purpose of the tests carried out in SUS-CON project was to measure and compare transit time and speed of ultrasounds both in SUS-CON and traditional concrete components. These data can be correlated with the concrete properties and, in such a way, can give at least an approximate idea of their acoustic insulation tendency. In **Figure 54** some steps of the tests carried out in CETMA labs are shown.

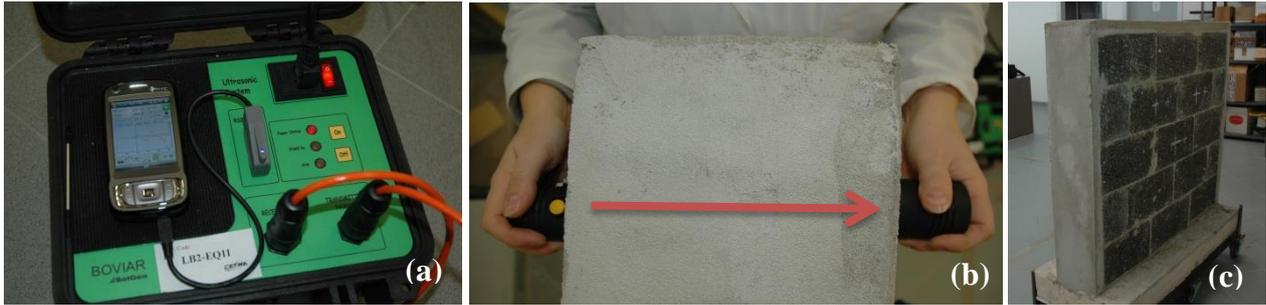


Figure 54. (a) Device used to perform UPV tests; (b) test performed on concrete in direct transmission mode and (c) small wall prototype, based on SUS-CON blocks, used for testing.

UPV tests were carried out according with the standard EN 12504-4 (*Testing concrete – determination of ultrasonic pulse velocity*); specific details on the test procedures are reported in D6.2. The device used for testing was provided by BOVIAR, it includes a data acquisition control unit and two probes (transmitting transducer – TSG-55 with a frequency of 55kHz and receiving transducer – RSG-55) connected to a computer.

The following concrete components have been tested:

- two slabs made, respectively, with traditional and SUS-CON RX4 concrete (Remix aggregate and PFA binder);
- two walls made, respectively, with traditional and SUS-CON PU30 construction blocks (PU aggregates and PFA/GGBS binder).

As far as regard the slabs 8 different points were inspected, while the walls were tested in 3 points located in the massive part of the block (only concrete); in both cases the test was repeated three different times on each measuring point.

The measured transit time and ultrasonic pulse velocity for the traditional and RX4 concrete slab are reported, respectively, in **Figure 55** and **Figure 56**. As shown in **Figure 55**, the average transit time for traditional concrete is 27 μs , while for SUS-CON concrete 73 μs (about three times); as a consequence, as reported in **Figure 56**, the average pulse velocity is 2032 m/s for traditional concrete and 756 m/s for SUS-CON concrete. It is evident that the use of Remix (mixed plastic) aggregate combined with PFA/GGBS binder, if compared with more traditional materials, allows a reduction of the ultrasonic pulse velocity of approximately 37%. This different behavior is mainly due to the nature of the component materials which, in turn, affects the structure and also the final density of the concrete component.

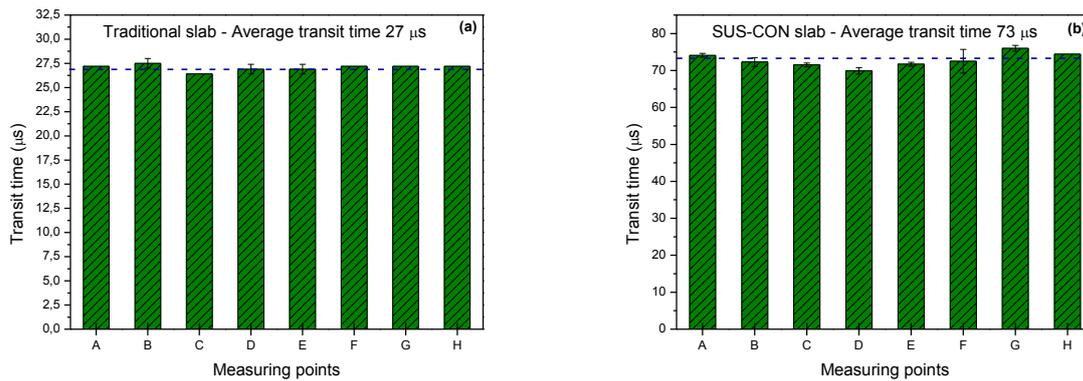


Figure 55. Comparison of ultrasounds transit time in a traditional (a) and a SUS-CON (b) concrete slab.

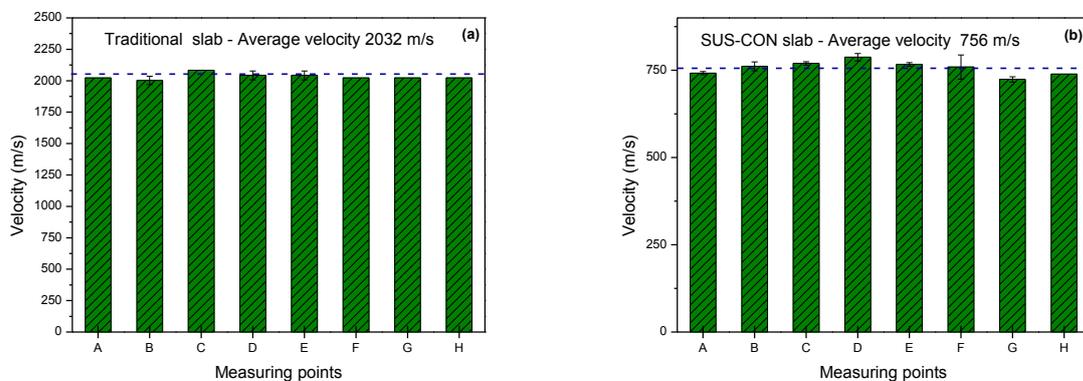


Figure 56. Comparison of ultrasounds velocity in a traditional (a) and a SUS-CON (b) concrete slab.

Similar tests were also carried out on the walls consisting of traditional and SUS-CON PU30 blocks. The results obtained in terms of transit time and ultrasonic pulse velocity have been reported, respectively, in **Figure 57** and **Figure 58**. As shown in **Figure 57** the average transit time for traditional blocks is 52 μs, while for SUS-CON blocks 171 μs (about three times); as a consequence, as reported in **Figure 58**, the average pulse velocity is 3727 m/s for traditional blocks and 1128 m/s for SUS-CON blocks. It is evident that the use of PU foam aggregate combined with PFA binder, if compared with building blocks based on more traditional materials, allows a reduction of the ultrasonic pulse velocity of approximately 30%.⁴ This different behavior is mainly due to the nature of the

⁴ For comparison the same test was also repeated in 3 other points of the block including voids (concrete/air/concrete). As expected, the air layer allows in both cases a further transit time increase. As a consequence this resulted, in both cases, in a further reduction of the pulse velocity; again the velocity of SUS-CON blocks, if compared with the traditional ones, was approximately reduced of 30%.

component materials which, in turn, affects the structure and also the final density of the concrete component.

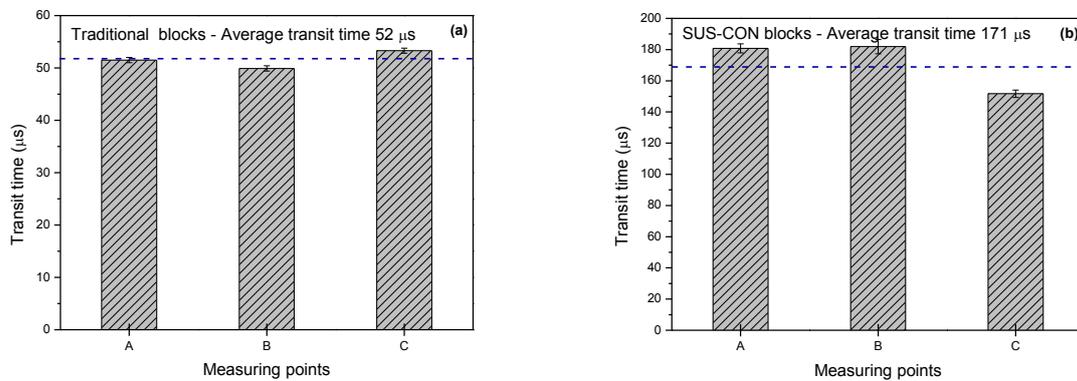


Figure 57. Comparison of ultrasounds transit time in traditional (a) and a SUS-CON (b) building blocks.

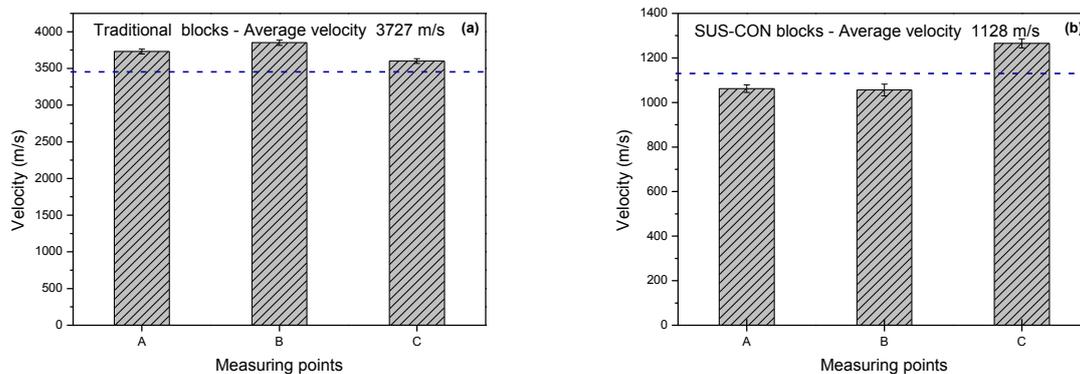


Figure 58. Comparison of ultrasounds velocity in traditional (a) and a SUS-CON (b) building blocks.

Summarizing it can be concluded that, in terms of tendency to transmit ultrasonic pulses, building components (i.e. slabs and blocks) made with SUS-CON concrete perform better than those manufactured with traditional concrete. As already observed, these outcomes give only qualitative indications about their capability to diminish acoustical waves. For a complete characterization specific acoustical tests have to be performed. However, it has to be specified that the acoustical insulation performance are not among the aims of SUS-CON project, being its focus the development of heat-insulating building components.

6. GENERAL CONCLUSION

This report deals with Task 6.3 of SUS-CON project, focused on prototypes characterization, and it includes all the results of tests performed on components (i.e. blocks, panels, slabs) based on SUS-CON innovative concretes. More specifically, the following tests have been performed: mechanical tests (bending test on panels), thermal transmittance tests and fire behaviour resistance (both on blocks and panels) as well as non-destructive tests that are thermographic and ultrasounds inspections (qualitative evaluation of thermal and acoustical performance). The prototypes tested, the methodology followed and the obtained results have been presented and widely discussed; moreover, reference concrete products have been tested and the performance compared with those obtained for the concretes developed within the Project.