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TECHNICAL SUITABILITY DOCUMENT: NO. 431R/20

Generic area / Intended use:	**Reinforced concrete panel load-bearing system with EPS core**
Trade name:	**EMMEDUE**
Recipient:	**EMMEDUE S.p.A.**
Head Office:	Via Toniolo, 39 b Z.I. Bellocchi 61032 Fano, Italy www.mdue.it
Place of manufacture:	Via Toniolo, 39 b Z.I. Bellocchi 61032 Fano, Italy
Validity. From:	8 January 2020
To:	8 January 2025 (Subject to annual monitoring)

Translation prepared by EMMEDUE on the basis of the original document in Spanish.

This Document consists of 24 pages

MEMBER OF:

EUROPEAN UNION FOR THE ASSESSMENT OF TECHNICAL SUITABILITY
UNION EUROPEENNE POUR L'AGREMENT TECHNIQUE EN CONSTRUCTION
EUROPEAN UNION OF AGREEMENT
EUROPÄISCHE UNION FÜR DAS AGREMENT IN BAUWESEN

VERY IMPORTANT

The TECHNICAL SUITABILITY DOCUMENT constitutes, by definition, a favourable technical assessment by the Eduardo Torroja Institute for Construction Sciences of the suitability for use in construction of non-traditional materials, systems and procedures intended for a determined and specific use. It does not, in itself, have any administrative effect, nor does it represent authorisation for use, nor does it represent a guarantee.

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C.D.U.: 692.251
Construction System
Construction Systems
Building System

DECISION NO. 431R/20

THE DIRECTOR OF THE EDUARDO TORROJA INSTITUTE FOR CONSTRUCTION SCIENCES,

- by virtue of Decree no. 3652/1963, of 26 December, of the Presidency of the Government, empowering the Eduardo Torroja Institute for Construction Sciences to issue the TECHNICAL SUITABILITY DOCUMENT for non-traditional construction materials, systems and procedures used in building and public works, and Order no. 1265/1988, of 23 December, of the Ministry of Relations with Parliament and the Government Secretariat, regulating the granting thereof,

- considering article 5.2, section 5, of the Technical Construction Code (hereinafter CTE) on conformity with the CTE of innovative products, equipment and systems, which establishes that a construction system is compliant with the CTE if it has a favourable technical assessment of its suitability for its intended use,

- considering the specifications set out in the DIT Tracking Regulation of 28 October 1998,

- considering the request made by EMMEDUE S.p.A. for the renewal of the TECHNICAL SUITABILITY DOCUMENT no. 431R/13 for the **EMMEDUE load-bearing system made of reinforced concrete panels with EPS core**,

- under the current Statutes of the *Union Européenne pour l'Agrément technique dans la construction (UEAtc)*,

- taking into account the reports of site visits carried out by representatives of the Eduardo Torroja Institute for Construction Sciences, the reports of the tests carried out at the IETcc, as well as the observations made by the Committee of Experts, at meetings held on 2 December 2003, 17 April 2008, 9 October 2013 and 17 December 2019,

DECIDES:

To renew the TECHNICAL SUITABILITY DOCUMENT number 431R/13, with the number 431R/20 to the **EMMEDUE load-bearing system of reinforced concrete panels with EPS core**, considering that,

The technical assessment carried out leads to the conclusion that the system is IN COMPLIANCE WITH THE TECHNICAL CONSTRUCTION CODE, provided that the full content of this document is respected and in particular the following conditions:

GENERAL CONDITIONS

This TECHNICAL SUITABILITY DOCUMENT exclusively evaluates the construction system proposed by the applicant and as described in this document, and in each case, in accordance with current regulations, it must be accompanied by the mandatory technical project and be completed by the corresponding works management.
The aforementioned technical project shall be signed, in each case, by EMMEDUE S.p.A., which shall approve the calculation report and the graphic documentation detailing the geometry and tolerances of each and every one of the panels and, in particular, the service study conditions of the slabs.
In general, both in the project and in the execution of the work, all the prescriptions contained in the regulations in force will be taken into account: the Technical Construction Code (CTE), the
"Structural Concrete Norms" (EHE) or Code that replaces it and the "Earthquake-resistant Construction Standard" (NCSR-02).

CALCULATION CONDITIONS

In each case, the manufacturer shall verify, in accordance with the calculation conditions indicated in the Technical Report of this Document, the stability, resistance and admissible deformations, justifying the suitability of the System to withstand the mechanical stresses that may derive from the actions corresponding to the ultimate and service limit states, under the conditions established in the Regulations in force and for the specific geographical situation.

CONDITIONS OF MANUFACTURE AND CONTROL

The manufacturer shall maintain his/her current self-monitoring of the raw materials, the manufacturing process and the finished product, in accordance with the indications given in section 7 of the Technical Report.

CONDITIONS OF USE AND INSTALLATION

The installation of the system must be carried out by qualified companies, recognised by EMMEDUE S.p.A., under its control and technical assistance. They shall ensure that the System is used under the conditions and in the fields of application covered by this Document, in accordance with the observations made by the Committee of Experts.
In accordance with the above, the present document covers only those works that have been carried out by qualified companies, recognised by EMMEDUE S.p.A.

All the necessary provisions shall be adopted regarding the stability of the constructions during assembly, the risks of falling suspended loads, the protection of persons and, in general, the provisions contained in the Health and Safety at Work regulations in force shall be taken into account, as well as what is specified in the Health and Safety Plan for the work site.

VALIDITY

This Technical Suitability Document No. 431R/20 supersedes document No. 431R/13 and is valid for a period of five years on the condition that:

- the manufacturer does not modify any of the product characteristics indicated in this Technical Suitability Document,
- the manufacturer performs systematic self-monitoring of the production as described in the Technical Report,
- the IETcc will monitor compliance with the above conditions on an annual basis, visiting, if it deems appropriate, some of the most recent projects.

With the favourable outcome of the monitoring, the IETcc will issue an annual certificate that must accompany the DIT in order to be valid.

This Document must therefore be renewed before 8 January 2025.

Madrid, 8 January 2020

[signature] [stamp]

THE DIRECTOR OF THE EDUARDO TORROJA
INSTITUTE FOR CONSTRUCTION SCIENCES

TECHNICAL REPORT

1. SUBJECT

EMMEDUE is a construction system based on a set of structural panels of corrugated expanded polystyrene with a basic reinforcement attached to their sides made up of high-strength steel mesh, linked together by electro-welded steel connectors. The steel meshes of some types of panels may incorporate rebar as required.

These panels are placed on site according to the layout of walls, partition walls and slabs in your project and are completed on site by the application of concrete through pneumatic drive devices.

In this way, the panels form the vertical and horizontal structural enclosure elements of a building with a load-bearing capacity that will be calculated according to the calculation model described in section 12 of this Technical Report.

This document is valid for System applications up to four levels or up to six levels with the conditions set out in point 3.2.

2. SYSTEM DESCRIPTION

The EMMEDUE reinforced concrete panel load-bearing system with expanded polystyrene core has a wet joint, since the connection between the different elements that make up the system is continuous. There are therefore no horizontal or vertical joints after the concrete has been cast.

EMMEDUE is an open system as it can be combined with other traditional and non-traditional building systems.

The elements that make up the EMMEDUE system are:

a) PSR vertical load-bearing panels:
Reinforced concrete elements with expanded polystyrene core for indoor or outdoor use. These elements work vertically and resist the horizontal forces transmitted in their alignment or those produced by horizontal thrusts from wind or earthquakes. They can also work in bending as large-edged beams, placed vertically. They are manufactured for finished thicknesses from 10 to 28 cm in variable lengths.

b) PSR floor panels:
Reinforced concrete elements with an expanded polystyrene core that make up the floor slabs, which can be horizontal or inclined. These are elements intended to support the vertical loads arising from the deck of each floor or on the roof. They also perform the function of transmitting and distributing horizontal loads to the vertical load-bearing elements.

This document studies and evaluates only the structural system of load-bearing and floor slab panels described so far, although the manufacturer has other elements which, used simultaneously with the previous ones, complete the system with enclosures and interior partitions.

c) PSN vertical non load-bearing panels:
Reinforced concrete elements with expanded polystyrene core for indoor or outdoor use. These are elements without structural function , with the same thickness as the PSR.

3. COMPOSITION OF THE SYSTEM'S COMPONENT PANELS

3.1 Panels

The structural cladding panel consists of a corrugated expanded polystyrene plate, density 15 $^{kg/m3}$ or more, with a standard width of 1125 mm, with steel mesh attached to its sides, linked together by 80 electro-welded steel connectors per square metre of surface area.

The thickness of the expanded polystyrene can vary from 4 cm to 28 cm, depending on the needs of the architectural project, as this, plus the average thickness of the shotcrete, which is a minimum of 3.5 cm on each side, make up the total thickness of the wall. The EPS wave depth is 12 mm and the wave spacing is 70.30 mm, resulting in 16 longitudinal waves per plate of nominal width 1125 mm (see figure 1).

The steel mesh consists of 20 longitudinal bars on each side, 6 of which are 5 mm diameter corrugated steel bars (see Figures 2 and 3) and the remaining 14 are 2.5 mm diameter galvanised plain bars. In the secondary direction there is a galvanised plain steel bar with a diameter of 2.50 mm every 6.50 cm.

The resulting reinforcement grid is then 6.25 x 6.50 cm.

These meshes are connected to each other by 70 bars of 3 mm diameter per square metre of panel surface, arranged in groups of 12 connectors every 13 cm, per 1125 mm wide plate.

For the meeting of enclosures that form an angle with each other, continuity is resolved by means of the corner meshes supplied for this purpose.

These panels, once installed vertically and after concreting, constitute the load-bearing wall of the building as they have the capacity to withstand

centric and eccentric compression, bending and shear stresses.

Horizontally laid panels constitute the floor slabs with spans of up to 5 m between supports, with the capacity to resist bending and shear, and are also used for the transmission of horizontal loads (see Figures 3a and 3b).

These panels may also be used as soil retaining walls up to a height of 3 metres, in each case verifying that the bending moments resulting from the active thrust are less than the permissible moments of the composite section; perpendicular vertical panels may be arranged as buttresses, which shall be reinforced with rebar as calculated.

The thickness of the steel cover shall be at least 30 mm on each side.

In floor slabs, the minimum concrete thickness of the compression layer is 50 mm. These coatings refer to the distance from the outside of the expanded polystyrene wave to the surface.

3.2 Vertical support panel for 6 heights

The EMMEDUE System may be used as a vertical load-bearing element in buildings up to 6 levels with the panel described in point 3.1, provided that the following conditions are met:

- On the ground and first floors, a minimum PR-80 panel shall be used, with a shotcrete overlay of 4.0 cm on each side (see Figure 2b).
- The floor slabs, over the full height of the building, must be supported on all four edges, working bi-directionally, and with a maximum span of 5.0m.

3.3 Joints and reinforcements

3.3.1 *Connection to the foundation*

The connection of the panels to the foundation is made with corrugated steel reinforcement of minimum diameter 6 mm in staggered arrangement, i.e. alternating on the sides of the panel.

This basic mounting reinforcement and the rest of the necessary anchorage shall be defined by calculation and as required in point 11.1 of this Technical Report. (See figures 11 and 12).

3.3.2 *Vertical connection between panels*

The steel mesh of the panels protrudes by 50 mm on opposite sides, so that when two panels are joined together, they overlap each other, ensuring continuity by juxtaposition, without the need for additional splicing elements.

3.3.3 *Connecting meshes*

For the connection or reinforcement of other single points, the following connecting meshes are used:

For the meeting of enclosures that form an angle with each other (see Figure 7 and 8), continuity is resolved by means of angular meshes 0.260 m long by 1.16 m wide, made of the same steel as the mesh of the panels (smooth galvanised steel with a diameter of 2.5 mm every 6.5 cm).

To ensure continuity on the sides of the panel without overlapping and to reinforce the corners of openings in the walls, flat meshes made of the same steel as the mesh of the panels with dimensions 0.325 m by 1.16 m are used.

The *U-shaped* meshes are intended to allow the concrete to adhere to the EPS at exposed panel edges: internal openings, eaves, etc. (see figure 8).

3.3.4 *Panel connection with floor slab*

The connections of the walls to the floor slabs can be solved as shown in Figures 5 and 6.

Where floors are supported on all four edges, additional corrugated reinforcement may be provided on site in the direction perpendicular to the 5 mm diameter rebars of the EMMEDUE panel meshes in order to form bi-directional floors. The perpendicular reinforcement may have at most the mechanical capacity of the main reinforcement of the panels (see Figure 3b). In these cases, the maximum span of the same may be 6.0 metres, verifying the service bending moments and the maximum admissible deflections in the elastic state as stipulated in the EHE or Code that replaces it.

3.3.5 *Connection with upper panel*

The continuity of one panel with the upper panel is resolved by means of flat meshes and according to the details provided by the manufacturer as shown in Figure 5.

4. MATERIALS

The pieces that make up the EMMEDUE System panels are made of expanded polystyrene (EPS) and steel mesh.

4.1 Expanded polystyrene

Expanded polystyrene is a thermoplastic material obtained by the polymerisation of styrene. EPS as a material is made by joining a multitude of expanded polystyrene beads, produced during a moulding process with heat in the form of water vapour.

Expanded polystyrene shall have a Declaration of Performance (CE marking) with at least the following characteristics according to UNE-EN 13163: 2013+A2:2017[1]:

- Nominal density: ≥ 15 kg/m³.
- Thermal conductivity: 0.038 W/m-K.
- Resistance to water vapour diffusion: $20 < \mu < 40$.
- Reaction to fire class according to UNE-EN 13501-1:2019[2]: E.
- Compressive stress at 10 % deformation: $\sigma_{10} \geq 80$ kPa.
- Bending strength: $\sigma_B \geq 120$ kPa.
- Designation code: EPS EN 13163 T1 L2 W2 S2 P5 DS(N)2 CS(10)80 BS120 TR100

The thickness of the expanded polystyrene core of the EMMEDUE panels must be such that the thermal insulation corresponding to the enclosure obtained meets the requirements of the CTE-DB-HE relating to Energy Saving.

As the expanded polystyrene is continuous in all enclosure walls, there are no thermal bridges. Where cut-outs are made in the walls for the passage of installations, the holes shall be filled with polyurethane foam.

Considering the thermal conductivity certified in accordance with UNE-EN 13163:2013+A2:2017[1] for the density 15 kg/m³ results in the thermal transmittance values "U", shown in Table 1, in W/m²-K.

Table 1. Thermal transmittance of panels

VERTICAL ENCLOSURE	
HORIZONTAL FLOW	
PANEL TYPE	U (W/m² K)
PSR-40	0.793
PSR-50	0.656
PSR-60	0.559
PSR-70	0.488
PSR-80	0.432
PSR-90	0.388
PSR-100	0.352
PSR-110	0.322
PSR-120	0.297
PSR-130	0.275
PSR-140	0.257
PSR-150	0.241
PSR-160	0.226
PSR-170	0.214
PSR-180	0.202
PSR-190	0.192
PSR-200	0.183

[1] UNE-EN 13163:2013+A2:2017. Thermal insulation products for buildings. Factory made expanded polystyrene (EPS) products. Specification.

[2] UNE-EN 13501-1:2019. Fire classification of construction products and building elements. Part 1: Classification using data from reaction to fire tests.

These values have been calculated according to the CTE- DB-HE relating to Energy Saving, considering a thermal conductivity of 1.8 W/m-K of the shotcrete.

4.2 Steel

4.2.1 *Rebar*

The rebars are of B 500 T quality with yield strength greater than 500 MPa, elongation at break greater than 8 % and tensile strength greater than 550 MPa according to UNE 36099:1996[3].

4.2.2 *Galvanised steel bars*

The meshes consist of galvanised steel smooth wires with a tensile strength of 700 MPa, associated yield strength (calculation value) 600 MPa and chemical composition according to (UNE-EN ISO 16120-2:2017[4].

The minimum galvanised layer shall be 45 g/m² for 2.4 mm diameter and 50 g/m² for 3 mm diameter, according to UNE-EN 10244-2:2010[5].

5. CONCRETE

Concrete that complies with the specifications set out in the EHE shall be used, according to the general environmental exposure class in which the work is located.

The shotcrete components shall comply with the requirements of UNE-EN 14487-1:2008[6].

The cements used will be CEM I or CEM II according to UNE-EN 197-1:2011[7], of resistance class 32.5 N/mm² or 42.5 N/mm², and must comply with the specifications set out in the EHE or Code that replaces it.

The aggregates may be natural or crushed and must comply with the prescriptions established in the EHE, with the only limitation that in order to favour the pneumatic impulsion the maximum size of the aggregate is 6 mm.

The mixture used for the pneumatic spraying of EMMEDUE structural concrete must meet the following requirements:

[3] UNE 36099:1996. Deformed steel wires for concrete reinforcing.

[4] UNE-EN ISO 16120-2:2017. Non-alloy steel wire rod for conversion to wire. Part 2: Specific requirements for general purpose wire rod. (ISO 16120-2:2017).

[5] UNE-EN 10244-2:2010. Steel wire and wire products. Non-ferrous metal coatings on steel wire. Part 2: Zinc or zinc alloy coatings.

[6] UNE-EN 14487-1:2008. Shotcrete. Part 1: Definitions, specifications and conformity.

[7] UNE-EN 197-1:2011. Cement. Part 1: Composition, specifications and conformity criteria for common cements.

- Consistency: it must be able to be applied in layers of about 2 cm without flaking.
- Strength: for calculation purposes, a compressive strength of 25 MPa shall be considered.
- Low setting shrinkage: to avoid cracking caused by evaporation of excess mixing water, the setting shrinkage should be less than 0.80 mm/m. For this purpose, microfibres can be used in the concrete.

The dosage of shotcrete, with the possible incorporation of admixtures, shall be carried out in accordance with the EHE and in such a way that the requirements described above are obtained.

An important factor for the final quality of the shotcrete is the energetic compaction provided by the pneumatic means of application of the shotcrete.

Industrial dry mortars produced by companies with a quality seal may also be used. In this case, industrial mortars shall comply with all the above requirements in addition to the provisions of UNE-EN 998-1:2018[8].

6. PRODUCTION OF EMMEDUE MODULAR PLATES

6.1 Place of manufacture

The EMMEDUE system is manufactured by EMMEDUE S.p.A. of Italy, located in Via Toniolo, 39b - Zona Industriale Bellocchi - 61032 Fano (PU) Italy. The industrial plant has a quality assurance system for the manufacture of its products. The Quality System complies with the UNI-EN ISO 9001:2015[9] standard, according to registration certificate no. 50 100 2912. The Certification Body has been TÜV Italia.

The design and manufacture of the panels is also within the scope of the Environmental Management Certificate 50 100 14986, in accordance with the requirements set out in UNI-EN ISO 14001:2015[10], issued by TÜV Italy.

6.2 Documents for manufacturing

The *Panel Production Log* is the specific document that lists the panels to be produced (type, quantity, dimensions, materials required, etc.) in which the assembly of panels in the panelling machine, dimensional, finishing controls are recorded.

final conformity. In the *process control sheets* , the verifications carried out for the previous activities of the manufacturing process are recorded: cutting of pantograph blocks, production of basic mesh and connecting and reinforcing meshes,

6.3 Manufacturing process

The manufacturing process of EMMEDUE panels basically consists of three stages:

6.3.1 *Cutting of expanded polystyrene blocks*

The core plate of the corrugated panels is obtained by pantograph cutting of expanded polystyrene blocks of 3000 x 1125 x 800 mm.

These blocks are cut with a cutting line consisting of a computerised machine that combines the horizontal translation movement of the block with the vertical movement of a set of wires that, separated according to the thickness of the panel to be manufactured, describes the corrugated profile shown in figure 1.

Alternatively, this operation can be carried out at the EPS supplier's factory and the sheets are received already cut to the required thickness and corrugated cross-section.

6.3.2 *Production of basic steel mesh*

From coils of smooth steel wires with diameters of 2.5 to 3.0 mm and corrugated wires of 5 mm, a microprocessor-controlled automatic machine assembles the electro-welded mesh which is composed of 20 longitudinal bars, spaced on average 6.25 cm apart with cross bars spaced 6.50 cm apart.

This automatic welding machine has full control of the welding quality with adjustable actuators from 0 to 100 operating on each of the following points:

- Pre-compression of the bars to be welded by the welding tongs.
- Current intensity.
- Retaining the welding tongs.

In this way, each of the necessary parameters is selected for the correct welding of the different steels that make up the mesh with maximum penetration.

Once each mesh of the programmed size has been produced, an automatic device unloads and collects the mesh.

6.3.3 *Panel assembly*

Placed on an infeed table the assembly consisting of two electro-welded steel meshes with a corrugated expanded polystyrene plate between them and the required production thickness,

[8] UNE-EN 998-1:2018. Specification for mortar for masonry. Part 1: Rendering and plastering mortar.

[9] UNI-EN ISO 9001:2015. Quality management systems. Requirements (ISO 9001:2015).

[10] UNI-EN ISO 14001:2015. Environmental management systems. Requirements with guidance for use (ISO 14001:2015).

an automatic machine joins these elements by means of 3.0 mm diameter steel connectors.

These connectors are fed by 12 vertical cylinders which are supplied by steel wire coils. These cylinders straighten, transfer and cut the spacers, while a set of 12 welding tongs (6 upper and 6 lower) join the connectors to the meshes.

In this case, as in the production of the meshes, the three complete parameters of each weld are controlled by a microprocessor.

This machine has a synchronisation of all tasks in such a way that it places the connectors as the panel is moved horizontally along the machine. Up to 160 spot welds can be made per square metre of panel.

6.3.4 *Production of connecting meshes*

A microprocessor-controlled machine is used to obtain the flat and angled reinforcement meshes, described in point 3.3, which produces simple cutting or cutting and 90º folding of whole mesh sections, producing flat and angled pieces of 0.260 m and 0.325 m in length and 1.16 m in width.

7. IDENTIFICATION AND LABELLING

The panels produced by EMMEDUE are labelled on the side of the EPS board with the following code:

- Code of the work.
- Panel type and EPS thickness.
- Panel length in metres.
- Installation plant (if applicable).

In addition, there shall be labelling per stack of panels, including:

- Trademark and manufacturer's identification.
- Logo and DIT number.
- Identification code of panels: batch, date of manufacture, etc.,
- Identification of the work of destination: project, delivery note, date of departure, etc.

8. QUALITY CONTROL

Quality control is carried out on the raw material components of the panels and on the finished product.

8.1 Incoming controls at the factory

The traceability of these materials is recorded in the document *Table for the control of materials on receipt* together with the supplier certificates and supply documentation.

8.1.1 *Expanded polystyrene*

The EPS reception control consists of verifying the correspondence between the purchase specification and the product received, as well as the validity of the Declaration of Performance (CE marking) of the product, issued by the supplier according to the UNE-EN 13163:2013+A2:2017[11] standard, which complies with the characteristics required in section 4.1 of this Technical Report.

In case the cutting is to be carried out in the factory, the reception of the EPS blocks is controlled from the following aspects:

1) *Visual*

A visual check is carried out on 100 % of the material received at the production plant, which involves:

- Integrity of the block.
- Correspondence of Purchase Order with Transport Document.
- Verification of the marking of each block.

2) *Dimensional*

Every 5 blocks that are received at the plant, a dimensional control is carried out where they are measured with a tape measure and verified with a dimensional tolerance of
± 2 cm; to be checked for visible defects.

3) *Density*

Once measured, they are weighed with a Class I electronic scale, in order to determine the ratio between their weight and volume in order to determine the density.
The density, calculated by weighing, must not be less than 95 % of the nominal density of the batch.

4) *Flammability*

A sample shall be taken from each consignment for the purpose of verifying compliance with quality F of the raw material.

In the case where the EPS boards are received already cut to the required thickness and corrugated section, the reception control consists of checking the correspondence between the order and the boards received.

8.1.2 *Steel*

The steels shall be checked according to the criteria established in the EHE, for normal level control.

[11] UNE-EN 13163:2013+A2:2017. Thermal insulation products for buildings. Factory made expanded polystyrene (EPS) products. Specification.

The steels shall comply with UNE 36099:1996[12], UNE-EN ISO 16120-2:2017[13] and UNE-EN 10244-2:2010[14] and certified by quality seal or mark. The control of the steel characteristics is carried out according to the certified supplier's report that accompanies each delivery of materials. The self-monitoring plan reflected in the Quality Manual of the industrial plant comprises the following procedure: the EMMEDUE Plant Manager carries out a control of the presence of the certificate of origin and of the conformity of the requested quality requirements.

The steel must be supplied by a certified supplier, and is controlled from the following aspects:

1) *Visual*

A visual check is carried out on 100 % of the material received at the plant, which involves:

- Correspondence of Purchase Order with Transport document.
- Labelled.
- Marking.
- Termination.
- Certificate of weldability.
- Mechanical characteristics.

2) *Dimensional*

One steel coil is checked every 5 received, the diameter is checked with a caliper, and the coil weight is checked with a Class I scale.

8.2 Manufacturing process

8.2.1 *Cutting of expanded polystyrene blocks*

As mentioned above, this process is carried out in a microprocessor-controlled pantograph, which combines the horizontal translation movement of the block with the vertical movement of a set of wires separated according to the thickness of the panel to be manufactured. Quality control consists of:

- checking the condition of the cutting wires;
- the correct separation of them according to the production part;
- checking the selected thicknesses with a tape measure after the cuts have been made;
- visual verification of the corrugated cuts inside the EPS block core.

8.2.2 *Production of basic steel mesh*

Mesh forming is carried out mechanised on automatic microprocessor-controlled equipment. The main control has to do with the welding of the longitudinal and transverse bars; this control at the knots is carried out in accordance with the UNE-EN 10080:2006[15] standard, for which it is performed:

- Visual check for untied knots.
- Tensile testing: daily, both at the beginning and at the end of production, samples are taken from knots of the steel mesh to perform the welded knot tensile test. Such tests are carried out internally in the production plant on all types of steel mesh produced and according to the UNE-EN ISO 15630-2:2011[16] standard (Determination of shear in welding). The results are recorded in an internal test report.

8.2.3 *Finished panel*

The following checks are carried out on the finished panel on an inspection table.

a) Dimensional.

The dimensions of the panels produced are checked with a tape measure with a dimensional tolerance equal to L/500.

b) Visual

The integrity of the assembly is checked by verifying that there has been no loss of EPS material due to tear-out during machining or combustion during welding.

c) Welding

A visual inspection of the connector welds is carried out in order to verify the correct welding of the connectors, welding manually with spot welding those connectors that have not been welded correctly in the automatic machine.

Samples of steel mesh are taken for tensile and welded knot separation tests both at the knots of the mesh and at the mesh-connector junction. Such tests are performed according to UNE-EN ISO 15630-2:2011[16] (Determination of shear in welding).

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[12] UNE 36099:1996. Deformed steel wires for concrete reinforcing.

[13] UNE-EN ISO 16120-2:2017. Non-alloy steel wire rod for conversion to wire. Part 2: Specific requirements for general purpose wire rod. (ISO 16120-2:2017).

[14] UNE-EN 10244-2:2010. Steel wire and wire products. Non-ferrous metal coatings on steel wire. Part 2: Zinc or zinc alloy coatings.

[15] UNE-EN 10080:2006. Steel for the reinforcement of concrete. Weldable reinforcing steel. General.

[16] UNE-EN ISO 15630-2:2011. Steel for the reinforcement and prestressing of concrete. Test methods. Part 2: Welded fabric and lattice girders. (ISO 15630-2:2010).

These internal manufacturing controls are recorded in the relevant mesh and panel production records, as well as in the knot release test reports.

8.3 On-site quality control

The manufacturer shall provide a Site Control Plan, in compliance with the EHE, which shall be approved by the Project Management. The Project Management shall determine the tests to be carried out on the concrete.

This Control Plan shall include a control of the receipt of materials.

8.3.1 *Concretes*

For the manufacture of concrete, there is quality control at the reception of the materials that are supplied to ensure that the requirements of its components as set out in UNE-EN 14487-1:2008[17] and those set out in the EHE are met.

- Aggregates shall comply with the requirements set out in the EHE and shall have a Declaration of Performance (CE marking).
- Cements shall follow the "Instruction for the Reception of Cements" (RC) in force, and shall have a Declaration of Performance (CE marking) as specified in standard UNE-EN 197-1:2011[18].
- The mixing water must comply with the requirements laid down in the EHE.
- The admixtures shall have a Declaration of Performance (CE marking), shall be in a proportion not exceeding 5 % by weight of cement and shall comply with the specifications of UNE-EN 934-2:2010+A1:2012[19].
- The additions must comply, in addition to the EHE, with the requirements specified in UNE-EN 206:2013+A1:2018[20].

When the concrete or industrial mortar is supplied from a plant that has an officially recognised Quality Seal, it is not necessary to carry out the on-site reception control of its components.

The concretes, both those made on site and those supplied to the site from a ready-mixed concrete plant, which must have a quality seal or mark, will be controlled according to the criteria of the EHE for the statistical control, in the number and quantity fixed by the Project Management, the tests to be carried out by an accredited external laboratory.

Where industrial mortars are used, the provisions of UNE-EN 1015-2:1999/A1:2007[21] shall be applied for total sample taking and preparation for testing.

8.3.2 *Steel*

The rebar to be placed on site shall be controlled according to the criteria established in the EHE for normal level control.

- The steels shall comply with UNE 36068:2011[22] and shall be certified by a quality seal or mark.
- The mesh shall comply with UNE 36092:2014[23] and shall be certified by a quality seal or mark.

On receipt of the steel, the corresponding certificates shall be requested and the tests shall be carried out by an external accredited laboratory. The following parameters are set for monitoring:

a) Batch

Material supplied to site at one time, of the same designation and origin.

b) Lot

Lot size: 20 tonnes
The following tests shall be carried out on each lot:

- Two equivalent section checks.
- Two comparisons of geometric characteristics to verify that they are within the limits set out in the bonding certificate or comply with the corresponding corrugation index.
- Two folding-unfolding checks.
- For each of the diameters used, verification of: type of steel, manufacturer, yield strength and breaking load and their relationship, elongation at break and elongation under minimum load.

9. STORAGE

The EMMEDUE panels will be stored in horizontal stacks, on wooden or EPS tie rods supported directly on the natural ground. Wooden or EPS boards or tie rods

[17] UNE-EN 14487-1:2008. Shotcrete. Part 1: Definitions, specifications and conformity.

[18] UNE-EN 197-1:2011. Cement. Part 1: Composition, specifications and conformity criteria for common cements.

[19] UNE-EN 934-2:2010+A1:2012. Admixtures for concrete, mortar and grout. Part 2: Concrete admixtures.
Definitions, requirements, conformity, marking and labelling

[20] UNE-EN 206:2013+A1:2018. Concrete. Specifications, performance, production and conformity.

[21] Test methods for masonry mortars. Part 2: Total sampling of mortars and preparation of mortars for testing.

[22] UNE 36068:2011. Ribbed bars of weldable steel for the reinforcement of concrete.

[23] UNE 36092:2014. Steel welded fabric for structural use in concrete reinforcement. Steel welded fabric made out of steel wires B 500 T.

shall be at least two per stack and shall be a maximum of 2.80 metres apart. The height of each pile shall not exceed 4 metres.

They will be protected from the wind, as due to their light weight they can fly and impact with any object in the surroundings.

Parts shall not be kept exposed to prolonged periods to sunlight.

10. TRANSPORT AND RECEPTION ON SITE

The panels shall be transported on horizontal stacks supported on tie rods spaced a maximum of 2.00 metres apart. The height of each stack may be a maximum of 4 metres.

Handling for loading and unloading may be done by means of forklifts with two lifting lugs or by means of cranes or other lifting devices with two attachment points up to a length of 6 metres. For lengths longer than 6 m and up to 8 m, they shall be handled with three attachment points.

11. INSTALLATION

11.1 Laying and positioning of restraints

The panels are simply placed on a continuous foundation such as a foundation beam or a reinforced or mass concrete slab in accordance with conventional calculations, dimensioned according to the permissible strength of the ground.

This foundation shall have a holding structure, consisting of corrugated steel bars of 6 mm diameter, in a number that arises from the corresponding structural calculation of each work, with a staggered arrangement, i.e. alternating on the sides of the panel. The distance between the rows of such standby bars shall be equal to the distance between the meshes, i.e. the thickness of the expanded polystyrene core plus
25 mm. These bars shall be straight and shall be embedded in the foundation as per EHE or superseding Code, not less than 20 cm; they shall protrude from the top plane of the foundation by a minimum length of 35 cm and shall be linked to the panel meshes by simple ties (see Figure 4).

The bars may also be placed by drilling into the concrete of the floor slab with a core drill and fixing the bars to the concrete with an epoxy adhesive, when required by the structural design.

11.2 Laying of panels

The succession of interlinked panels materialises all the enclosure planes of the building: exterior walls, interior walls, floor slabs and roofs (see Figures 5, 6, 7 and 8).

The panels, when coplanar, are joined to each other through the 50 mm overlap that their meshes have on opposite sides; these overlaps shall be linked by means of simple wire ties spaced approximately 50 cm apart. Alternatively, the panels may be joined together by stapling with manual or automatic staplers.

The horizontal and vertical edges of the panel joints shall be reinforced by means of corner meshes arranged along the horizontal and vertical edges and on each of their sides (see Figures 5, 6, 7 and 8).

By cutting the panel, the spans corresponding to the openings are opened, with the minimum clearance necessary to avoid thermal bridges (approximately 10 to 20 mm) for the placement of the frames, whose fastening clips are attached to the meshes.

Internal openings or eaves can be reinforced with *U-shaped* mesh of a width corresponding to the width of the wall, enclosing the edges of the entire opening.

In addition, all free edges of walls, e.g. overhangs, shall be reinforced with this type of mesh (see Figure 8).

The openings shall have 45° reinforcement at the corners of the openings and the longitudinal reinforcement shall be that obtained by calculation.

These reinforcements can be made with special meshes that are supplied together with the EMMEDUE panels for this purpose (see Figure 9).

When panels that have been cut and therefore do not have the mesh overlaps on opposite sides are to be joined together, special meshes shall be used for these joints to allow for a juxtaposition joint.

These same special meshes will be used whenever, for various construction site reasons, the pre-arranged meshes of the EMMEDUE panels have to be cut.

The connection between walls and slabs is resolved as indicated in point 3.3.4 and Figures 5 and 6 of this Technical Report, taking care to give vertical continuity to the thicknesses of shotcrete applied on the support sides.

The perimeter edges of the floor slab shall be reinforced by means of an in-situ concrete tie beam, reinforced according to the calculation.

It must be ensured that the enclosure planes are correctly aligned and plumb. This may be done by the use of tie rods, metal rulers, telescopic props or any other element suitable for this purpose.

The ducts can then be installed in the expanded polystyrene by depressing the polystyrene using a hot air gun, in which the corresponding ducts will be housed.

11.3 Concrete spraying

Once the operations described above have been carried out, the concrete is sprayed, taking into account the EHE and the provisions of UNE-EN 14487-2:2008[24].

The spraying can be done with *hopper-gun* type pneumatic spraying devices connected to an air compressor of suitable power or with continuous spraying machines of the Turbosol, Putzmeister or similar type.

The *hopper-gun* spray guns have a compressed air circulation supplied by a compressor, which must operate at a constant air pressure of 500 to 600 kPa, as a vehicle for the delivery of the fresh mixture. This compressor must deliver between 300 and 350 litres of air per minute for each of the devices connected to it.

If electro-compressors are used, the recommended power ratings are shown below:

Table 2. Recommended spraying powers.

Motor power (HP)	Air flow rate (Litres/min)	Number of spray guns
2 ½ to 4	350 to 400	1
5 to 6	600 to 700	2 to 3
8 to 10	900 to 1.000	3 to 4

Concrete spraying converts all enclosures and slabs made up of panels, as well as their joints, into continuous and monolithic elements.

The pneumatic concrete spraying operation may be carried out in two passes. The first is 2 cm thick, covering the steel mesh, and the second is for finishing until the required final thickness of at least 3 cm is reached. For this purpose, guides are used as masters, which can simply be 20 mm square steel tubes, against which the planned shotcrete thicknesses are cut. The plastering will be of the designer's choice with conventional materials: plaster and paint on screeded surfaces, plaster, plastic splatter, elastomeric paint, etc.

In order to create the horizontal or inclined planes, a system of supports and props must be available on which the panels will rest, which will be joined together by means of their corresponding overlaps.

A first layer of shotcrete is then applied to the underside to stiffen and form the panels. Subsequently, the 5 cm compression layer is poured, which may be made of conventional concrete or the shotcrete used in the walls.

[24] UNE-EN 14487-2:2008. Shotcrete. Part 2: Execution.

Once the estimated strength of the poured concrete has been reached (with the approval of the Project Management), the supports may be removed, changing some props that ensure the non-deformability of the slab until it is completely concreted, applying the second layer of shotcrete on the underside. This second layer of shotcrete will completely fill in the areas occupied by supports and props.

11.4 Final checks

The side plumb error (transverse) of a panel shall not exceed 8 mm (on the mean generatrix).

The positional error (offset) between adjacent sides of overlapping panels shall be less than 15 mm.

Any lead and position error that is not within the above tolerances is considered to be an exceptional execution error. If such defects occur during execution, the calculations shall be repeated for the functional justification of the affected elements.

12. CALCULATION REPORT

The buildings constructed with the EMMEDUE Construction System are conceived as structures made up of large vertical and horizontal elements, which are formed when the pre-industrialised panels are grouped together once they have been concreted on site.

These large vertical and horizontal elements work as composite sections due to the bonding provided by the 80 steel connectors of 3 mm diameter per square metre of panel surface, so that the two layers of shotcrete work together as a composite section.

12.1 Vertical elements

The joint between each of the elements is hinged in such a way that the transverse stiffness of each vertical element is negligible compared to its in-plane stiffness.

The Modulus of Elasticity in the longitudinal direction E_x is that corresponding to HA25 concrete while the Modulus of Elasticity in the perpendicular direction is that corresponding to the composite section and will be obtained by calculation, depending on the thicknesses to be considered.

To give stability to buildings it is necessary to arrange panels in two directions in such a way that, in addition to receiving the load of the slabs, they provide the transversal stability of the building, in two directions, together with the possible existing bracings in each floor and studying in each case, the transmission

of the horizontal loads through the floor slab or possible bracing.

The stress analysis of the structure will be carried out using the actions defined in the Basic Document "Structural safety. Actions in the building" of the CTE (DB-SE-AE) as appropriate and the sections shall be dimensioned with the results obtained according to the EHE or Code that replaces it.

12.2 Horizontal elements

As for the horizontal elements that make up the floor slabs, these are also considered to be hinged at their supports, i.e. they are considered to be isostatic so that no embedding moment is transmitted to the vertical supporting elements.

Their bending stiffness is limited to the consideration of a longitudinal modulus of elasticity obtained as indicated in the previous point and shall be calculated within the elastic behaviour zone.

Sections shall be dimensioned according to EHE or Code replacing it.

The panels have a reinforcement of 6 rebars with a diameter of 5 mm on each side. Rebars shall be increased when the stresses determine the need to increase the mechanical capacity of the section.

For two-way slabs, the criterion for the addition of perpendicular bars will be determined by the calculation, with no more reinforcement than that provided by the panels.

The loads may be calculated with any of the conventional reinforced concrete floor design methods.

13. REFERENCES FOR USE

The EMMEDUE system has been in use since 1980 in various parts of the world due to its presence in 60 industrial plants in various countries. The EMMEDUE building system has been used in more than 100,000 constructions worldwide.

Among those built in Italy with panels supplied from this factory, the manufacturer provides as a reference:

Table 3. References for use

Work	Heights	Year
Building in Fano	3	1980
240 flats in Rieti	3	1995
House 280 m² Gualdo Tadino-Umbria (this house withstood the effects of the great earthquake of 1999).	3	1998
School of 390 m² in Viale dell'Emigrazione, Montagano	1	2004
Residence of 50 m² in Vignola a Mare di Aglientu.	2	2006
Nursing home in Via Fontetta, Cagli.	2	2011
Semi-detached villa in Via Tratturo, Villa Oliveti di Rosciano.	2	2011
Semi-detached villa in Via S. Maria a Colle, Scoppito.	3	2011
School in Via D'Annunzio, Manzolino di Castelfranco Emilia.	1	2012
School of 730m² in Via Firenze, Medolla.	1	2012
Gymnasium in Viale Torre Costiera, Città Sant'Angelo.	3	2012

The following references are also provided:

Table 4. Other references for use

Work	Heights	Year
Detached houses in Libreville (Gabon).	1	2011
Residential building in Cañada Aparicio, Maldonado (Uruguay).	3	2012
Semi-detached villa in Chengalpattu, Tamil Nadu, India.	3	2013
Detached villa in Ouesso (Republic of Congo).	2	2015

The IETcc has carried out several site visits and a survey, all with satisfactory results.

14. TESTS

Part of the tests were carried out at the Eduardo Torroja Institute for Construction Sciences (IETcc) whose results are reflected in the reports 18 167-1, 18 167-2 and 18 167-5; and another part of the tests were provided by EMMEDUE, S.p.A. and carried out in other laboratories.

14.1 Mechanical characteristics of the concreted panel

The characteristics of the materials, reinforcement, arrangement and number of reinforcements in the tested panels correspond to that defined in point 3.1 of this report.

14.1.1 *Flexural behaviour*

14.1.1.1 Tests carried out at the IETcc

a) Subject of the test

The aim is to study the mechanical behaviour of panels subjected to a series of vertical loads that produce flexural stresses.

b) Test layout

The PSR-80, PSR-60 and PSR-50 panels were tested with an upper compression layer of 5 cm and the lower one with a thickness of 2.5 cm, 2.40 m long and 0.34 m wide, with a span of 2.30 m between supports.

The test arrangement is reflected in test dossier 18.167-2.

c) Results obtained

From the study of the load-deformation curves, it can be deduced that the sections of the panels work as a composite section formed by two slabs of 5 cm and 2.5 cm joined by the joint reinforcements working together, with the stiffness modulus E-I in the elastic zone corresponding to the values provided by the manufacturer according to his/her calculation forecasts.

14.1.1.2 Tests provided by the manufacturer

With regard to the behaviour of the panels under flexural stress, EMMEDUE has provided the following tests carried out at the RITAM (Research and Technology Laboratory for Anti-seismic, Structural and Material Systems) of the University of Perugia (Italy) in September 2000.

Tests carried out on various EMMEDUE panels with thicknesses from 165 mm to 225 mm, lengths of 4 m, with 3.60 m support spacing.

The results obtained confirm that the shotcrete sections of the panels work as united sections, and in accordance with the manufacturer's theoretical calculation forecasts.

14.1.2 *Compression behaviour*

14.1.2.1 Tests carried out at the EITcc

Test 1

a) Subject of the test

The aim is to study the mechanical behaviour of a panel subjected to the vertical loads of the upper elements of the building.

b) Test layout

A PSR-40 panel, 2.60 m high, 1.125 m wide, and with a concrete thickness of 3 cm on each side of the panel, was tested.

The layout of the test is reflected in the test dossier 18 167-2.

c) Results obtained

Localised breakage of the panel head occurred under the 450 kN load, due to localised tensions at the point of load application.

There were no cracks in the panel and no remaining deformations were visible, as the two concrete layers worked together and no lateral changes or deformations were visible.

Test 2

a) Subject of the test

The aim is to study the mechanical behaviour of a wall consisting of a PSR-80 panel with a 4 cm overlap on each side, subjected to the vertical loads of the upper elements of the building.

b) Test layout

Two PSR-80 panels, 2.55 m high, 1.20 m wide, and with a concrete thickness of 4 cm on each side of the panel, with an eccentricity of 2 cm, were tested.

The test arrangement is reflected in the test dossier 18 167-5.

c) Results obtained

The first test was stopped at 740 kN, without failure of the system.

In the second test, the load was increased until the panel failed at 800 kN. The failure was caused by panel buckling and localised head loading.

In both cases, the two layers of shotcrete worked together and no lateral changes or deformations were observed.

14.1.2.2 Tests provided by the manufacturer

Test carried out by RITAM of the University of Perugia (Italy), studying the behaviour of PSM-80 panels, 2.72 m long, under a centred load or under an eccentric load.

The panels were concreted with a thickness of 20 cm at their head and values of 800 to 1000 kN were obtained for the centred axial forces, while the same panels concreted without a top head and with an eccentricity of 5 cm supported a load of 600 kN, although these panels (by means of jacks and metal profiles) were confined at their load-bearing head. It is verified that, under the action of axial loads, the two concrete layers work together.

14.1.3 *Bi-directional bending behaviour*

a) Subject of the test

It is studied whether a plate consisting of a series of panels supported on all four sides of its contour, with corrugated reinforcement in both directions, behaves like a slab supported on all four sides.

b) Test layout

A slab of PSR-120 panels with a total thickness of 20.5 cm and plan dimensions of 4.00 m x 4.00 m was tested with a uniformly distributed load.

The test arrangement is reflected in the test dossier 18 167-5.

c) Results obtained

From the reading of the flexometers it can be deduced that the plate is working in both directions and the two layers of shotcrete worked together.

The deflections obtained 20 hours after the plate was loaded were similar to those verified at the time of the last loading step.

14.1.4 *Shear behaviour*

a) Subject of the test

Verify that at the junction of the horizontal panels acting as floor slabs with the vertical structural panels, the transmission of the floor loads to the vertical panels is carried out, checking the order of magnitude of their shear resistance.

b) Test layout

An H-shaped gantry frame was tested, consisting of two vertical PSR-40 panels, with two 3 cm concrete layers, the panels being 1.125 m wide and 1.10 m high, joined at their intermediate height by another PSR-40 panel, with a concrete thickness of 5 cm as the upper layer and 3 cm on the lower face, and with a length of 1.05 m, which is the free distance between the vertical panels, and a width of 1.125 m.

The layout of the test is reflected in the test dossier 18 167-2.

c) Result obtained

The ultimate load applied to the panel was 74.2 kN, resulting in the stoppage of the test, not due to shear exhaustion of the joint, but due to the flexural rupture of the panel, taking into account the loads to be considered and the lengths of the panels, it is verified that the slab panel transmits the shear forces to its support panels.

14.1.5 *Mechanical behaviour of the vertical panel to horizontal stresses*

a) Subject of the test

The behaviour of vertical panels is studied against a horizontal stress in the plane of the panel, representing the stresses transmitted by wind or earthquake.

b) Test layout

An assembly consisting of two PSR-40 panels, with their concrete layers of 3 cm on each side and a height of 2.6 m, was tested on a footing of 2.60 x 0.40 x 0.40 m.

The layout of the test is reflected in the test dossier 18 167-2.

c) Results obtained

The test is concluded for a load value of 70 kN by the breakage of the footing. The wall formed by the two panels remains straight without any cracks or crevices, other than the horizontal crack at the junction of the wall and the footing.

The test confirms that the two layers of concrete, joined by the basic reinforcement, work together under the action of the horizontal load in the plane of the panel, resisting a breaking moment of 182 kN-m in a panel width of 0.80 m. The behaviour of the wall is therefore valid and in accordance with the structural calculation.

14.1.6 *Deformability of the slab-panel*

a) Subject of the test

To study whether the deflections or deformations that occur in a slab-panel, produced by the action of the permanent loads and overloads acting on the panel, correspond to those defined according to the theoretical calculation model indicated by the manufacturer.

b) Test layout

A PSR-80 panel 1.125 m wide and 3.80 m long, with a top layer of 5 cm as the compression slab and 2.5 cm as the bottom layer, subjected to a uniform overload and with a span of 3.20 m between supports, was tested.

The layout of the test is reflected in the test dossier 18 167-2.

c) Results obtained

The flexometers gave deflections of the same order, with an average value of 6.27 mm half an hour after loading. The load was maintained for 24 hours, with no significant increase in deflection; when the load ceased, the deformation ceased and a small remaining deformation of 0.7 mm was maintained, verifying that the deflections produced correspond to their theoretical calculation.

14.2 Conductivity coefficient

Obtained through testing in accordance with UNE-EN 92202, DIN 52612 and ASTM-C-518, to a PSR-80 panel, with a shotcrete thickness of 30 mm, with dimensions of 60 x 60 cm, in dry state.

$$\lambda = 0{,}50 \text{ W/m-K}$$

14.3 Suitability for use tests

14.3.1 *Soft body impact resistance*

The wall formed by PSR-40 panels, as defined in section 14.1.5, was subjected to the soft impact of a 50 kg bag with impacts of 900 and 1200 joules, with a satisfactory result, as the panel did not crack.

14.3.2 *Tightness test of panel joints*

4 panels of PSR-80 of 0.5 x 0.5 m are laid out on both sides to be coated with
30 mm of concrete. After 28 days, they were subjected to horizontal water projection, verifying that no water penetration was observed, neither through the panel itself, nor through the joints, whether horizontal or vertical.

The test arrangement is reflected in the test dossier 18 167-1.

14.3.3 *Flexural test of two slab panels*

a) Subject of the test

Test to evaluate the degree of stress transmission through the joint of two slab panels, at the same time as the study of the mechanical behaviour of these slabs subjected to flexural stress.

b) Test layout

An assembly consisting of two 1.12 m wide and 3.20 m long PSR-80 panels covered with a shotcrete thickness of 5 cm as the top layer and 2.5 cm as the bottom layer was tested.

The span between supports was 2.80 m.

The layout of the test is reflected in the test dossier 18 167-2.

c) Results obtained

The test shows that the connection between slabs transmits the loads transversely to the adjacent panel, but it also indicates that the transverse load transmission in this type of panel is lower than in full concrete section panels, so that the direct application of a point load is not recommended for these systems.

14.3.4 *Mechanical serviceability test of the system*

a) Subject of the test

To study the mechanical behaviour of the joints between horizontal and vertical panels, in which one is subjected to the vertical loads of the upper elements of the building itself, plus the weights and overloads of the floor slab corresponding to the horizontal panel.

b) Test layout

A gantry was tested consisting of:

- as vertical elements, PSR-40 panels with shotcrete coatings of
  30 mm, 1.125 m wide and 3.40 m high.
- as a slab, a PSR-80 panel, with shotcrete coatings of 50 mm top layer, 25 mm bottom layer and 4.20 m in length.

The slab was loaded with a uniformly distributed overload and a vertical point load was applied to one of the vertical panels.

The layout of the test is reflected in the test dossier 18 167-2.

c) Results obtained

The test ended with a point load value of 375 kN, the load to be considered for the 4-storey buildings with a support spacing of 5.00 m being 100 kN/ml with a load increase coefficient in the order of 3.6 times, and with an unbraced top wall.

14.3.5 *Sound insulation*

a) Laboratory test

Test carried out at the Giordano Institute - Centro Politecnico di Ricerche e Certificazioni, according to ISO 140-3:1995 and ISO 717-1:1996 standards with report number N. 178090.

A 3.60 m long and 3.00 m high wall was tested, consisting of PSN-80 panels with 30 mm shotcrete coatings on both sides. The wall was plastered on both sides with a cement, light aggregate and cellulose plaster, with a polymer and fine marble finish, with a total thickness of 12 mm.

A sound insulation value of 40 dBA was obtained.

b) On-site measurement

Measurement carried out by Sinthesi - Divisione Isolamento Acustico, according to ISO 140-4 and ISO 717-1:1996 dated 24 January 2006 and report number 415ARED0202.

A façade wall consisting of PSN-80 panels was tested with 30 mm shotcrete coatings on both sides.

On the inside, the wall was clad with 3 cm thick, laminated plasterboard panels with Isover brand rock wool.

A sound insulation value of 49 dBA was obtained.

15. ASSESSMENT OF SUITABILITY FOR USE

15.1 Compliance with national regulations

15.1.1 *SS - Structural safety*

The walls and slabs built with the EMMEDUE System constitute part of the building envelope, slabs and structure or part of the structure of the building.

The present technical evaluation, with the tests carried out, has verified that the structural performance of the System is in accordance with the manufacturer's calculation assumptions, as described in point 12.

The building project must have its corresponding structural calculation annex, specifying the calculation criteria adopted, which must be in accordance with the provisions of this document and justify compliance with the basic requirements of strength and stability (SE 1) and suitability for service (SE 2) of the CTE.

The structure and, in particular, the floor panels must be dimensioned, in addition to the Ultimate Limit State, by the Serviceability Limit State, within the elastic behaviour zone.

Particular attention shall be paid to a verification of the expected deformations in the structure, which shall be such that they do not compromise the integrity of the intended construction elements (in particular enclosures, partitions and finishes).

To give stability to the building, it is necessary to have alignments of panels in both directions to resist wind or seismic thrusts, if any, or to use another stabilisation system.

15.1.2 *FS - Fire safety*

Compliance with the basic fire resistance requirement of the structure (SI 6) must be justified according to the type of construction envisaged, and the reinforcement coatings that guarantee the required stability and fire resistance must be established (DB-SI 6, Annex C).

The number of floors above ground shall be limited by justification (by calculation or testing) according to EN 13501-2[25]) of the sufficient fire resistance of the structural elements in relation to the evacuation height of the building (SI 6).

The necessary cladding shall also be provided to comply with the fire resistance of walls and ceilings delimiting fire compartments (SI 1) and in relation to the external spread (SI 2).

15.1.3 *SUA - Safety in use and accessibility*

The basic requirements of the CTE-DB-SUA, relating to safety in use and accessibility, will be taken into account; in particular with regard to the application of finishes (SUA 1).

15.1.4 *HS - Health*

The water tightness tests of the panels and joints allowed to verify the correct behaviour of the system under this stress, and the execution of joints had to be carried out as described in the Technical Report.

In any case, special attention should be paid in the design of the façades to the incorporation of windows and lighting elements, as well as to the correct solution of singular points, external fixings, etc.

The absence of condensation of any kind inside the walls formed with these panels shall be a design condition. The verification of the limitation of surface and interstitial condensation dampness must be carried out according to the provisions of part 2 of the Supporting Document to the Basic Document DB- HE 1 of the Technical Construction Code (DA/2 DB-HE1, CTE), part 2, in its epigraph 4.

The system components, as declared by the system manufacturer, do not contain or release hazardous substances according to national and European legislation.

15.1.5 *HR - Noise protection*

The system allows for the subsequent incorporation of acoustic insulation.

The complete solution of the construction elements (external enclosure, internal partitions, floor slabs and roof) must comply with the requirements of the CTE-DB-HR, relating to noise protection.

15.1.6 *HE - Energy Saving*

The system allows the interior and/or exterior cladding of the panels, giving rise to different cladding solutions.

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[25] Classification according to the fire performance of construction products and building elements. Part 2: Classification on the basis of data obtained from fire resistance tests excluding ventilation installations.

The complete enclosure solution must meet the requirements of the CTE-DB-HE, relating to Energy Saving, in terms of hygrothermal performance; compliance with the basic requirement for limiting energy demand (HE 1) for the corresponding climate zone must be justified for each type of enclosure.

Point 4.1 of the Technical Report gives the coefficients of the thermal transmittance of enclosures, partitions and floors made with the System.

15.2 Use of the product. Implementation and limitations of use

15.2.1 *Commissioning*

The suitability of this system depends fundamentally on the installation being carried out by qualified companies, recognised by the manufacturer, with demonstrable experience in the installation of the system.

They shall ensure that the System is used in accordance with the conditions and fields of application covered by this Document, in compliance with the observations made by the Committee of Experts, by issuing a certificate of conformity at the end of the work.

15.2.2 *Limitations of use*

This Document is valid for System applications up to four levels, or six levels with the conditions set out in point 3.2 of the Technical Report; the maximum height per floor being 4 m, provided that the calculation allows for this.

For taller buildings, given the possible problems of local instability and buckling that may occur, a local analysis with the various lateral bracing options and a global analysis of second order deformations should be carried out. Likewise, the level of on-site execution control shall be appropriate to the solution to be designed.

Particular attention shall be paid to the height limitation imposed by the fire resistance of the structure as referred to in 15.1.2.

In any case, the overall construction solution adopted must be justified by calculation in the technical project referred to in the general conditions for granting the DIT.

15.2.3 *Durability, service conditions and maintenance*

The System is considered to perform satisfactorily in accordance with the durability requirements, provided that the particular cladding solution has been designed in such a way as to ensure the absence of condensation in the core of the panels (see 15.1.4), that the System has been installed as described in this document and is subject to proper use and maintenance, in accordance with the provisions of the CTE and the instructions given by the manufacturer.

15.3 Waste management

For the waste produced during the manufacturing and commissioning processes of the system, the instructions given by the manufacturer shall be followed in accordance with the regulations in force for each product.

In general, the specifications of Royal Decree 105/2008 regulating the production and management of construction and demolition waste will be followed, as well as the applicable regional and local regulations.

15.4 Monitoring conditions

The granting of the DIT is linked to the maintenance of an annual monitoring of the manufacturer's factory production control and, where appropriate, of some of the works carried out. This monitoring does not constitute an endorsement or guarantee of the works carried out.

16. CONCLUSIONS

Whereas:

- EMMEDUE S.p.A. carries out a manufacturing quality control comprising a self-monitoring system by which the manufacturer checks the suitability of the raw materials and components, of the manufacturing process and of the final product;
- the methods of project development, panel manufacture and commissioning are sufficiently proven by practice, test results and site visits.

The suitability for use of the system proposed by the manufacturer is considered favourably, subject to the comments of the Committee of Experts of this DIT.

17. OBSERVATIONS OF THE COMMISSION OF EXPERTS [26]

The main observations of the Committee of Experts[27] were as follows:

- In order to ensure the viability of the System, a technical report of the structural calculation including the ultimate and serviceability limit state analyses shall be provided for each case to be applied. This report must adequately justify the correct structural response of the different elements and the connections between them. The safety coefficients required in accordance with the regulations in force, the applicable tolerances and the solutions to be adopted in the event of expansion joints shall also be established. In addition, the correct connection of the floor slabs to the vertical panels in both alignments or directions must be foreseen, to guarantee the transmission of the horizontal thrusts occurring in the building to both alignments.
- The panels shall be identified on entry to the site according to whether they are PSR or PSN, and shall be stored in clearly identified locations to avoid errors during installation.
- It is essential to check that the connectors are welded to the meshes to ensure that the sections are working together.
- The risk of condensation (according to CTE DB-HE) must be avoided by the enclosure as a whole.
- The minimum reinforcement coatings shall be studied and justified on a case-by-case basis, and essentially in aggressive environmental situations or when a specific fire resistance is required. Complementary protections (cladding, linings, etc.) that are necessary to comply with the necessary fire resistance in accordance with current regulations shall be considered.
- For horizontal stresses, allow for increases in these thrusts, taking into account the additional eccentricity of the seismic action, paying attention to the low ductility of these types of shielded buildings.
- The application of localised loads on the panels is not recommended. It is not advisable for panels to be corbelled, except for small eaves and overhangs.
- In the event that the foundation holding structure does not correspond to the concrete layers of the panels, new holding layers shall be laid out in accordance with these layers.
- When it is necessary to increase the acoustic insulation, the thickness of the mortar layer shall be increased or the walls shall be lined until the acoustic insulation value required by the regulations in force is reached.
- It is recommended that installations are planned with non-panel systems so that insulation is not removed on site for this purpose. If it is necessary to depress the EPS in some areas (as foreseen in point 11.2), care shall be taken to minimise the loss of insulation as much as possible.
- It shall be clearly defined in the Building Records which panels are load-bearing (PSR) and which are non load-bearing (PSN). The Building Records must also state that for the modification of any load-bearing element (PSR panels), including the opening of openings, a project justifying the structural calculation of the new layout, as well as the necessary construction details, must be provided.
- A specific study of seismic behaviour will be required where appropriate.
- It is recommended that a copy of this Technical Suitability Document be incorporated into the Building Records.

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[26] The function of the Committee of Experts, in accordance with the Regulation on the granting of the DIT (O.M. of 23/12/1988), is to advise on the test plan and the procedure to be followed for the technical evaluation proposed by the IETcc.

The comments and observations made by the members of the Commission do not in themselves constitute a technical endorsement or recommendation for the preferential use of the system evaluated.

The responsibility of the Committee of Experts does not extend to the following aspects:

a) Intellectual property or patent rights to the product or system.

b) Rights to market the product or system.

c) Works executed or being executed in which the product or system has been installed, used or maintained, as well as their design, construction methods and training of operators involved.

[27] The Committee of Experts was composed of representatives of the following Agencies and Entities:

- Higher Council of the Colleges of Architects of Spain (CSCAE).
- Polytechnic University of Madrid (UPM).
- University School of Technical Architecture of Madrid (EUATM).
- ACCIONA INFRAESTRUCTURAS.
- FCC Construcción, S.A.
- Instituto Técnico de Materiales de Construcción, S.A. (INTEMAC, S.A.).
- "General Marvá" Army Engineering Laboratory (INTA - MINISDEF).
- CEP IBÉRICA and AIC.
- Dragados Obras y Proyectos, S.A.
- Technical Institute for Inspection and Control (INTEINCO).
- NECSO, S.A.
- Sociedad Española para el Control Técnico en la Construcción S.A. (SECOTEC, S.A.).
- BUREAU VERITAS.
- Technical Control and Risk Prevention (CPV).
- FERROVIAL AGROMAN.
- INTEC Quality Control.
- Ministry of Housing.
- QUALIBÉRICA.
- AENOR.
- SGS.
- ASECE.
- Eduardo Torroja Institute for Construction Sciences (IETcc).

Figure 1. Geometry of the EPS wave (dimensions in mm)

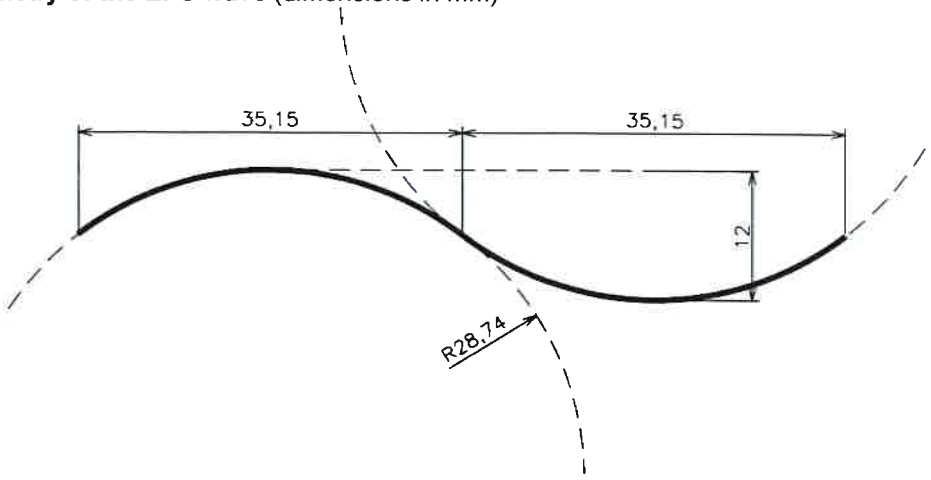
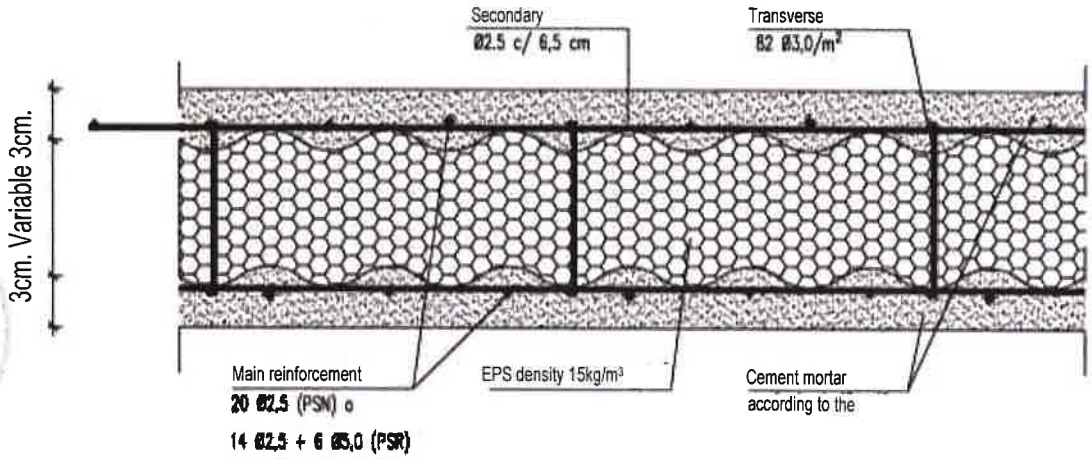
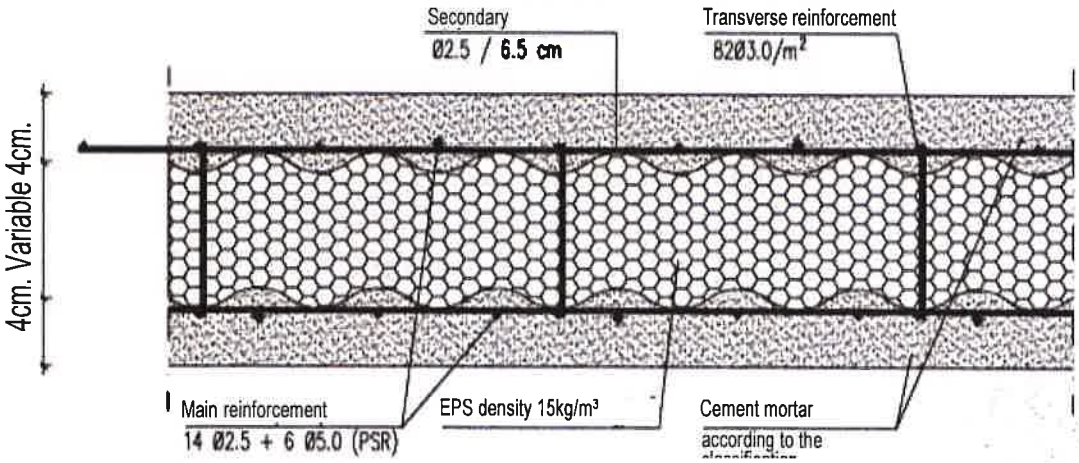


Figure 2a. Cross-section of load-bearing (PSR) and non load-bearing (PSN) wall panel



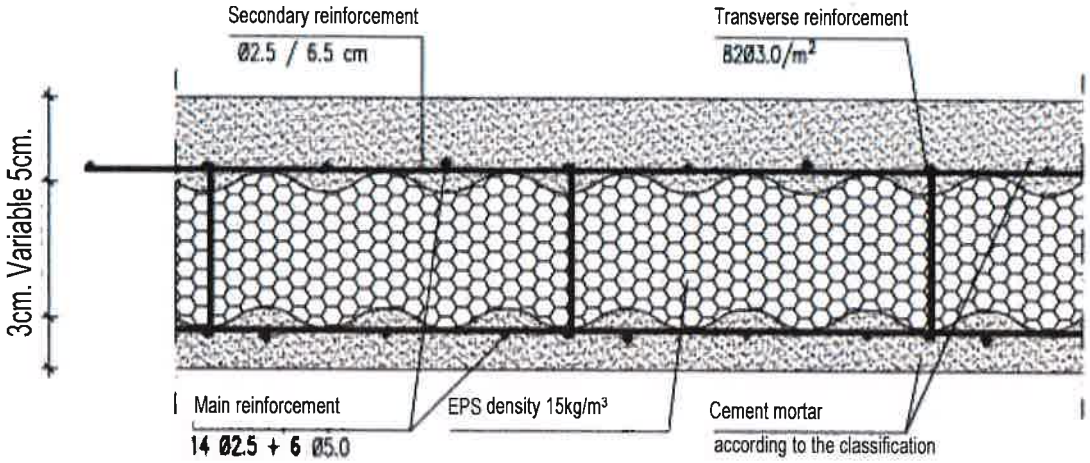
THE COATINGS SHALL BE FIXED ACCORDING TO THE REQUIREMENTS OF THE (EHE)

Figure 2b. Bearing wall panel cross-section (PSR) for more than 4 and up to 6 heights



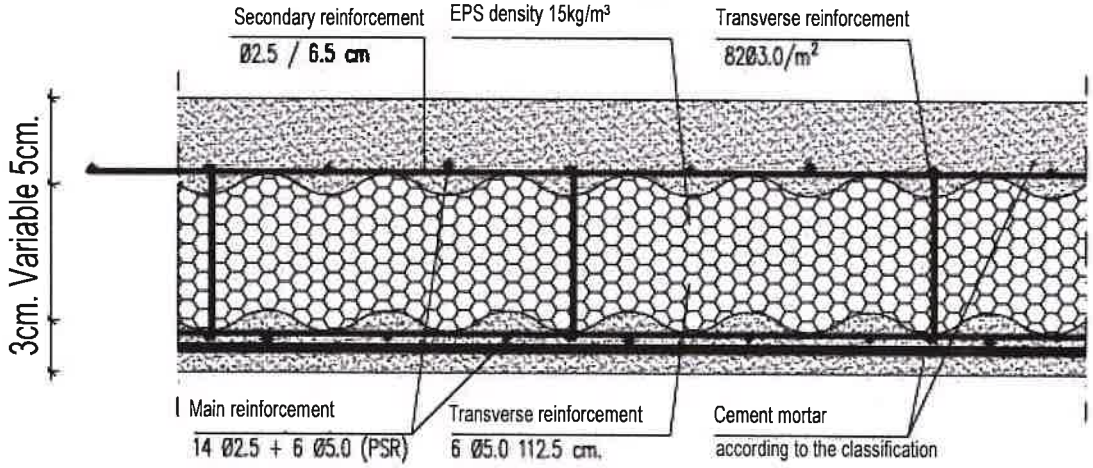
THE COATINGS SHALL BE FIXED ACCORDING TO THE REQUIREMENTS OF THE (EHE)

Figure 3a. PSR floor panel



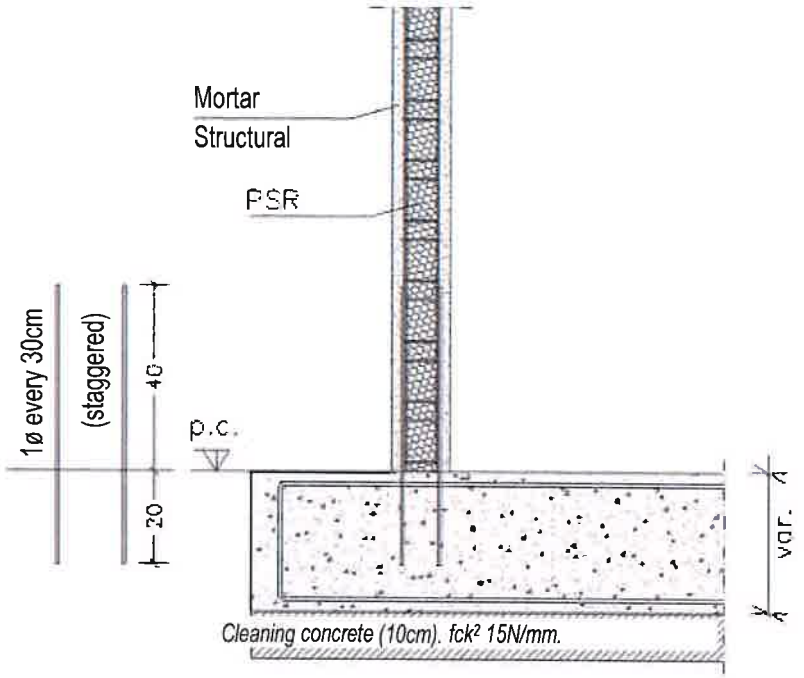
THE COATINGS SHALL BE FIXED ACCORDING TO THE REQUIREMENTS OF THE (EHE)

Figure 3b. Two-way floor panel PSR



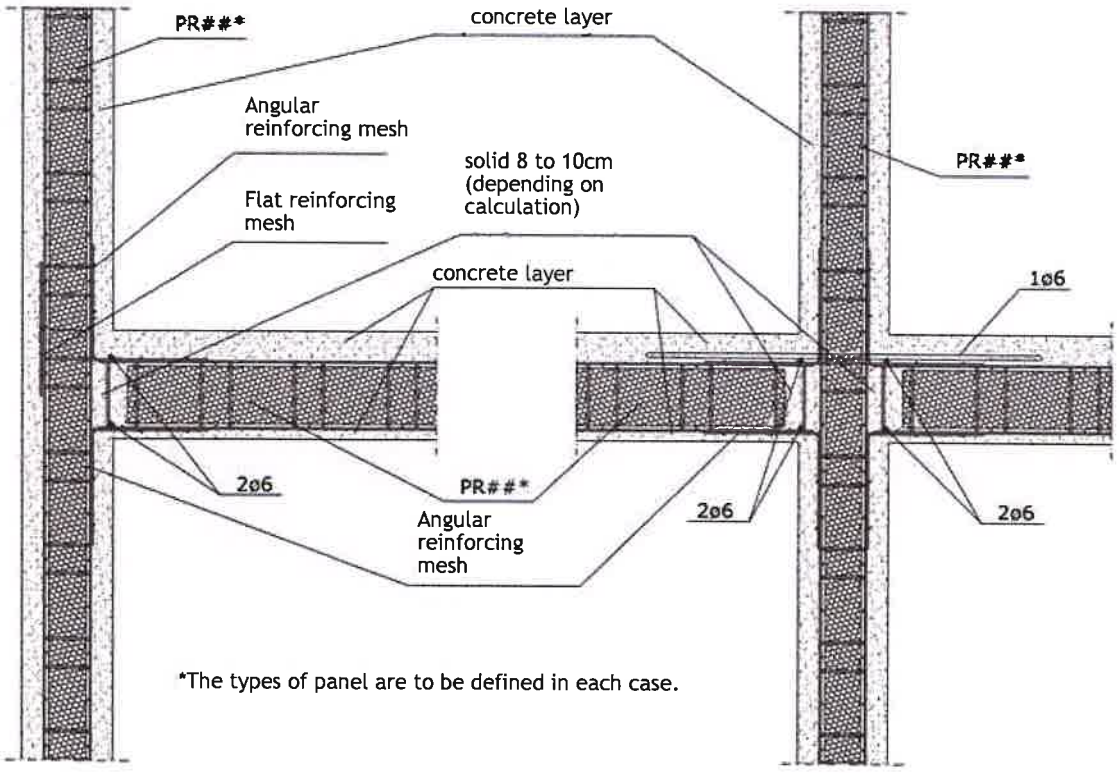
THE COATINGS SHALL BE FIXED ACCORDING TO THE REQUIREMENTS OF THE (EHE)

Figure 4. Detail of panel connection to the foundation



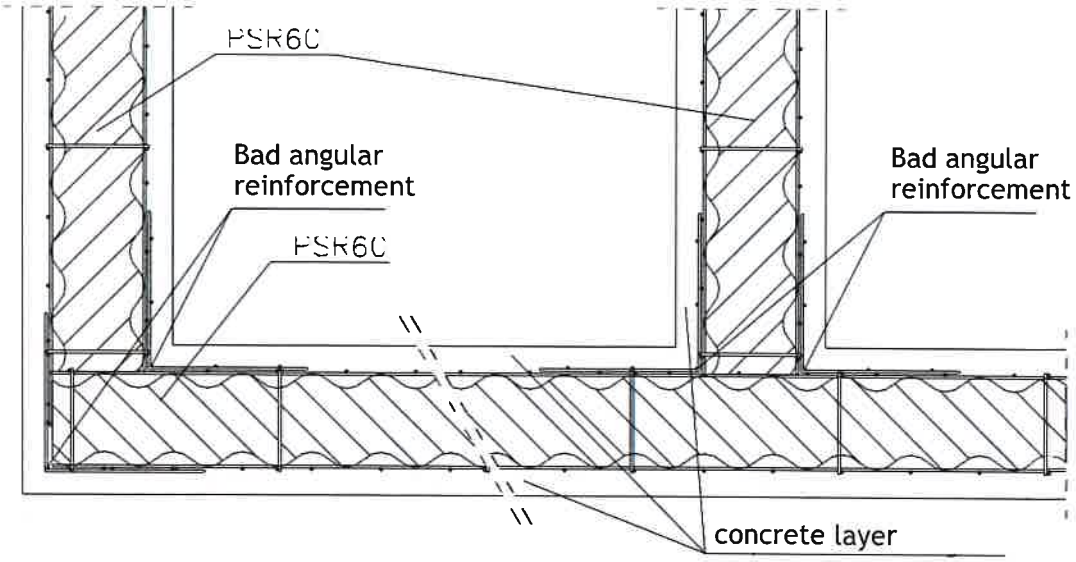
THE TYPE OF PANEL AND DIMENSIONS ARE INDICATIVE (TO BE DEFINED IN EACH CASE).

Figures 5 and 6. Detail of junction between walls and slabs (section)



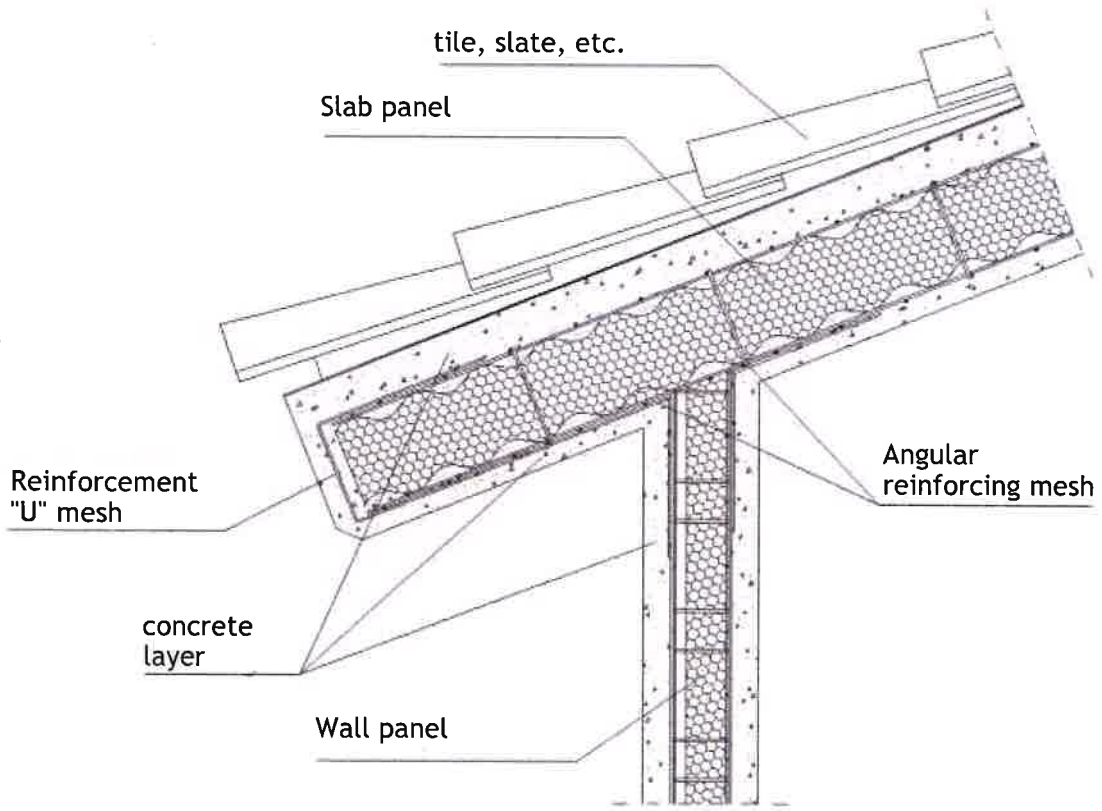
PANEL TYPES AND DIMENSIONS ARE INDICATIVE (TO BE DEFINED ON A CASE-BY-CASE BASIS)

Figure 7. Detail of joint between walls (ground plan)



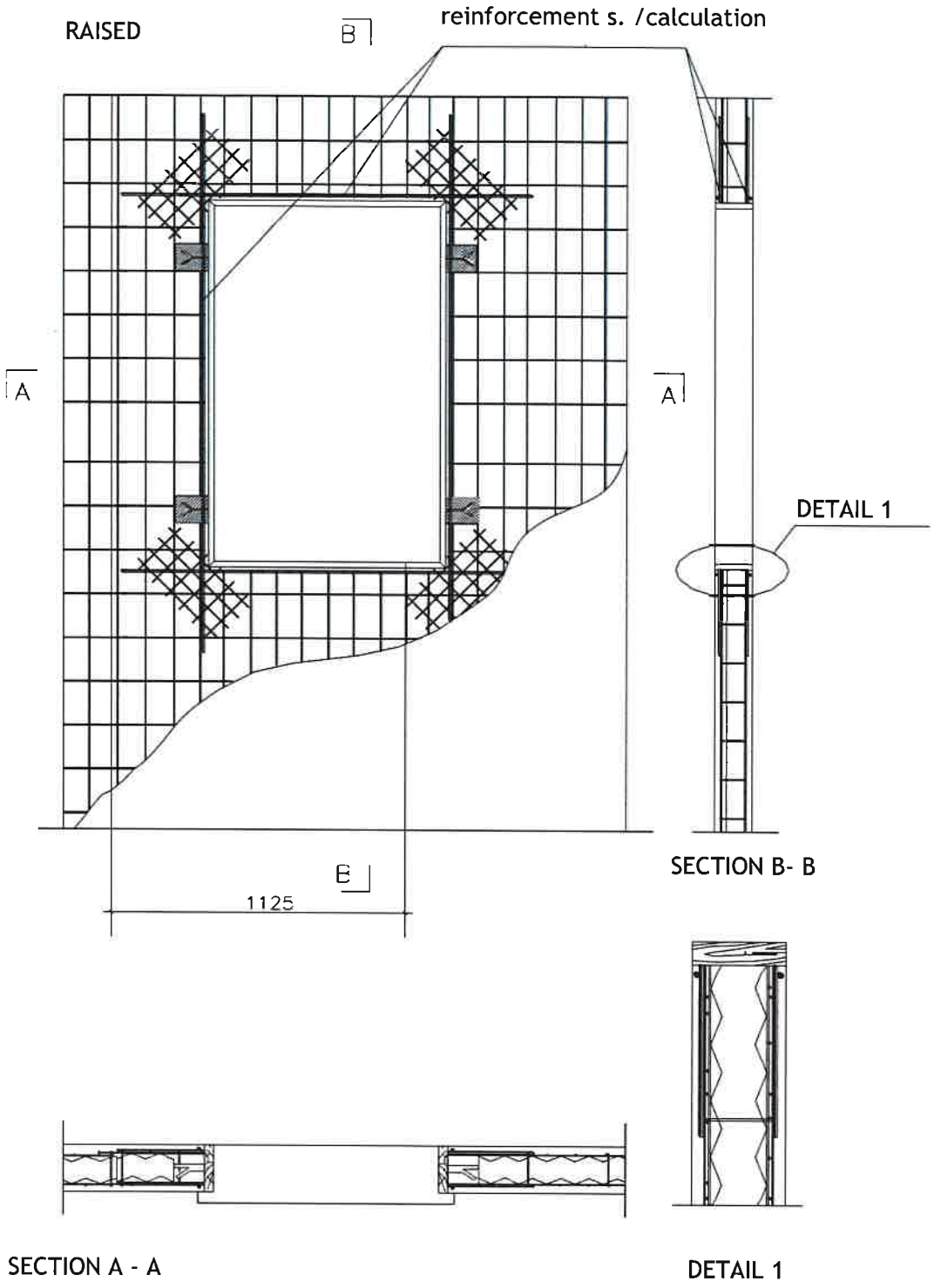
PANEL TYPES AND DIMENSIONS ARE INDICATIVE (TO BE DEFINED ON A CASE-BY-CASE BASIS)

Figure 8. Detail of the joint between walls and pitched roof (section)



PANEL TYPES AND DIMENSIONS ARE INDICATIVE (TO BE DEFINED ON A CASE-BY-CASE BASIS)

Figure 9. Solution of door or window openings



TRIBUNALE DI SPOLETO

Ufficio Asseveramento Perizie e Traduzioni

N. 1619/2023 R.G.V.G..

VERBALE DI ASSEVERAZIONE TRADUZIONE

Addì, 19/10/2023 nella Cancelleria del Tribunale suddetto, avanti il Funzionario sottoscritto, è comparsa la Sig.ra Bizzarri Eleonora, nata a Foligno il 09/05/1987, identificata con Carta d'identità rilasciata dal Ministero Dell' Interno in data 05/08/2021 avente n.CA74706JO, Codice Fiscale n. BZZLNR87E49D653E la quale chiede di asseverare con giuramento la traduzione allegata, nell'interesse di Emmedue S.p.a.

Il Funzionario, previa ammonizione sulla responsabilità penale (art. 483 c.p.) derivante da dichiarazioni mendaci, invita il comparente al giuramento, che egli presta ripetendo: **"Giuro di avere bene e fedelmente adempiuto all'incarico affidatomi al solo scopo di far conoscere la verità".**

Letto, confermato e sottoscritto.

Il Traduttore

N.B. L'Ufficio non si assume alcuna responsabilità per quanto riguarda il contenuto e la regolarità formale del documento tradotto.

TRIBUNALE DI SPOLETO

Il Direttore
Dott.ssa M. Letizia Simoncini

Ministero dell'Economia e delle Finanze
MARCA DA BOLLO
€16,00
SEDICI/00
Agenzia Entrate
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00050428 18/10/2023 17:55:03
4578-00088 AP3236892308D819
IDENTIFICATIVO : 0123D035795098
0 1 23 003579 509 8

PROCURA DELLA REPUBBLICA
PRESSO IL TRIBUNALE DI SPOLETO

APOSTILLE

(Convention de La Haye du 5 octobre 1961)

1. Paese : ITALIA
2. Il presente atto pubblico e' stato firmato da
   SIMONCINI Maria Letizia
3. operante in qualità di Direttore
4. è munito del sigillo/bollo del Tribunale
   di Spoleto

Attestato

5. in Spoleto (Italia) 6. il 20.10.2023

7. da Procura Repubblica del Tribunale di Spoleto

8. col numero 245

9. Sigillo/bollo

10. Firma

IL SOSTITUTO PROCURATORE DELLA REPUBBLICA
~~Dott.~~ Alessandro Tarsia