TECHNICAL MEMORY

M2 CONSTRUCTIVE SYSTEM

M2 TECHNOLOGY

Seismic and thermal and acoustic isolating construction system

GENERAL INDEX

Advanced Building System

Advanced Building System

1. FUNDAMENTAL CONCEPTS

This memory constitutes the presentation of construction rationalized technology called EMMEDUE. This technology of Italian origin is almost 20 years old, and is produced in 27 industrial plants in different countries of all continents which are:
Spain, Italy, Ireland, Portugal, Russia, United States, Mexico, Guatemala, Costa Rica, Panama, Venezuela, Chile, Argentina, Egypt, Nigeria, Mozambique, Eritrea, Algeria, Saudi Arabia, Iran, Iraq, Lybia, Turquey, Philipines, Malasya and Australia.

There is also an important number of different types of constructions in countries not mentioned above such as: Bolivia, Uruguay, Brazil, Peru, Bahamas, Germany, United Kingdom, Hungary, Greece, South Africa, Senegal and Burkina - Faso. We should also point out the presence of 4,100 m2 covered surface homes at the Esperanza scientific base in the Antarctic continent.

Among the different brands under which our technology is known all over the world one can find:

EMMEDUE S.p.A. – Via Toniolo 39 B – Z.I. Bellocchi – 61032 FANO (PU) ITALY – Tel. ++39 0721 855650/1 – Fax ++39 0721 854030 Stabilimento impianti – Via Conselvana 163/A – 35020 Maserà di Padova (PD) ITALY – Tel. ++39 049 8862993 – Fax ++39 0721 854030 – Capitale sociale € 900.000 i.v. – Iscr. R.E.A. 123367 - Cod. Fisc. / P.IVA / VAT (IT) 01326180419

w w w . m d u e . i t – i n f o @ m d u e . i t

Advanced Building System

- EMMEDUE
- MONOLITE
- CASSAFORMA
- EMEKADOS
- EMEDOS
- CONSNOLITE
- POLISUD
- TICARET
- FRIDULSA
- CONCASSAGE

M2 is the constructive system that gathers in one element all the necessary functions to carry out the architectural work, from family housing up to a building of great height, including all types of constructions and destinies with maximum efficiency.

The functions contained in the elements of our constructive technology are:
1- High capacity continuous thermal isolation;
2- Structural resistance fit to support all types of loads;
3- Construction of horizontal and vertical enclosures;
4- Continuos hydro-isolation;
5- Fire resistance according to requirements of standards and regulations;

All these features are possible thanks to effective combination of its three constituent materials:

a) Expanded polystyrene,
b) Steel of high fluence limit,
c) Cement Mortar

2. CONSTITUENT ELEMENTS

The basic element of the constructive system is the expanded polystyrene corrugated panel, which has steel meshes attached to both sides linked through 80 electrowelded connectors per square meter of surface.

The expanded polystyrene web thickness may vary from 3 cm up to 20 cm, in function of the requirements of the architectural project. The minimum density generally used is that of Class III of 15 Kg/m3 type F (hardly inflammable and self-extinguishable).

The meshes are made of high resistance galvanized steel, with an ultimate stress of 700 Mpa and are made up of 3mm diameter bars with an average separation of 7.28 by 6.50 in the secondary direction.

The meshes stand out 50 mm in opposing sides, in such a way that when they overlap each other they assure continuity by juxtaposition of the frameworks, without the need of placing additional connecting elements. For the union between enclosures, the continuity is solved by angular meshes supplied for that purpose, always satisfying the requirements of the applicable standards.

It is important to mention that all processes that intervene in the manufacture of the elements that compose M2 are exposed to permanent controls required by the ISO standard in force.

Because of this the Certificate of conformity of Standard UNI EN ISO 9001:1994 has been obtained, through the Certification entity TÜV with the following scope:

Design and production of panels for the constructive system, production of electrowelded meshes and commercialisation of machinery and equipment for the production of panels and electrowelded nets.

We should mention that all installed industrial plants in the world use exactly the same type of machinery and technology for the production of panels, so the ISO 9001 Certificate reaches all operating factories and naturally, all future ones.

GENERAL TYPOLOGY OF THE WALL PANELS

Secondary reinforcement
Ø 2.5 mm c/ 6,5 cm

Transversal reinforcement
82 Ø 3.0 mm /m^2

a
b
c

d

Main reinforcement 20 Ø 3 mm
every 5,62 cm average

a = nominal EPS thickness

b = distance between frameworks
(a + 2 cm)

c = total thickness
(a +7 cm)

d = mortar thickness: *3,5 cm*

EPS
Density 15 Kg/m^3

Cement mortar According
to dosification
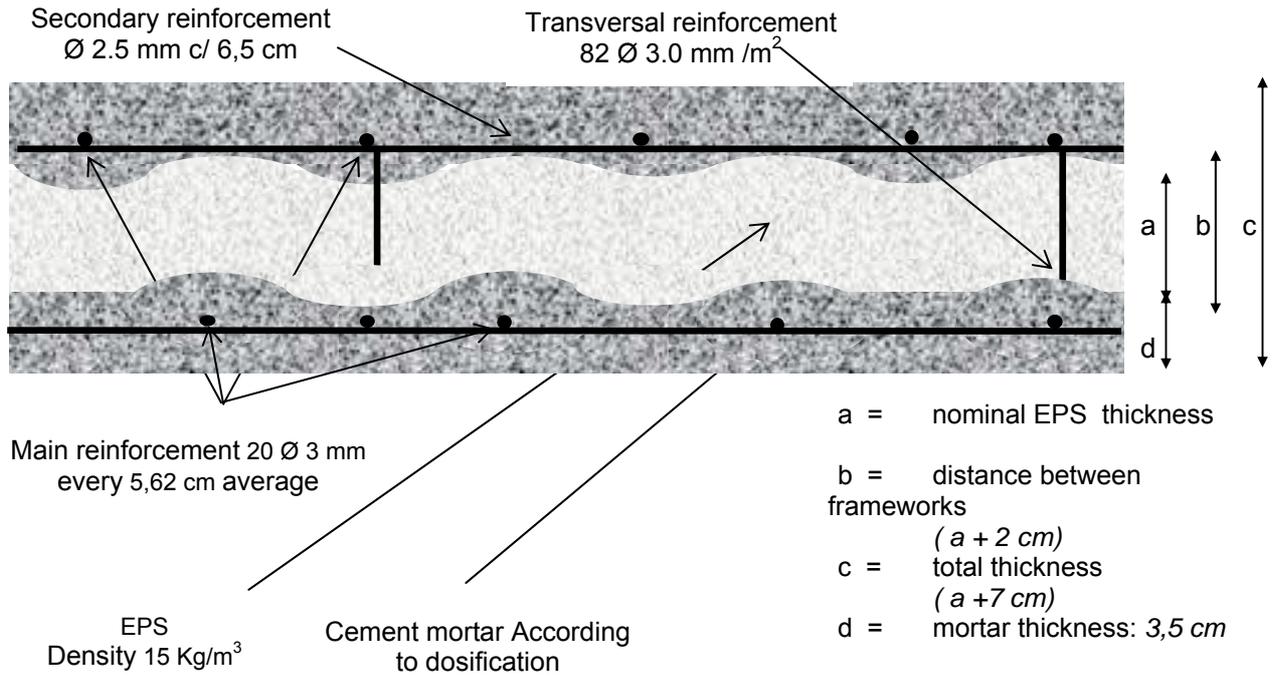
GENERAL TYPOLOGY OF THE WALL PANELS FOR SLABS

Secondary reinforcement
Ø 2.5 mm c/ 6,5 cm

Transversal reinforcement
82 Ø 3.0 mm /m²

Compression layer
Min. thickness = 5 cm

Main reinforcement 20 Ø 3mm

EPS
Density 15 Kg/m³

Cement mortar
according to dosification

a = nominal EPS thickness
b = distance between frameworks
   (a +2 cm)
e = total thickness
   (a +8 cm)
d = mortar thickness: *3.0 cm*
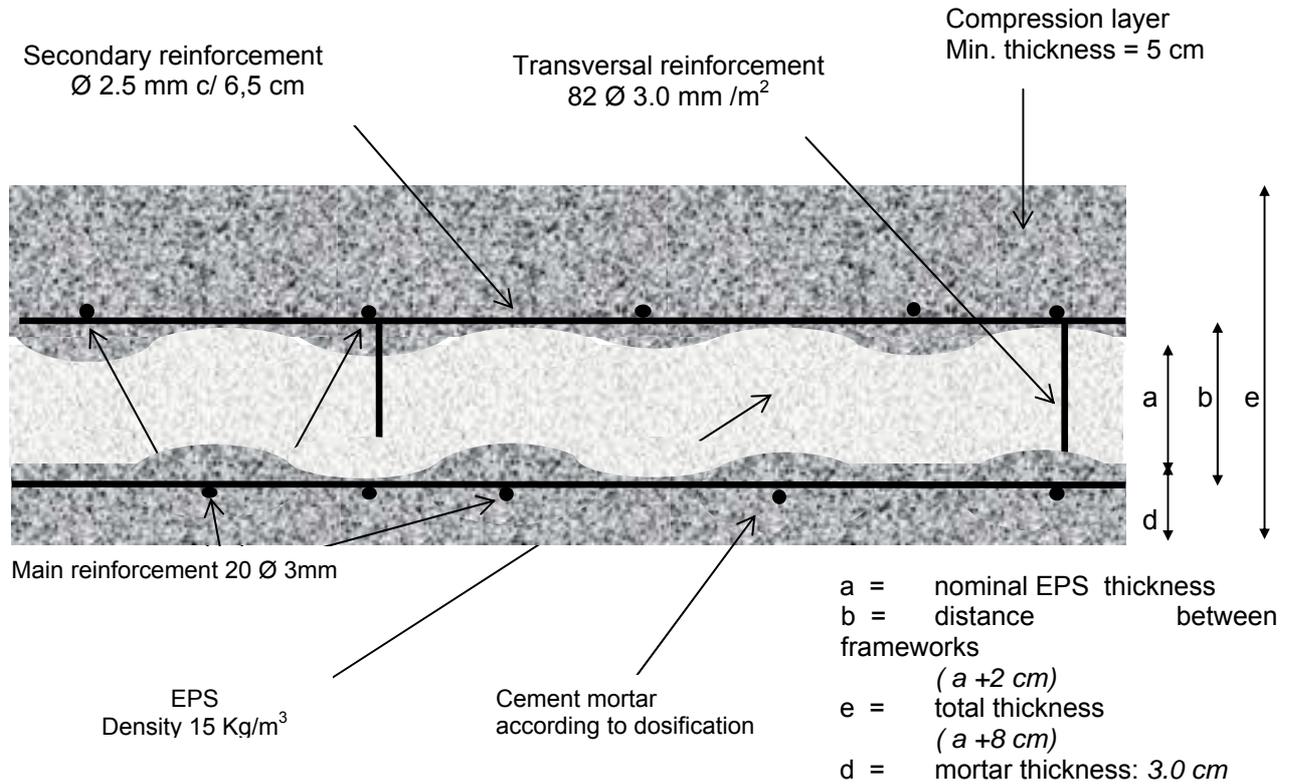
PANEL TYPE	a mm	b mm	c mm	d mm
PSM 40	40	55	110	120
PSM 50	50	65	120	130
PSM 60	60	75	130	140
PSM 70	40	85	140	150
PSM 80	40	95	150	160
PSM 90	40	105	160	170
PSM 100	40	115	170	180
PSM 110	40	125	180	190
PSM 120	40	135	190	200
PSM 130	40	145	200	210
PSM 140	40	155	210	220

3. BASIC PROCEDURES

The sequence of linked panels materializes all the enclosure planes of the construction: exterior walls, interior walls, mezzanine slabs or slabs and roof coverings.

Through a simple cutting operation the bay openings are opened, with the necessary space (approximately 25 mm) for the placement of frames, whose fixation clamps are tied to the meshes.

It is of vital importance to assure that the enclosure planes are correctly aligned and plumbed. This can be easily done through the use of tie beams, metallic rulers, telescopic braces or any other element suitable for this purpose.

Next, canalisations are executed in the expanded polystyrene depressing it with a hot air pistol, in which the corresponding conducts will be.
Once the described operations are done the next procedure is the projection of the cement mortar, which can be done with pneumatic projection devices of the "Hopper gun" type connected to an air compressor of adequate power or with continuous wet projection machines of the Turbosol, Puztmaister, Maltech or PFT types.
 M2 panels also admit the projection of dry mortar with conventional tunnelbuilders.
It's very convenient to use projectable dry mortars of known brands that have some quality certification. This way the minimum characteristic resistance required will be guaranteed. On the other hand, continuous projection machines guarantee uniformity in the mixture since it only supplies mixture water which will result constant in each application.

Manual projectors of the Hopper gun type use as a vehicle for the impulsion of fresh mixture, a circulation of compressed air supplied by a compressor that must operate at a pressure of constant air at 500 to 600 kPa.   These compressors should supply between 300 and 350 litres of air per minute for each one of the devices employed. In the case of using electrocompressors, the recommended powers are:

Motor power (HP)	Air flow (Litres / min.)	Amount of applicators
2 ½ to 4	350 to 400	1
5 to 6	350 to 700	2 to 3
8 to 10	350 to 1,000	3 to 4

The mortar's projection changes all the enclosures and slabs conformed by panels, as well as their unions, in rigid and monolithic elements. The structure achieved this way has a very high grade of hyperstaticity by internal links and at the same time a very high ductility, and thus its reserve of plastic load is very significant, even though it's not taken into account when evaluating resistance capacities.

The operation of pneumatic projection of the mortar is done in two coats. The first one of 2 cm thick, which covers the steel mesh, and the second one is the finishing coat until reaching the necessary thickness of 3 cm. To do this, guides are used, as molds, which can simply be steel square 25mm section pipes, against which the mortar thicknesses of projected cement are cut . The plastering will be chosen by the planner with conventional materials (single layer coating, paint on smoothed out surfaces, plaster, plastic, elastomeric paint, or any other variant required by the planner.

In the case of horizontal or inclined planes, such as slabs or roof coverings, once the panels are placed and linked, they are shored up and after the first projection of the inferior side the next step is to cast the compression layer, which is 5 cm thick of conventional concrete, according to the criterion of structural conditions.

4. DOSIFICATION OF STRUCTURAL M2 MORTAR

The mixture with which pneumatic projection of the structural M2 mortar is done the following requisites listed must be complied:

- EASY TO APPLY: It must be able to be applied in layers of about 2 cm without producing detachments, with fluidity and plasticity.

- HIGH RESISTANCE: It must provide the necessary resistance to satisfy the structural functions to which it will be subject of.

- LOW RETRACTION AND HARDENING: To avoid fissure provoked by the evaporation of excess mixing water.

To satisfy all the described conditions it is necessary to have a mixture of low water content and with a cement-sand relation (in volume) between 3.5 and 4.5.

The unit content of normal Portland cement will vary in function of the sand's granulometry and the aggregate-binder ratio chosen between 350 kg/m³ and 400 kg/m³.

The water / cement ratio, should not exceed 0.52 in weight including the sand's free humidity.

As for the admixtures it is necessary, because of the low workability of the mixtures obtained with these dosifications, to add a mixing water / plastifier reducer, in the proportions recommended by the supplier.

It is convenient to use polypropylene fibre of 1.25 cm at a ratio of 0.90 kg for each m^3 of mixture. The goal is to provide a hardening anti-retraction net and at the same time increasing the tenacity of the cement mortar.

The curing is of vital importance as in all concrete with large surface concrete and little volume due to the action of atmospheric agents. Correct curing consists of allowing for the process of hydration of the cement, avoiding premature evaporation of the free water, for which it is necessary to maintain superficial humidity (spraying frequently with water), taking special care to avoid direct exposure to solar radiation and wind during the first 24 hours.

An important factor for the final quality of the cement mortar made at the building site, is vigorous compacting provided by pneumatic means of application and this also influences on the high reachable characteristic resistance values.

4.1 INDUSTRIAL MORTAR

In the market it is normal to get industrial mortars (micro-concrete). These should comply with the following minimum features:

a) To guarantee a characteristic resistance fck $\geq$ 20 N/mm2.
b) To be projectable in layers of about 2 cm thick.

The basic composition of these mortars may be the following:

Aggregate:
Crushed limestone of controlled granulometry and humidity always inferior to 1.00%

Cement:
CEM II/B-M (V-L) 32.5 N or CEM II/A-M (V-L) 42.5 R

Admixtures:
The formulation that easily complies with the established dispositions (minimum amount of cement and maximum water/cement ratio)

The recommendation at the building site for this type of mortar is the following:
Adjust the projection machine's system that regulates water pressure and its dosification through the hydrometer.

Mixing water (14% - 14,5% over dry sample) leads to a drainage of 175 $\pm$ 5 mm measured at the vibrating table S/UNE EN 1015-3 (approximately equivalent to a settlement in the Abrams Cone of 120 mm). The consistency obtained this way is adequate for its projection.

Before beginning we need to know all about the application surface since the projection must be done without interruptions whenever possible.
Application at 3 or 4 cm according to what is necessary, must be done in two coats. In the first coat the product must be loaded as much as it will allow us without it falling down, for which a compressor of 400 litres per minute air flow is recommended, so that it "bites" the polystyrene and the product is as compacted as possible. The second coat is done within a 48 hour interval until the desired thickness is reached .
Of the machinery existing in the market, for the application of the product it is recommended, because of its technical and design features, those of type Maltech M5 and PFT G 54 amongst those of small flow and Cayman 30 of PFT or Plasterjet of Maltech, Trubosol Uni 30 or Putzmaister P13.

The normalized hardening curve of this type of mortar is usually:

Mechanical Resistances to Compression
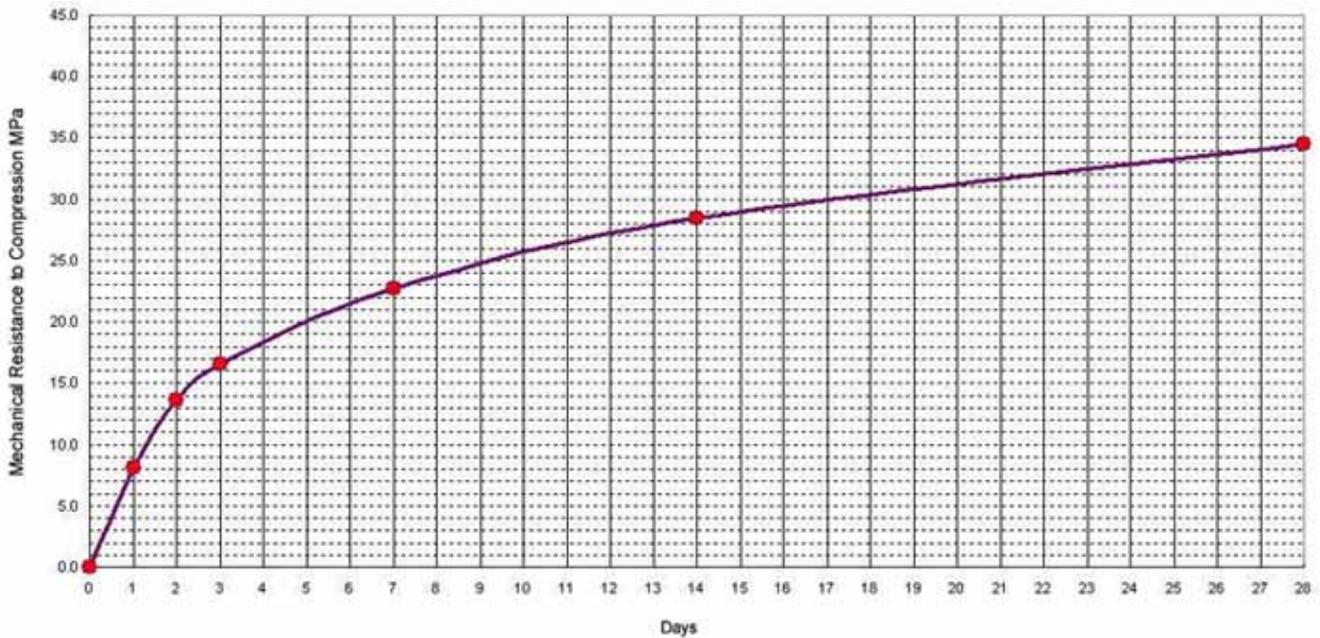
5. MECHANICAL AND HABITABILITY TESTS

At this instance we should point out that the regulation trials and tests necessary for obtaining the different Aptitude Certificates our technology obtained have been done in prestigious Laboratories and Institutions such as Melbourne and Deakin Universities (Australia), Padova, Bologne and Peruggia Universities and Giordano Institute (Italy), The Mexican Institute of Cement Mortar and Cement, The Institute of research and Testing of Materials (Chile), The Argentine Institute of Portland Cement, and the Institute of Technological Research of San Pablo (Brazil), "Eduardo Torroja" Institute (Spain).

Also Fire Resistance Tests have been carried out in walls 3.4 m high under a load of 30 Tons and in slabs with 4.00 m x 4.00 m of free light in the AFITI – LICOF, obtaining results of stability to fire for more than 120 minutes.

M2 EMMEDUE

Publicación emitida por el Instituto de Ciencias de la Construcción Eduardo Torroja. Prohibida su reproducción.

MATERIALES Y PROCEDIMIENTOS NO TRADICIONALES DE CONSTRUCCIÓN
DOCUMENTO DE IDONEIDAD TÉCNICA

Sistema portante EMMEDUE de paneles de hormigón armado con núcleo de E.P.S.

431
CONCESIÓN

INSTITUTO EDUARDO TORROJA

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Concesionario en España:
EMMEDUE
CONTINENTAL, S.L.
C/ Rafael Salgado, 7
Bajo Izqda.
28036 MADRID
España

C.D.U. 692.251
Systèmes de Construction
Building System

MUY IMPORTANTE

El DOCUMENTO DE IDONEIDAD TÉCNICA constituye, por definición, una apreciación técnica favorable por parte del Instituto de Ciencias de la Construcción Eduardo Torroja, de la aptitud de empleo en construcción de materiales, sistemas y procedimientos no tradicionales destinados a un uso determinado y específico. No tiene, por sí mismo, ningún efecto administrativo, ni representa autorización de uso, ni garantía.

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La modificación de las características de los productos o el no respetar las condiciones de utilización, así como las observaciones de la Comisión de Expertos, invalida la presente evaluación técnica.

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DECISIÓN NÚM. 431

EL DIRECTOR DEL INSTITUTO DE CIENCIAS DE LA CONSTRUCCIÓN EDUARDO TORROJA,

- en virtud del Decreto nº 3.652/1963, de 26 de diciembre, de la Presidencia del Gobierno, por el que se faculta al Instituto de Ciencias de la Construcción Eduardo Torroja, para extender el DOCUMENTO DE IDONEIDAD TÉCNICA de los materiales, sistemas y procedimientos no tradicionales de construcción utilizados en la edificación y obras públicas, y de la Orden nº 1.265/1988, de 23 de diciembre, del Ministerio de Relaciones con las Cortes y de la Secretaría del Gobierno, por la que se regula su concesión,

- considerando la solicitud formulada por la Sociedad EMMEDUE, S.R.L., para la concesión de un DOCUMENTO DE IDONEIDAD TÉCNICA al Sistema portante EMMEDUE de paneles de hormigón armado con núcleo de E.P.S.,

- en virtud de los vigentes Estatutos de la Union Européenne pour l'Agrément technique dans la construction (UEAtc),

- teniendo en cuenta los informes de visitas a obras realizadas por representantes del Instituto de Ciencias de la Construcción Eduardo Torroja, los informes de los ensayos realizados en el IETcc, así como las observaciones formuladas por la Comisión de Expertos, en sesión celebrada el día 2 de diciembre de 2003,

DECIDE:

Conceder el DOCUMENTO DE IDONEIDAD TÉCNICA número 431 al Sistema portante EMMEDUE de paneles de hormigón armado con núcleo de E.P.S., bajo las siguientes condiciones:

MINISTERO DEI LAVORI PUBBLICI
PRESIDENZA DEL CONSIGLIO SUPERIORE
SERVIZIO TECNICO CENTRALE

CERTIFICATO DI IDONEITÀ TECNICA DEL SISTEMA INDUSTRIALIZZATO A SETTI PORTANTI "MONOLITE"

DICHIARAZIONE DI IDONEITÀ

IL PRESIDENTE DEL CONSIGLIO SUPERIORE DEI LAVORI PUBBLICI

Vista la legge 2 febbraio 1974 n. 64;

Vista la Circolare del Servizio Tecnico Centrale n. 6090 dell'11 agosto 1969;

Vista la domanda presentata in data 4-1-1985 dalla Ditta Impresa Costruzioni Candiracci S.p.A., con sede in Fano afferente la richiesta di rilascio del certificato di idoneità tecnica del sistema di prefabbricazione MONOLITE;

Vista la documentazione tecnica presentata ad illustrazione del sistema;

Visto il voto n. 24 espresso dalla 1ª Sezione del Consiglio Superiore dei Lavori Pubblici, nell'adunanza del 24-1-1985;

DICHIARA

Le strutture portanti realizzate secondo il sistema di prefabbricazione MONOLITE definite, per quanto attiene alle loro caratteristiche tecniche, dalla descrizione che fa parte integrante del presente certificato, sono considerate idonee ai fini della costruzione di edifici anche in zone sismiche, a condizione che siano rispettate le prescrizioni dianzi riportate.

Il presente certificato di idoneità è valido per tre anni a decorrere dalla data del suo rilascio. Nel periodo di validità del certificato dovranno eseguirsi, presso un laboratorio ufficiale o autorizzato, prove sui materiali ed elementi strutturali al fine di indagare sul loro comportamento in esercizio.

Roma, li 3 ottobre 1985

IL PRESIDENTE
(Dott. Ing. Roberto Rivelli)

Registrato presso il 1º Ufficio del Registro Atti Privati di Roma il 4 ottobre 1985 al Nº C/44697

NUMBER: V90/12
EXPIRY DATE: 31 DEC 1991
VICTORIA

CERTIFICATE OF ACCREDITATION

WHEREAS Monolite Construction Panels Pty. Ltd. of 129 Northern Road, West Heidelberg 3084 has applied to the Building Control Accreditation Authority for the accreditation of the Monolite 130mm thick sprayed reinforced concrete loadbearing external cladding or internal partitioning sandwich panel system

the Building Control Accreditation Authority appointed under Part V of the Building Control Act 1981 has examined the application and determines that the system may be used in buildings containing up to 2 storeys (maximum storey height of 4 metres) except those having special post-disaster functions as per AS 1170 Pt. 2 and complies with the requirements of Regulation(s) 40.1 (1), 43.1 (1) and 47.1 (2) of the Victoria Building Regulations 1983.

Conditions of use and identification details are provided in the ten (10) data sheet(s) attached.

BUILDING CONTROL ACCREDITATION AUTHORITY VICTORIA

C. McBurney

DATE 7 DECEMBER 1990   REGISTRAR

ZERTIFIKAT ◆ CERTIFICATE ◆ CERTIFICAT ◆ CERTIFICADO ◆ CERTIFICATO ◆ СВИДЕТЕЛЬСТВО ◆ CERTIFICAT ◆ CERTIFICATO

CERTIFICATE

TÜV MANAGEMENT SERVICE

Certificato Nr. 50 100 0805

Si attesta che / This is to certify that
IL SISTEMA QUALITÀ DI
THE QUALITY SYSTEM OF

EMMEDUE SRL
VIA TREVES 7
I-61030 BELLOCCHI DI FANO (PS)

È CONFORME AI REQUISITI DELLA NORMA
HAS BEEN FOUND TO CONFORM TO THE REQUIREMENTS OF

UNI EN ISO 9001:1994

Questo certificato è valido per il seguente campo di applicazione:
This certificate is valid for the following product or service ranges:

Progettazione e produzione di pannelli per sistema costruttivo Emmedue, produzione di reti elettrosaldate e commercializzazione di macchinari ed attrezzature per la produzione di pannelli e reti elettrosaldate

Design and production of panels by Emmedue building system, production of electrowelded wire meshes and marketing of machinery and equipment for the manufacture of panels and electrowelded wire meshes

Luogo e data
Place and date
Cinisello, 2000-05-11

Data di scadenza
Expiry date
2003-04-17

Per l'Organismo di Certificazione
For the Certification Body
TÜV Italia S.r.l.
Cinisello Balsamo (MI)

Roberto Majocchi   Nico Mastrorillo

SINCERT

The Italian Certificate of Technical Aptitude, first obtained in October 1985, was declared by the Ministry of Public Works of Italy, with the approval of the First Section of the Superior Council for Public Works. The supporting structures of our constructive system are also considered apt for the construction of buildings in **seismic areas.**

The results of the tests and trials are summarized below and they succinctly gave the following results:

5.1 FLEXOCOMPRESSION

For the flexocompression stress the breaking load of a 10 cm thick M2 panel made of 4 cm of expanded polystyrene and 3 cm of cement mortar in each side, whose measures are 1.15 m in width and 2.60 m in height, in no case this was less than 650 kN per linear meter.

The basis for this trial is the following:
• Joined in the inferior end
• Support of the first type in the superior end
• Free at the vertical borders.

The load, uniformly distributed, is located in a line parallel to the sides and at a distance of one third of the thickness of one of them (that is, practically on one of the layers of the cement mortar).

5.2 SIMPLE FLEXION

The results of the trials done with simple flexion, variable according to the link conditions and form of application of the loads, demonstrate a behaviour that is totally compatible with the homogenous elements of solid reinforced concrete in all its width, in virtue of:

• The neutral axis of the solicited section remains within the compression layer;
• the amount of steel that resists traction is such that the deformation diagram of the section is within the range of "ductile fracture";
• the confinement state of the expanded polystyrene and the connector density allow for the deviations in the main loads.

For example, the ultimate real capacity observed for an expanded polystyrene panel 7 cm thick with a compression layer of 3cm is 12.2 kNm/m, and its ultimate theoretical capacity is 7.10 kNn/m. It's possible to observe that taking a safety coefficient of 1.75 on the

ultimate theoretical capacities the result is a real margin over the ultimate capacities greater than 3.

5.3 FLEXION IN THE PLANE OF THE PLATE

For loads that involve coplanar flexion with the panel, the internal structure of the elements built with our technology is equivalent in behaviour to a homogenous reinforced concrete element, of effective width equal to the sum of the widths of the cement mortar. In this case only the structural contribution of these layers is considered. Depending on what the element in question's basis is, its behaviour will be equivalent to that of a pillar of great height or to that of a concrete screen.

5.4 DYNAMIC LOADS AND IMPACTS

The behaviour of our elements under the effect of dynamic loads is outstanding, thanks to the response of the set expanded polystyrene – reinforced concrete, which involves a resilience and a ductility that in addition to having been confirmed by laboratory trials, has been verified in real life when it supported <u>without any type of damage</u> earthquakes of intensities that destroyed constructions made with traditional ant seismic systems (for example: Richter magnitude 6.8 in the city of andacollo, Chile 1997). We should also point out the behaviour of the constructions that were affected by strong earthquakes in the cities of: Mexico, Rieti and Macerata (Italy) among others, always without any type of damage.

With regards to the dynamic crashes and impacts, the trials done all over the world demonstrated a superior capacity for the "soft" impact (mass of 50 Kg. striking perpendicularly on a vertical panel from different heights), as well as "hard" impact (steel mass of 1 Kg striking in free fall on a panel placed horizontally). In both cases it was very significant how well these tests were exceeded.

The load reserve of structures done with our technology, achieved thanks to the properties of a combination of materials and to the hyperstaticity itself of their (SU) link, is translated as an important capacity to resist all types of loads, even those that are unpredictable by calculations, such as foundation giving away, or vehicle impacts, of which numerous experiences have been registered, of which we have graphic registries.

6 CATALOG OF TESTS AND THEIR STANDARDS

SPAIN – INSTITUTE OF CONSTRUCTION SCIENCES EDUARDO TORROJA
RESISTANCE TO SOFT BODY IMPACT
COMPRESSION TRIAL
LATERAL HORIZONTAL STRENGTH
FLEXION TRIAL
FLEXION IN 3 POINTS TRIAL
FLEXION IN 4 POINTS TRIAL
TRIAL ON SET OF 2 PANELS
TRIAL OF RESISTANCE TO SHEAR STRESS AT THE nudos
TRIAL ON THE SYSTEM AS A WHOLE: PORTICO

SPAIN – CENTRE OF FIRE TESTING AND RESEARCH
STABILITY TO FIRE OF A WALL UNDER LOAD
STABILITY TO FIRE OF A SLAB UNDER LOAD

MEXICO – MEXICAN INSTITUTE OF CEMENT AND CEMENT MORTAR
COMPRESSION TEST	ASTM E72-80
SHEAR TRIAL	ASTM E519-81
STATIC CHARGE FOR RESISTANCE TO	
CUTTING OF WALLS FOR BUILDINGS	ASTM E564-86
INFLAMMABILITY FEATURES	
OF CONSTRUCTION MATERIALS	ASTM E84-87

CHILE – INSTITUTE OF RESEARCH AND TESTING OF MATERIALS
SOFT IMPACT	NCH 804 EOF 71
ECCENTRIC COMPRESSION	NCH 801 EOF 71
MONOTONIC AND CYCLIC HORIZONTAL LOAD	NCH 802 EOF 71
SLAB SUPPORTED ON FOUR BORDERS	
RESISTANCE TO WALL FIRE	NCH 935/1
RESISTANCE TO SLAB FIRE	NCH 935/1

AUSTRALIA – DEAKIN UNIVERSITY
WATER PERMEANCE TEST	
(Water permeance outdoor exposition)	ASTM E564-74
TRIAL OF FLEXION BY LATERAL PRESSURE	
AIR BAG	s/ AS 3600
COMPRESSION TEST	ASTM E72-80

AUSTRALIA – CONNEL WAGNER INSTITUTE
FLEXION TRIAL   s/ AS 3600

AUSTRALIA – MELBOURNE UNIVERSITY – CIVIL ENGINEERING DEPT.
CENTRED AND ECCENTRIC COMPRESSION

AUSTRALIA – CSIRO DIVISION OF BUILDING CONSTRUCTION AND ENGINEERING
RESISTANCE TO FIRE   AS 1530

PHILLIPINES - UNIVERSITY OF THE PHILLIPINES – BUILDING RESEARCH SERVICE
COMPRESSION TEST   ASTM E72-80
SHEAR TRIAL   ASTM E519-81

ITALIA – UNIVERSITA DI PERUGIA – FACOLTA DI INGEGNERIA
COMPRESSION TEST
FLEXION TRIAL
SHEAR TRIAL
SEISMIC TRIAL

ITALIA – UNIVERSITA DI PERUGIA – FACOLTA DI INGEGNERIA
COMPRESSION TEST
FLEXION TRIAL
SHEAR TEST
TRACTION OF ELECTROWELDED MESHES TRIAL
SEPARATION OF MESH WELDS TRIAL   UNI ISO 10-287

ITALIA – GIORDANO INSTITUTE
UNITARY THERMAL TRANSMITANCE TEST   ASTM C 236
PHONOISOLATION CAPACITY TEST
FIRE RESISTANCE TEST   CIRC. 91
SOFT IMPACT TEST   ICITE 3.1.2.1.
ECCENTRIC VERTICAL LOAD

BRASIL – INSTITUTO DE PESQUISAS TECNOLÓGICAS
RESISTANCE TO HORIZONTAL LOADS   ME 45/81
SOFT IMPACT TEST   ME 43/81
RESISTANCE TO FIRE
THERMAL SHOCK
SOUND ISOLATION
RESISTANCE TO FUNGUS DEVELOPMENT

7   SUMMARY OF SIGNIFICANT TEST RESULTS

7.1 CENTRED AND ECCENTRIC COMPRESSION

An enormous amount of tests have been done on panels of different thickness and heights, and the representative results of all tests are shown below:

Centred Compression
4 cm Panel – Height 240 cm – Maximum linear load =   760 kN/m
6 cm Panel – Height 400 cm – Maximum linear load =   590 kN/m
6 cm Panel – Height 300 cm – Maximum linear load =   1130 kN/m
8 cm Panel – Height 270 cm – Maximum linear load =   1340 kN/m

Eccentric Compression (with eccentricity of 1/3 total thickness)
4 cm Panel – Height 240 cm – Maximum linear load =   566 kN/m
6 cm Panel – Height 300 cm – Maximum linear load =   707 kN/m
6 cm Panel – Height 400 cm – Maximum linear load =   360 kN/m
8 cm Panel – Height 270 cm – Maximum linear load =   680 kN/m

7.2 SIMPLE FLEXION

The flexion trials have in general been done in different configurations, which is why the ultimate representative momentums of the tested panels are shown.

4 cm Panel: 3 cm compression layer – Ultimate Momentum = 8,1   kNm/m
7 cm Panel: 3 cm compression layer – Ultimate Momentum = 12.2   kNm/m
            With registry of the ultimate shear stress   = 13.6   kNm/m
8 cm Panel: 3 cm compression layer – Ultimate Momentum = 12   kNm/m
            Rupture deflection = Light/100 (*)

(*) Keep in mind the sample's basis is simply supported on the extremes, thus the transversal deformation is not limited and the deflexion is not that of the behaviour of the plates to flexion.

7.37.3 CUTTING TEST (SHEAR STRESS)

The shear stress shown by the trials is referred to the total thickness of the panel:
4 cm Panel (10 cm total) = 1.5 MPa
8 cm Panel (15 cm total) = 1.3 MPa

7.4 HORIZONTAL LOAD TEST CONTAINED IN THE PLANE

The capacity of the panels against this stress is such that the trials are always stopped because of failure of the anchorage elements, even though these values are high enough to limit a more than acceptable behaviour.
(50/100 kN to 2.40 m height – 4 cm Panel)
In trials with alternate cyclic horizontal load, values of 350 kN (4 cm Panel) have been reached.

7.5 SOFT IMPACT TEST

Panels 4 cm thick have received impacts of 1250 Joules (50 Kg weight with a falling altitude = 2.50) recovering the instantaneous deflections and without presenting any damage exceeding regulation requirements.

7.6 SOFT IMPACT TEST

The 2 m fall of the 3.5 Kg steel sphere makes impressions on the cement mortar's surface that are imperceptible.

7.7 ECCENTRIC VERTICAL LOAD TEST

Panels with a 4 cm thick EPS cores have supported, in compliance with standards, flexor momentums of 300 Nm for 24 hours without any type of consequences.

7.8 SEISMIC TRIALS

A housing prototype built totally with panels (walls, slabs, stairs and covering) at horizontal accelerations of 10 m/s2, with variable frequencies including the structure's own, registering absolutely no type of damage or fissure.
For example, it is considered that a standard earthquake in a high risk area is considered one that implies horizontal acceleration designs of around 3.5 m/s2.

7.9 WELD SEPARATION TEST

Compliance was verified with requirements of the standard UNI ISO 10-287 and concordant for the resistance of the welded points. In every case a resistance of over 2.26 times the comparison force required by the standard was obtained (0.3 of the resistance to breakage of the bar of smallest diameter).
Minimum separation load of the trial series = 1.66 kN
Comparison load = 0.74 kN

7.10 OUTDOOR IMPERMANCE TEST

The panels have been classified as E (the highest) after been exposed to 140 mm/h precipitations with 106 km/h winds during 24 + drying + 72 hours.

7.11   TRIAL OF RESISTANCE TO FUNGUS DEVELOPMENT

The results of these trials show a better behaviour of M2 surfaces than traditional alternatives, verifying **level 0** (free micro organism growth substrates) in the described surfaces, against **level 1** (disperse Micro organisms) in samples of traditional rubblework.

7.12   RESISTANCE TO FIRE

Different trials have thrown out consistent results with respect to the ignition capacity of the described technology and some significant results are:

- 60 minutes at 2500 ºC without vapour emission or production of flames (6 cm panel with 35 mm cement mortar).
- 4 cm panel with 25 mm cement mortar
  Fire Resistance Level:
  Structural Adecuacy =   241 min.
  Integrity =   241 min.
  Insulation =   172 min.
- None of the trials threw results inferior to F90 (90 minutes of resistance to fire).

7.13   BALLISTIC IMPACTS

In no case did projectiles coming from short guns go through the plates of any thickness, even with calibres such as .357 Magnum or .45 Auto. The same ocurrs with projectiles of the Brenneke calibre 12 type (gun: Franchi SPAS) shooting distance = 5.50 m.

8 HABITABILITY AND CONFORT FEATURES

8.1   THERMAL ISOLATION

To complete this presentation of this technology's unique features we will mention regarding thermal isolation, that applying the standard treatment to measure total thermal transmittance K of an enclosure wall a value of K= 0.72 W / m² ºK is obtained, for an expanded polystyrene 4 cm thick Class III (15 kg/m3) panel plus application of 3 cm cement mortar layers making a total wall thickness of 10 cm.

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In the case of a wall built with an expanded polystyrene 8cm Class III panel the calculated thermal transmittance value K reaches 0.39 W / m² °K. As one can observe, the level of thermal isolation obtained with our technology exceeds that provided by enclosure walls of traditional systems.

It is said that two enclosures are thermally equivalent when they have the same value of thermal isolation. As an illustrative example we indicate the following values of thermal transmittance K expressed in W/m2°C for different classes of traditional construction enclosures, and their relation with a wall with 10 cm total thickness made with our technology using Class III EPS, which represents a value of K = 0.72. This relation will show by how many times this M2 wall is a better thermal isolator of minimum thickness and density against any of the ones mentioned in the following table:

Type of enclosure	Thickness (cm)	K (W/m²°C)	ratio
• reinforced concrete	27.5 cm	2,51	3,49
• Common solid brick	15.0 cm	2,91	4,04
• Double wall of common solid brick w/ 3m air chamber	30.5 cm	1,47	2,04
• Double wall of solid fairface brick and hollow brick 8 cm opening w/ 3m air chamber.	25.0 cm	1,86	2,58
• 12 cm hollow brick w/ 3cm air chamber and common plastered brick	30.0 cm	1,90	2,64
• Hollow concrete blocks	19.0 cm	2,70	3,75

The following table summarizes the values reached by the total thermal transmittance coefficient K for different enclosure walls built with this technology.

TOTAL THERMAL TRANSMITTANCE K (W/m2°C)

PANEL TYPE	DENSITY (Kg/m3)		
	12	15	20
PSM 40	0,86	0,72	0,68
PSM 50	0,72	0,59	0,56

PSM 60	0,64	0,50	0,48
PSM 70	0,56	0,44	0,41
PSM 80	0,49	0,39	0,36
PSM 90	0,44	0,35	0,32
PSM 100	0,40	0,32	0,30
PSM 120	0,34	0,27	0,24

8.2 ACOUSTIC ISOLATION

Acoustic isolation of the M2 panels constitutes one of the advantages the system offers to achieve excellence in comfort in accordance with the most demanding conditions.

Below the results of the acoustic isolation trials are shown, done on panels of the following features:
1) Simple 4 cm thick expanded polystyrene panel with a density of 12 Kg/m³, plastered with cement mortar on both sides to a final thickness of 9.5 cm.
2) Simple 8 cm thick expanded polystyrene panel with a density of 12 Kg/m³, plastered with cement mortar on both sides to a final thickness of 14 cm.

Made at the Instituto de Pesquisas Tecnológicas – Sao Paulo-Brazil, and without showing any type of termination stucco or plaster.

The test results have been evaluated in compliance with the methods established in DIN 4109, ISO 717 and IRAM 4043.
Application of the described method threw out the following unique numbers for the curves obtained in the trials:

- EPS M2 PN 04 Panel 4 cm thick   38dB
- EPS M2 PN 04 Panel 8 cm thick   45dB

For example: The standard IRAM 4044 suggests the following unique isolation numbers for air noises in typical cases:

- Internal partitions in a department   37dB
- Privative walls between departments of the same building   44dB

The following table specifies the unique numbers, measured in laboratory, for typical materials used for the construction of walls and partitions.

- Hollow bricks 12/20/40 not filled with mortar
    36dB
- Hollow bricks 11/17/31 filled with mortar on both sides (15 cm)
    38dB
- Hollow bricks 18/19/40 not filled with mortars
    42dB
- Hollow bricks 18/19/40 filled with mortar on one side (20 cm)
    43dB
- Common Bricks 12 without plaster
    40dB

If we compare the information shown earlier we reach the conclusion that from an acoustical point of view, a 4 cm polystyrene M2 panel completed at the working site has the same isolation as a 15 cm hollow brick wall and exceeds IRAM requirements for interior partitions. Applying the 8cm polystyrene panel, acoustic isolation is greater than that of a 20 cm plastered hollow brick wall, and greater than the requirements specified by standards for division walls.

In the case of special acoustic isolation the problem can be solved with the use of special panels that have a layer of mineral wool of variable thickness and density according to necessity inserted in the expanded polystyrene.

8.3   RESISTANCE TO FIRE

Resistance to fire typical of this typology, verified in the trials carried out in different laboratories, more than satisfies the requisites required by the strictest of regulations. For example, a finished 10 cm thick wall, obtained from a 4 cm expanded polystyrene panel, has a resistance to direct fire of 110 minutes (Institute of Material Research and Trials, Chile).

Expanded polystyrene is a poorly inflammable material and needs great volumes of combustive air (approximately 150 times its own volume) for the fire to destroy it completely. Therefore since it is confined it cannot burn. In addition, the quality of expanded polystyrene used by M2 is type F self-extinguishable according to standards DIN 4102, so the material itself avoids the tendency from the beginning of the combustion.

The relevant composing fraction of its combustion gases, from a toxicological point of view, is like in wood, Carbon monoxide, but in a very limited amount. According to DIN standards, emission of Carbon Oxide during the combustion of different materials is the following:

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- Wooden fibre: 69.000 ppm at 600 ºC
- Wood: 15,000 ppm at 600 ºC
- Cork: 29,000 ppm at 600 ºC
- Expanded polystyrene F: 1,000 ppm at 600 ºC

As can be observed in the previous table, exhalation of carbon monoxide is between 15 and 69 times less than with wood and its derivatives as construction materials.

8.4   PHYSICOCHEMICAL STABILITY

Polystyrene as well as cement mortar are materials of well-know great chemical stability, virtue that our technology logically inherits, since it is the result of a combination of both materials. Also, the absence of empty spaces and biodegradable materials in the interior of the walls and slabs of our system, prevent the development of insect colonies of any type.

The superior water isolation can be verified thanks to the low absorption of the composing materials. That of the cement mortar obtained because of its dosification, a feature of vertical isolation layers and to the compactation obtained by its pneumatic projection; that of polystyrene, inherent to its own hermetically closed cell structure and that the total immersion test during 28 days verifies an absorption of only 2% in weight.

8.5   **RESISTANCE TO WATER VAPOR DIFFUSION**

Resistance to water vapour diffusion of M2 walls is a lot greater than most walls of traditional construction. If for example, we make a comparison with a wall of 0.2 M vibrated concrete blocks and calculate the resistance Rv according to IRAM 11625 this results in the following values without considering any element as vapour barrier:

Calculated permeabilities

Expanded polystyrene, δ = 0,003750 g / m h kPa
Cement Mortar: δ = 0.0150 g / m h kPa
Hollow concrete blocks δ = 0.0520 g / m h kPa
Ceramic brick 0.18 m; δ = 0.1870 g / m h kPa
Interior plaster: δ = 0.0600 g / m h kPa
Exterior plaster δ = 0.0487 g / m h kPa
With basic values results in:

Rv wall 0.20 Hº   = 3,801 m^2 h kPa / g

Rv M2 $= 20$ m^2 h kPa / g (for a wall with panel PN 60)

The raise in resistance to water vapour diffusion provided by M2 in this case is equal to: **5.2 times**

This resistance to vapour diffusion of M2 walls is centralized reinforced cement mortar that coats each one of the sides of the panel and that because of its pneumatic application technology results very compact and with very low porosity.

The vapour barriers are necessary to minimize the risks of interstitial condensation, which is the water vapour condensation produced in the interior of the layers of the wall or roof due to the decrease in its temperature to below dew point. Therefore, fusion of a vapour barrier will consist in reducing the vapour pressure inside the wall or roof at the parts in which the temperature begins to decrease. When a wall has the conditions both of high thermal isolation and high resistance to water vapour diffusion, it provides the fundamental elements to assure that no condensation is produced, since the evolution of the temperature across the wall is maintained above dew temperature, and at the same time it falls rapidly because of the high resistance to water vapour diffusion of its composing elements.

Continuing with the examples, we will make a comparison with a 20 cm thick ceramic brick wall.

Rv ceramic brick wall 0,22 m = 1,707 m^2 h kPa / g

The raise in resistance to water vapour diffusion provided by M2 in this case is equal to **12 times**

This condition added to the fact that there are no cracks or fractures in relation to traditional masonry, offers a protection far superior against the risk of condensation. This provides a longer durability of the plasters and paints, in addition to an improvement in the salubrity conditions of the surfaces built with this system.

9 **ASPECTS OF M2 SYSTEM AGAINST TRADITIONAL SYSTEMS**

The M2 system is the only technology that rationalizes the execution of constructions in a way that is effective and at the same time efficient.

With the use of usual and well known materials (reinforced concrete to resist stress and expanded polystyrene to provide thermal and acoustic isolation), used in such a way that boosts their properties, all requisites that a building site has to comply with are satisfied, especially in the case of housing.

To that respect, it is valid to mention that the main and fundamental requisite that a construction destined for housing must comply with, is the one referred to thermal isolation, an essential reason for its existence.

And it is because of the compliance with this particular condition, that the need arises for the satisfaction of other requisites, such as: mechanical resistance, structural capacity, execution facility, rational use of resources, architectural flexibility, resistance to fire, good acoustic absorption; even though each has its own importance, none of these reaches that of thermal isolation, and it is an illustration of this aspect, the fact that if a home complies with all the "secondary" requisites and has deficient thermal isolation, it would not be satisfactory to its occupants, no matter how well it complies with all the other aspects.

This influences sensibly in the habitability conditions of the housing and contributes to decrease the costs of thermal conditioning, in the summer as much as in winter, even in extreme conditions. Testimony of the virtue are innumerable constructions built in the most diverse countries, with especially hostile climates (Equatorial Africa, Antarctica, Siberia).
Associated with the property of high thermal resistance mentioned is the advantageous total absence of thermal bridges, due to the total continuity of expanded polystyrene in all the exterior surface of the housing.

9.1 ECONOMY – RATIONAL USE OF THE RESOURCES – EXECUTION FACILITY

At this point the degree of industrialization reached by the system of execution of civil works influences predominantly.
It is necessary to point out that even the most conservative and traditional systems, to which for different reasons everyone has become accustomed to, also have their own degree of industrialization, that tends to optimise the use of resources during their execution.

Thus it is clearly rational to submit the M2 system to a critical judgement under the light of the concepts that are based on the use of the up to now called traditional systems, analysis which should be not only theoretical, but predominantly practical, since the number of constructions done all over the world well justifies this attitude: in every place they have been used, they have satisfied all requirements, resulting in a better alternative for the execution of housing, from an economic as well as technical point of view.

The main consequence of the features that make for rationality is translated into important savings in all issues in which the constructive system has influence.

9.2 INDIRECT SAVINGS - EVALUATION

The reduction of total costs provoked by the use of M2 technology with respect to traditional construction systems, is clearly calculable by comparison of direct costs of Hand Labour and materials.

However, there is a series of additional indirect savings provoked by our technology, of very important relative weight and which are grouped in the following points:

9.2.1 <u>General expenses:</u> The reduction of the execution period of shell and core (foundations-structure-vertical enclosures-covering-installation grooves) allows for a reduction of expenses of administration, energy for the movement of equipment, salaries of foremen, and employees, amortization of machinery, scaffolding, reparations, trucks and automobiles for the inspection and chiefs of the construction work, as well as financing and interest service fees. This reduction of the shell and core period which is intimately related to the greatest possible velocity execution reaches 50%. This way and considering that the shell and core represents between 40 and 50% of the period of total construction work, it would result possible to reduce the duration of the construction works by approximately 22%. If we consider that a construction company has a general pondered expense in 15% of the sum of materials and hand labour, application of the M2 system would reduce it to **11.70%.**

9.2.2 <u>Help from the professions:</u> Defined as supply of Hand labour and materials to cover the canalisations done in the walls by the electricity, water and gas installators, their participation in the decrease of total costs can easily be determined. To illustrate this, for a 60 m2 surface unit 1 days work of an official and an assistant is necessary to cover all canalisations; this leads to a reduction in costs of **1.40 %.**

9.2.3 <u>Canalisation openings:</u> Canalisation openings that installators have to make on traditional brick walls, have a hand labour consumption that results inexistent when using this technology. For the example we can consider that 2 days assistant work is needed for the job of opening the channels and cleaning the work area; in economic terms this means a reduction of **1.20 %.**

9.2.4 <u>Difference paid hours-worked hours:</u> As a consequence of the systematisation of the tasks, and based on the experience of construction companies that have replaced the traditional system with M2 technology, it is possible to affirm that the saving due exploitation of a day's labour is 6.25%. This means that a savings of ½ hour per working day has been considered in task assignments during the period corresponding to shell and core.

If we consider that hand labour participation in the total cost of the construction work to be 45%, this aspect will mean a saving of: 0,0625 x 45 % x 50% = **1,40 %** on the total cost.

9.2.5 <u>Working site cleanup:</u> This issue is of particular importance since the system has only one wet stage which is the application of the cement mortar, while the elevation of the walls is dry and with manipulation of clean elements that don't produce debris. In addition, during the installation stage, there is no channel opening and therefore there is also no debris generation with the consequent necessity of its clean up and removal.

The volume of debris produced in a building site done with brick factory is normally 0.12 m3 per covered m2, and hand labour that must be employed for cleaning and hauling is 3 HH/m3.

The cost of construction in Spain is of approximately 20 €/m3 so the total cost of this issue represents and economic incidence of more than **2.00 %.**

9.2.6 <u>Less total surface to equal useful surface:</u> The use of M2 technology allows for an important decrease in the thicknesses of exterior and interior walls of a home. For example, let's consider the thickness of exterior walls of a traditional 28 cm housing (double wall with air chamber) with a thermal transmittance K = 1,90 W/m2ºC and interior walls 12 cm total thickness, compared with exterior M2 walls 15 cm total thickness with K = 0,39 W/m2ºC (See page 15) and interior walls 10 cm total thickness. In this case for the same useful surface, a construction done with

M2 represents a decrease of total surface equal to **5.74%.**

Adding the points detailed earlier we obtain that the indirect economy in addition to the decrease in direct costs can be considered to exceed **15%** and it is the reason for which M2 technology can also be used to replace traditional systems of constructions in countries where the cost of hand labour is low.

9.3 ARCHITECTONIC LEXIBILITY

This aspect, although it is secondary, wins importance in certain housing categories, in which the architectonic variables play an important role. This is so because the functional necessities in what refers to daily habitability of the house are too variable according too customs, family composition and other unique characteristics.

For these reasons the possibility that a constructive system offers to achieve a wide range of styles practically unlimited and at the same time simple, should be considered as an authentic and important virtue

With the M2 system the most diverse architecture can be achieved, and proof of this is that in all the world constructions that represent the most unlike cultures have been done, from traditional and modern architecture housing, to temples and churches of various architectonic styles as well as industrial constructions.

9.4 GENERAL MAINTENANCE - ADAPTABILITY WITH OTHER CONSTRUCTIVE SYSTEMS

Once finished, constructions done with M2 require a little less maintenance than the usual. This is because they have a superior hydro-isolation capacity which translates into longer duration of plasters and paints. Also of help to this virtue, is the greater mechanical resistance, which implies absence of fissures in the constructions.

In what refers to adaptability to combination with other constructive systems, experience has demonstrated that its capacity is not only large but also of easy execution, and adapts to the most rational solutions for any type of unions and combinations.

10 VERIFICATION OF MECHANICAL RESISTANCES

Next we provide the strict technical frame of solid bases for the verification and dimensioning of structures done with our material, with safe reliability margins under any analysis.

We will make use of structural knowledge and of known resistances of basic materials, to the effects of maintaining the concepts poured into the field used for traditional structures of reinforced concrete and not use special theories that, although in same cases, may give results closer to reality, they lack practical utility for not having the necessary diffusion for its general application. To this respect it should be clear that the differences between theoretic modelling and practical cases leave the ladder ones on the safety side.
Behaviour of the sections under load will be analysed without detailing about their origin and determination, since that is an issue of structural analysis that does not correspond to the scope of the present memory and as such it must be done by professionals that can clearly interpret the behaviour of structural typology done with continuous plates with rigid unions and high grades of static indetermination by internal links.

So characteristic values are referred for each case, taken from a great amount of trials done all over the world and with them behaviour patterns are made out for different loads, that are poured into diagrams of interaction of direct reading. Next we will refer to

particular cases taken form real constructions to the effects of comparing the maximum loads calculated with the load capacities of those elements.

The trials used are those of simple compression on short samples, eccentric compression on tall samples (heights in the order of 270 cm) and simple flexion.

The points corresponding to these trials are dropped on interaction diagrams of direct reading for each type of panel.
In these diagrams the proposed theoretical curves are also dropped so they can be used as ultimate state of service of the sections under study.

These curves were done taking the maximum deformations corresponding to the ultimate service states, according to the conventional hypothesis of the calculation of sections to rupture and calculating the loads that produce them, exactly in the same manner as is done with solid sections of reinforced concrete .
The qualities of the materials employed in the theoretical calculations are:

f'_{ck} = 20 MPa (HA – 20 Normal Control)
f_{yk} = 500/550 MPa (σ_{02} = 500 MPa)
The calculation hypothesis results conservative since according to what was stated on page 6, the recommended dosification of concrete leads to characteristic resistances very superior to the one used.

Steel Section = 2,82 cm2/m (40 Ø 3 mm), for each 112.5 cm panel with 2.5 cm coatings.

The diagrams of direct reading are advantageous since one can observe the safety margins of real situations in common practice.

10.1 GENERAL HYPOTHESIS ON BEHAVIOUR

In general it is useful in practice to assimilate behaviour under load of the sections conformed by the M2 system to homogenous sections of reinforced concrete. For the verification of resistance to centred compression, the thickness of this ideal section is 7 cm which results from the sum of the thicknesses of each one of the mortar layers.

For the verification of resistance to flexion, in the same manner, the plate done with M2 technology is assimilated to an equivalent homogenous one of reinforced concrete, of the same total section. The appropriateness of such hypothesis in the analysis with simple flexion, should not really surprise us, if it is considered that:

1. The neutral axis in M2 sections is totally inside the concrete compression layer, so the compressions are totally absorbed by that material.

2. The traction stresses are absorbed, as are the normal slabs, by active frames, which in this case are of similar amounts to common ones, but with better distribution, since they have a smaller diameter and smaller separation, which assures better behaviour.

10.2 SIMPLE FLEXION

The calculation of compound sections can be done according to the limit state theory with the hypothesis stated earlier or in State I considering that the neutral axis of the section is baricentreed and the volume of the traction loads are absorbed by the inferior layer concrete.

Naturally one will always count on the panel frame which must have enough amount to absorb the resultant of these traction loads.

By any of these methods, we obtain similar values for the verification of the resistant sections.

10.2.1 ULTIMATE LIMIT STATE

Exhaustion of the section is considered to be reached when deformation of the steel reaches the value of 10‰, while the most compressed fibre reaches 2‰.

The situation in the M2 panel of less thickness results:

PR 40

CC	5,00 cm
d	10,70 cm
x	1,78 cm
Z	10,11 cm

It can be observed that the superior reinforcement is also tractioned

Z₁	1,52 cm		
Lengthening	1,70 per thousand	steel bar stress	5,00 Ton/cm2
Tu′	8,29 Ton	Tu	8,29 Ton
Mu	0,96 Tm/m		
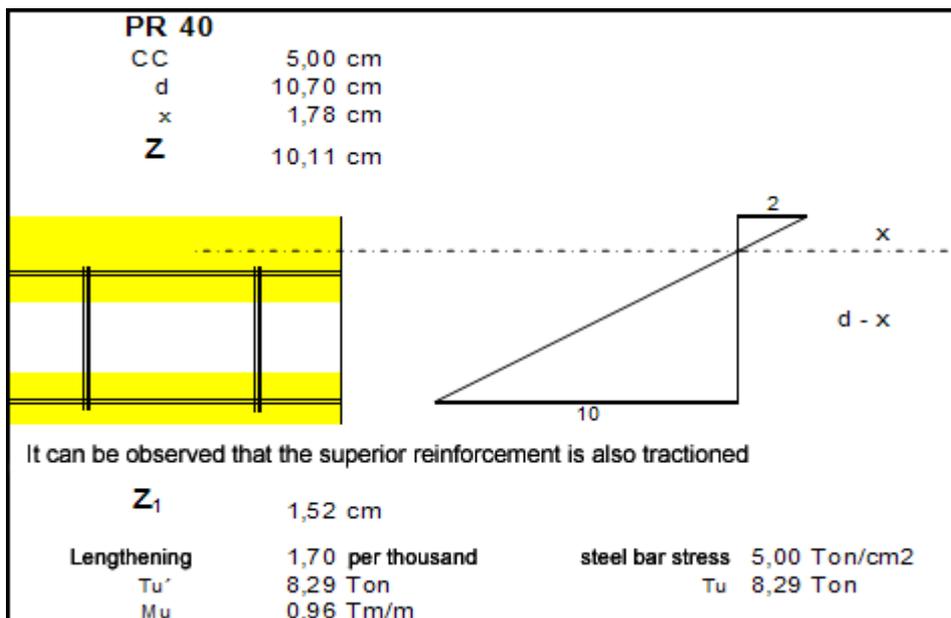
and on the other extreme, for a PR 200 results:

PR 200

CC	5,00 cm
d	26,70 cm
x	4,45 cm
Z	25,22 cm

It can be observed that the superior reinforcement is also compressed

Z₁	-1,15 cm
Shortening	-0,52 per thousand
Tu·	-2,14 Ton
	2,09 Tm/m
Steel bar stress	-1,3 Ton/cm2
Tu	8,29 Ton
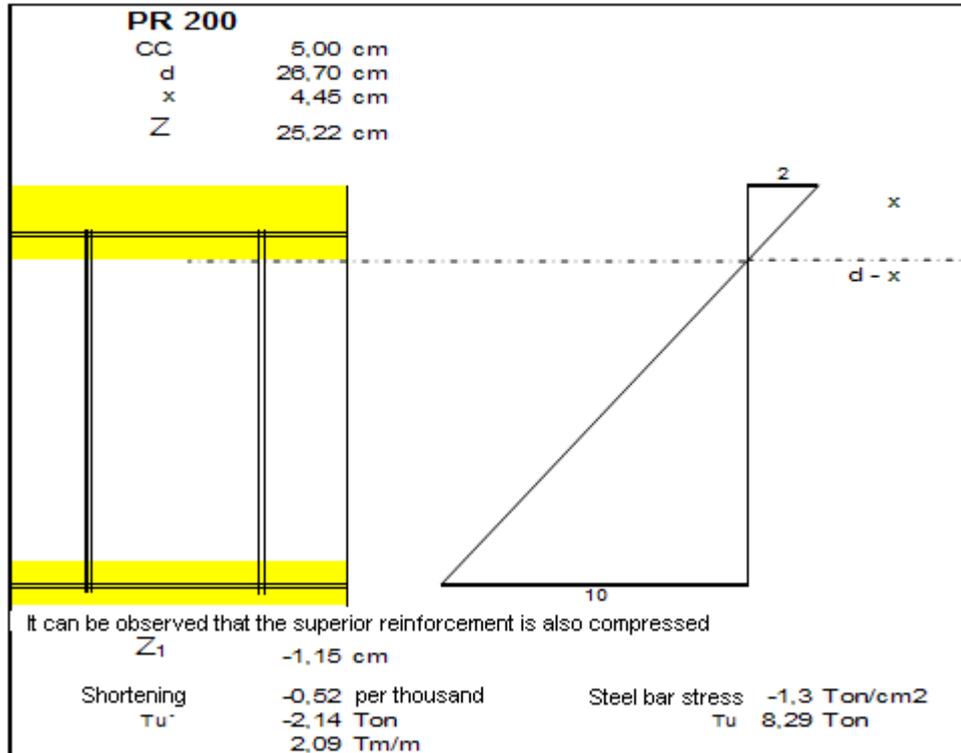
The term *z'* represents the distance from the neutral axis to the superior frame depending if its sign is positive or negative, and it indicates that the superior frame is tractioned or compressed respectively.

The value of ultimate Momentum obtained in this manner corresponds to the ultimate Limit State of exhaustion of the section by frame traction, and supposes a ductile type fracture, greatly preannounced due to the piece's important deformations.

This situation is perfectly verified when flexion trials are done, obtaining a good correlation between the proposed model and experimental results.

Extending the concept to the whole series of M2 panels we obtain the following table of ultimate Momentums Mu where Md are the design values, that is, Mu reduced by the security coefficients of steel and concrete (1.15 and 1.5 respectively):

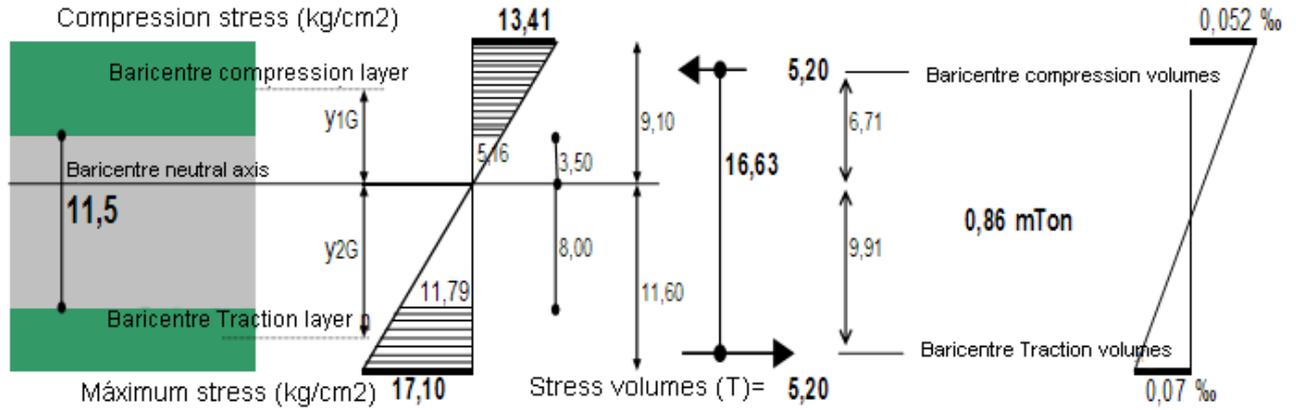| PANEL TYPE	EPS Thick.	Layer - cm	Layer + cm	Width cm	d cm	x lim cm	M u Tm/m	M d Tm/m
PR-40	4	5,6	3,6	100	10,7	1,78	0,84	0,49
PR-50	5	5,6	3,6	100	11,7	1,95	0,92	0,53
PR-60	6	5,6	3,6	100	12,7	2,12	0,99	0,58
PR-70	7	5,6	3,6	100	13,7	2,28	1,07	0,62
PR-80	8	5,6	3,6	100	14,7	2,45	1,15	0,67
PR-90	9	5,6	3,6	100	15,7	2,62	1,23	0,71
PR-100	10	5,6	3,6	100	16,7	2,78	1,31	0,76
PR-110	11	5,6	3,6	100	17,7	2,95	1,39	0,80
PR-115	11,5	5,6	3,6	100	18,2	3,03	1,43	0,83
PR-120	12	5,6	3,6	100	18,7	3,12	1,46	0,85
PR-130	13	5,6	3,6	100	19,7	3,28	1,54	0,89
PR-140	14	5,6	3,6	100	20,7	3,45	1,62	0,94
PR-150	15	5,6	3,6	100	21,7	3,62	1,70	0,98
PR-160	16	5,6	3,6	100	22,7	3,78	1,78	1,03
PR-170	17	5,6	3,6	100	23,7	3,95	1,86	1,08
PR-180	18	5,6	3,6	100	24,7	4,12	1,93	1,12
PR-190	19	5,6	3,6	100	25,7	4,28	2,01	1,17
PR-200	20	5,6	3,6	100	26,7	4,45	2,09	1,21

10.2.2 STATE I (CONCRETE WITH NO FISSURES)

A compound section is considered a continuous solid where the compression and traction loads are absorbed by the mortar Design Momentum Md is then calculated as the product of the resultants of the volumes of the loads multiplied by the distance between them, responding to the following scheme developed as an example in a pr 115 panel.

Compression stress (kg/cm2) **13,41**

Baricentre compression layer

y_{1G}

Baricentre neutral axis

11,5

y_{2G}

Baricentre Traction layer

Máximum stress (kg/cm2) **17,10**

5,16   3,50

11,79

9,10

16,63

5,16

8,00

11,60

Stress volumes (T)= **5,20**

5,20

6,71

0,86 mTon

9,91

Baricentre compression volumes

Baricentre Traction volumes

0,052 ‰

0,07 ‰

PANEL TYPE	EPS	layer -	layer +	width	y1G+y2G	y1G	y2G	I	I solid	I / I solid	E x I	W mín	M adm
	cm	cm	cm	cm	cm	cm	cm	cm4	cm4	%	Kg cm2	cm3	Tm/m
PR-40	4	5,6	3,6	100	8,6	3,37	5,23	18.059	19.166	94%	5,42,E+08	2567	0,44
PR-50	5	5,6	3,6	100	9,6	3,76	5,84	22.047	23.861	92%	6,61,E+08	2884	0,49
PR-60	6	5,6	3,6	100	10,6	4,15	6,45	26.474	29.265	90%	7,94,E+08	3208	0,55
PR-70	7	5,6	3,6	100	11,6	4,54	7,06	31.338	35.429	88%	9,40,E+08	3537	0,60
PR-80	8	5,6	3,6	100	12,6	4,93	7,67	36.641	42.404	86%	1,10,E+09	3869	0,66
PR-90	9	5,6	3,6	100	13,6	5,32	8,28	42.383	50.238	84%	1,27,E+09	4205	0,72
PR-100	10	5,6	3,6	100	14,6	5,71	8,89	48.562	58.982	82%	1,46,E+09	4544	0,78
PR-110	11	5,6	3,6	100	15,6	6,10	9,50	55.180	68.687	80%	1,66,E+09	4885	0,84
PR-115	11,5	5,6	3,6	100	16,1	6,30	9,80	58.653	73.915	79%	1,76,E+09	5056	0,86
PR-120	12	5,6	3,6	100	16,6	6,50	10,10	62.236	79.401	78%	1,87,E+09	5228	0,89
PR-130	13	5,6	3,6	100	17,6	6,89	10,71	69.730	91.175	76%	2,09,E+09	5573	0,95
PR-140	14	5,6	3,6	100	18,6	7,28	11,32	77.663	104.060	75%	2,33,E+09	5919	1,01
PR-150	15	5,6	3,6	100	19,6	7,67	11,93	86.033	118.104	73%	2,58,E+09	6266	1,07
PR-160	16	5,6	3,6	100	20,6	8,06	12,54	94.842	133.358	71%	2,85,E+09	6614	1,13
PR-170	17	5,6	3,6	100	21,6	8,45	13,15	104.090	149.873	69%	3,12,E+09	6964	1,19
PR-180	18	5,6	3,6	100	22,6	8,84	13,76	113.775	167.697	68%	3,41,E+09	7314	1,25
PR-190	19	5,6	3,6	100	23,6	9,23	14,37	123.899	186.881	66%	3,72,E+09	7665	1,31
PR-200	20	5,6	3,6	100	24,6	9,63	14,97	134.461	207.476	65%	4,03,E+09	8016	1,37

If we compare the results of calculating the design momentums from the theoretical consideration of the methods described earlier, we obtain the following table.

PANEL TYPE	var.II/I %
PR-40	10,6%
PR-50	7,7%
PR-60	5,1%
PR-70	2,8%
PR-80	0,8%
PR-90	-0,9%
PR-100	-2,4%
PR-110	-3,8%
PR-115	-4,5%
PR-120	-5,1%
PR-130	-6,2%
PR-140	-7,2%
PR-150	-8,1%
PR-160	-8,9%
PR-170	-9,7%
PR-180	-10,4%
PR-190	-11,0%
PR-200	-11,6%

From the table above it can be deducted that the method of calculation of the sections by ultimate limit state or by state of concrete without fissures gives out design flexor Momentum values that are very similar in the range of EPS panels between 6 and 12 cm thick.

In the thinner panels the Limit State leads to values of up to 10.6% greater, while in thicker panels results are the opposite.

In both cases the values of the service flexor Momentum obtained from mechanical testing lead to significantly greater values, reason for which, whatever the chosen method, values are always on the safety side.

10.2.3 SHEAR STRESS

Behaviour with cutting stress is similar, even though in moderately thin plates, of the type that respond to concrete, the shear stress is practically insignificant. In this case the main loads are absorbed without inconvenient

when the unloading zones get closer by the set formed by composing materials.

For a fixed number of connectors: 80 of Φ 3 mm values for dimensioning are tabulated from the panels against shear stress, V_{rd} being the most unfavourable value obtained from inequations (1) and (2):

$$V_{rd} \leq V_{u1} \qquad (1)$$

$$V_{rd} \leq V_{u2} \qquad (2)$$

Following the calculation criterion of article 44º of EHE the result for panels used as walls, where the mortar section is symmetric of 30 mm on the EPS wave for each side is:

b_0	f_{cd}	f_{ck}	$f_{y90,d}$	A_{90}	A_s
mm	N/mm2	N/mm2	N/mm2	mm2/mm	mm2
1125	16,67	25	608,70	0,636	186,532

SHEAR STRENGTH IN WALLS

PANEL TYPE	e_{hor}	e_{EPS}	e_{hor}	d	ξ	ρ_1	$V_{rd,adm}$	V_{u1}	V_{u2}
	mm	mm	mm	mm			kN	kN	kN
PR 40	36	40	36	89	2,499	0,002	58,86	275,63	58,86
PR 50	36	50	36	99	2,421	0,002	60,54	275,63	60,54
PR 60	36	60	36	109	2,355	0,002	62,14	275,63	62,14
PR 70	36	70	36	119	2,296	0,001	63,68	275,63	63,68
PR 80	36	80	36	129	2,245	0,001	65,16	275,63	65,16
PR 100	36	90	36	139	2,200	0,001	66,58	275,63	66,58
PR 110	36	100	36	149	2,159	0,001	67,97	275,63	67,97
PR 115	36	115	36	164	2,104	0,001	69,96	275,63	69,96
PR 120	36	120	36	169	2,088	0,001	70,61	275,63	70,61
PR 130	36	130	36	179	2,057	0,001	71,88	275,63	71,88
PR 140	36	140	36	189	2,029	0,001	73,12	275,63	73,12
PR 150	36	150	36	199	2,003	0,001	74,33	275,63	74,33
PR 160	36	160	36	209	1,978	0,001	75,52	275,63	75,52
PR 170	36	170	36	219	1,956	0,001	76,68	275,63	76,68
PR 180	36	180	36	229	1,935	0,001	77,82	275,63	77,82
PR 190	36	190	36	239	1,915	0,001	78,93	275,63	78,93
PR 200	36	200	36	249	1,896	0,001	80,03	275,63	80,03

In the case of slabs, panel coating is asymmetric with a 5 cm compression coating thickness and 2 cm inferior coating, always measured from the EPS core crest.

For the calculation of shear stress exhaustion by oblique compression of the stem, only the effective concrete section is considered

SHEAR STRENGTH IN SLABS

PANEL TYPE	e_{hor} mm	e_{EPS} mm	e_{hor} mm	d mm	ξ	ρ_1	$V_{rd,adm}$ kN	V_{u1} kN	V_{u2} kN
PR 40	36	40	56	109	2,355	0,002	69,11	388,13	69,11
PR 50	36	50	56	119	2,296	0,001	70,65	388,13	70,65
PR 60	36	60	56	129	2,245	0,001	72,13	388,13	72,13
PR 70	36	70	56	139	2,200	0,001	73,55	388,13	73,55
PR 80	36	80	56	149	2,159	0,001	74,94	388,13	74,94
PR 100	36	90	56	159	2,122	0,001	76,28	388,13	76,28
PR 110	36	100	56	169	2,088	0,001	77,58	388,13	77,58
PR 115	36	115	56	184	2,043	0,001	79,47	388,13	79,47
PR 120	36	120	56	189	2,029	0,001	80,09	388,13	80,09
PR 130	36	130	56	199	2,003	0,001	81,30	388,13	81,30
PR 140	36	140	56	209	1,978	0,001	82,49	388,13	82,49
PR 150	36	150	56	219	1,956	0,001	83,65	388,13	83,65
PR 160	36	160	56	229	1,935	0,001	84,79	388,13	84,79
PR 170	36	170	56	239	1,915	0,001	85,90	388,13	85,90
PR 180	36	180	56	249	1,896	0,001	87,00	388,13	87,00
PR 190	36	190	56	259	1,879	0,001	88,08	388,13	88,08
PR 200	36	200	56	269	1,862	0,001	89,14	388,13	89,14

For loads contained in the panel plane, whick exert a flexion on it, as a stem of great height, verification is done under the same hypothesis, taking reference values of reinforced concrete, that is, the values of comparison tangent stress τ_{02} that corresponds to the net section of reinforced concrete.

10.3 INTERACTION DIAGRAMS

Following the outline of calculation of a rectangular section with symmetric double reinforcement, direct reading interaction diagrams can be constructed that facilitate behaviour reading of M2 panels in the cases of Compound Flexion from Domains 2 to 5.

$$N_u = 0,85 \times b \times h \times f_{cd} + A_s \times f_{yd}$$
$$x_{lim} = 0,259 \times d$$

f ck =	250,00 Kg/cm2
f yk =	5000,00 Kg/cm2

f cd =	166,67 Kg/cm2
f yd =	4347,83 Kg/cm2

A s = 1,66 cm2/m

δ = d" / h
A total 3,32 cm2/m

Effective rec = 3,50 cm
Calculation rec = 3,50 cm
d" = 2,4 cm

Safety coefficients addopted for this analysis:

γ G = 1
γ c = 1,5   1,5   1,6
γ s = 1,15

γ tot = 1,725

AXIL v	α1	α2	α3
0,10	-0,09	2,01	2,00
0,20	-0,15	1,99	2,08
0,30	-0,19	2,00	2,00
0,40	-0,20	1,96	2,19
0,50	-0,18	2,05	2,17
0,60	-0,15	2,15	2,03
0,70	-0,11	2,26	1,89
0,80	-0,05	2,30	1,76
0,90	0,03	2,31	1,62
1,00	0,12	2,31	1,49
1,10	0,21	2,32	1,38
1,20	0,30	2,32	1,27
1,30	0,39	2,33	1,18
1,40	0,48	2,33	1,10
1,50	0,58	2,33	1,03

PANEL TYPE	eps cm	rec cm	b cm	h cm	d cm	δ	ω
PR 40	4	3,50	100	11	8,60	0,22	0,079
PR 50	5	3,50	100	12	9,60	0,20	0,072
PR 60	6	3,50	100	13	10,60	0,18	0,067
PR 70	7	3,50	100	14	11,60	0,17	0,062
PR 80	8	3,50	100	15	12,60	0,16	0,058
PR 90	9	3,50	100	16	13,60	0,15	0,054
PR 100	10	3,50	100	17	14,60	0,14	0,051
PR 110	11	3,50	100	18	15,60	0,13	0,048
PR 120	12	3,50	100	19	16,60	0,13	0,046
PR 130	13	3,50	100	20	17,60	0,12	0,043
PR 140	14	3,50	100	21	18,60	0,11	0,041
PR 150	15	3,50	100	22	19,60	0,11	0,039
PR 160	16	3,50	100	23	20,60	0,10	0,038
PR 170	17	3,50	100	24	21,60	0,10	0,036
PR 180	18	3,50	100	25	22,60	0,10	0,035
PR 190	19	3,50	100	26	23,60	0,09	0,033
PR 200	20	3,50	100	27	24,60	0,09	0,032

INTERACTION DIAGRAM   PR 40 to PR 100

Nd (T/m)

Md (Tm/m)

PR 40   PR 60   PR 80   PR 100

INTERACTION DIAGRAM PR 120 to PR 200

Nd (T/m)

Md (Tm/m)

—— PR 120 —— PR 140 —— PR 160 —— PR 180 —— PR 200
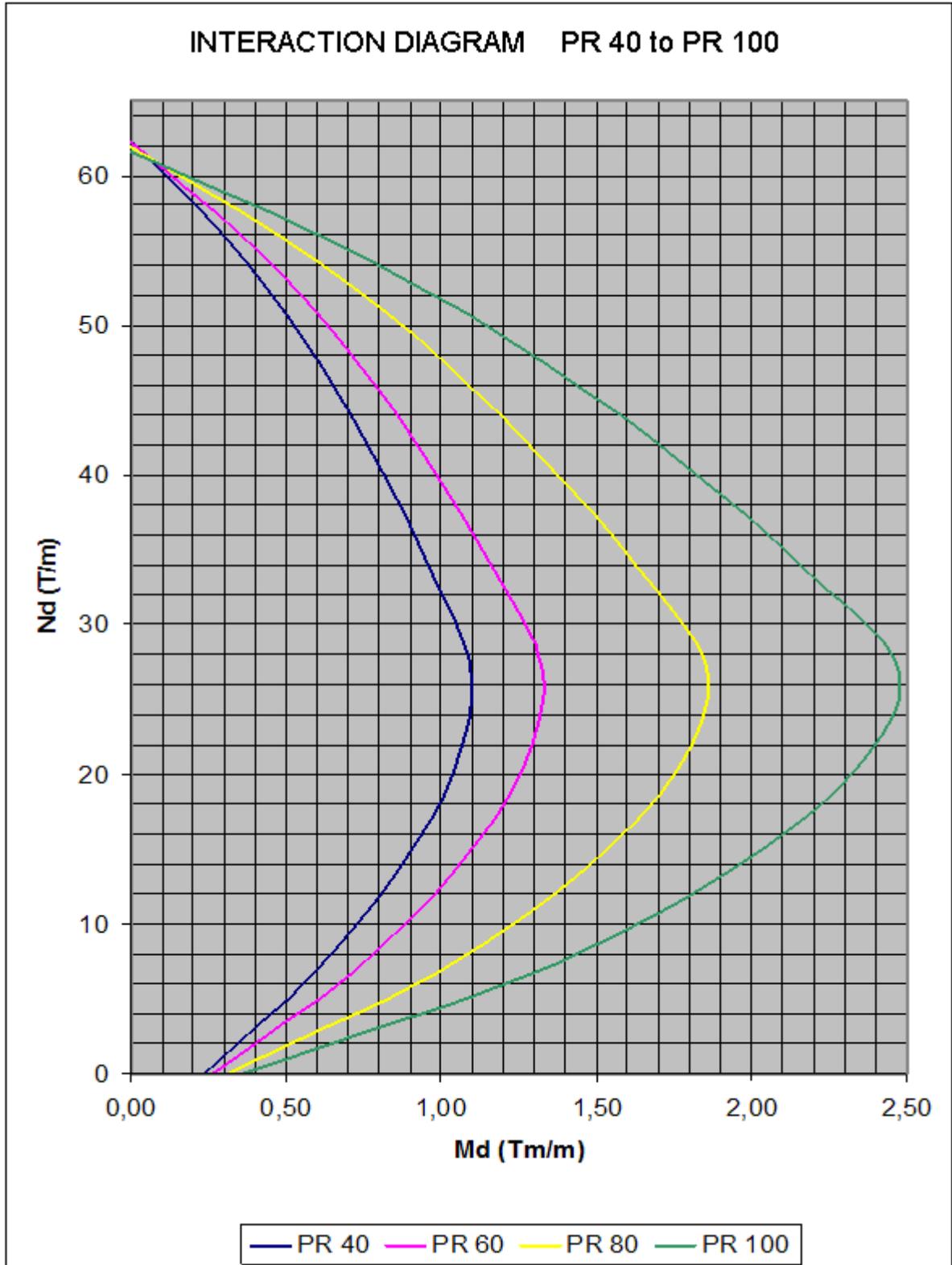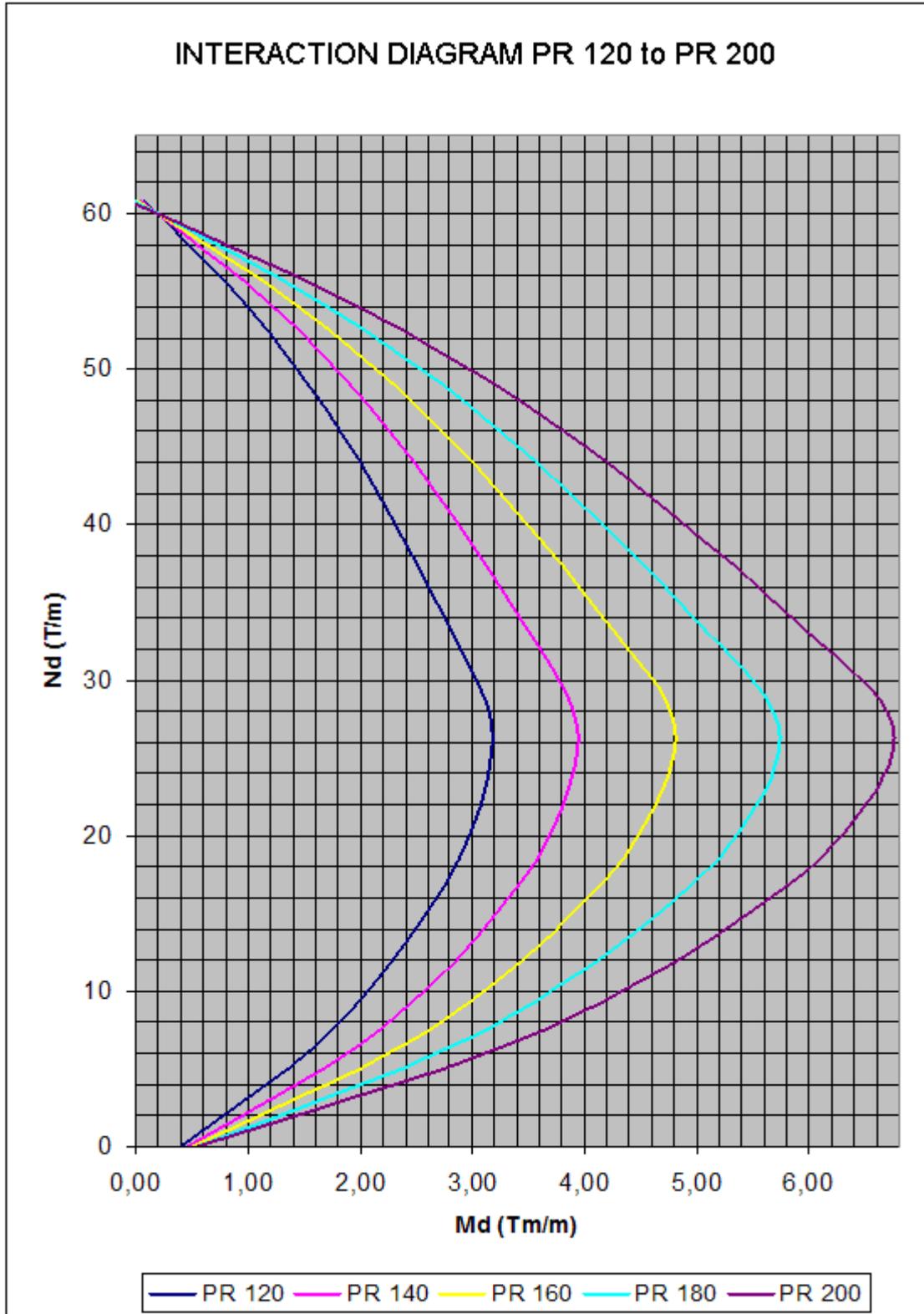
The curves obtained are homothetic of the ordinate origin (centred compression) since it corresponds to the resistance of the solid section of the mortar and steel present in all panel series.

The abscissa origins correspond to the capacity for simple flexion of each panel and as has been explained in former points, they vary according to the thickness of the EPS core of each type of panel.

One can input these diagrams with values of maximum stress of the structural element of a building maximised by safety coefficients. If the point obtained is within the interaction diagram, this means that the element verifies the loads it supports with the adequate safety.

10.4 SIGNIFICANT TEST RESULTS POURED INTO INTERACTION DIAGRAMS

Results from the following trials, representative of minimum resistances corresponding to each type of panel have been poured into direct reading interaction diagrams. See study of ultimate Limit State of each panel.

Torroja Testing(Eccentric compression)
Height   = 280 cm
PR40 PANEL
Total thickness   = 11 cm
Ultimate load   = 560   kNm/m

Melbourne Testing 1(Centred compression)
Height   = 300 cm
PN 60 Panel
Total thickness   = 13 cm
Ultimate load   = 1.134   kNm/m

Melbourne Testing 2(Centred compression)
Height   = 300 cm
PN 60 Panel
Total thickness   = 13 cm
Ultimate load   = 707 kN/m (initial eccentricity 3,5 cm)

Padova Testing 1(Centred compression)
Height   = 55 cm
PN 40 Panel
EPS thickness   = 11 cm

Ultimate load   = 903   kNm/m
Smallest value obtained from a series of 6 trials. The largest value reached 1,460 kN

Padova Testing 2(Centred compression)
Height   = 55cm
PN 80 Panel
Total thickness   = 15 cm
Ultimate load   = 1,019   kNm/m
Smallest value obtained from a series of 6 trials. The largest value reached 1,337 kN

Padova Testing 3(Centred compression)
Height   = 275 cm
PN 80 Panel
Total thickness   = 15 cm
Ultimate load   = 830 kN/m (initial eccentricity 3,5 cm)

Padova Testing 1(Centred compression)
Height   = 240 cm
PN 40 Panel
Total thickness   = 10 cm
Ultimate load   = 566 kN/m (initial eccentricity 3,5 cm)

Argentina Testing 1 (Flexion)
PR 40 Panel
Total thickness   = 12 cm
Light   = 270 cm
Load in the CUARTOS DE LA LUZ
Maximum load   = 24 kN

Connell Wagner Testing 1 (Flexion)
PR 60 Panel
Total thickness   = 14 cm
Light   = 360 cm
Load in the TERCIOS DE LA LUZ
Maximum load   = 8 kN (with a maximum shear stress of 14 kN/m)

Perugia Testing 1 (Flexion)
PR 80 Panel
Total thickness   = 16 cm
Light   = 360 cm
Load in the TERCIOS DE LA LUZ
Maximum load   = 21 kN

INTERACTION DIAGRAMS PR 40 to PR 100

Legend:
- PR 40
- PR 60
- PR 80
- ✳ Torroja
- ✕ Melbourne 1
- ● Melbourne 1
- + Padova 3
- − Chile 1

X-axis: Md (Tm/m)
Y-axis: Nd (T/m)
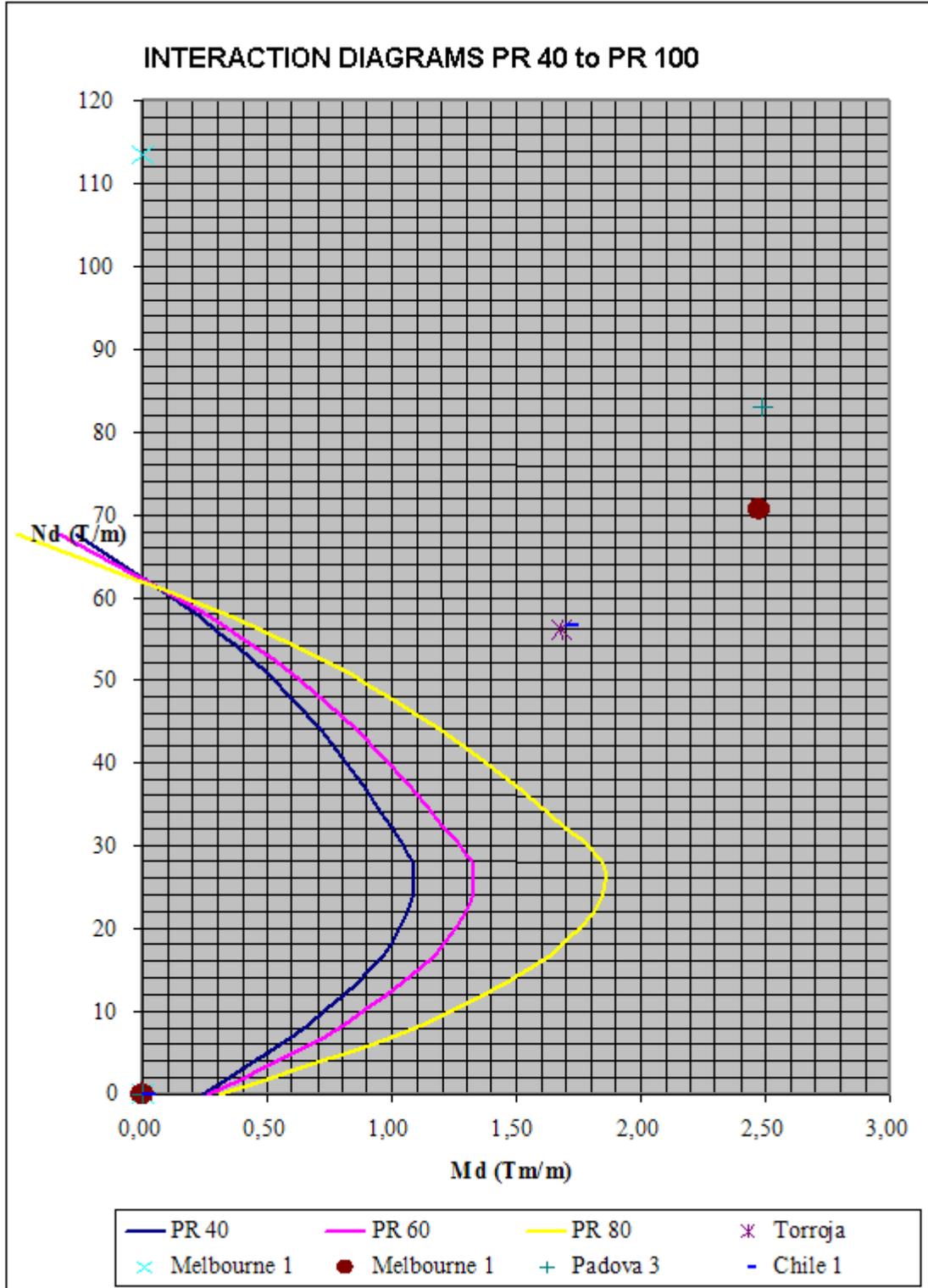
It can be observed that the representative points of the loads reached in the trials, are outside the interaction diagrams that correspond to the panels on which the trials have been carried out.

10.5 OBSERVATIONS ON COMPRESSION TESTS

The basic evaluation trial of resistance capacities to flexo-compression is done on panel samples, projected on site, of variable heights between 2.50m and 4.00 m, even though there are trials done short samples in which second order effects loose significance.

The sustent for samples used in the trials is always articulated in the inferior end (free rotation) and simply supported in the superior end (free vertical displacements and rotations) and the load is distributed on a line parallel to the sides. The vertical borders of the samples remain free during all trials. This configuration implies, against a second order load, slenderness that do not coincide with the those corresponding to the plates in the real cases.

The reasons for the differences are, briefly: the self support, which in real cases, whether it's by linkage to the foundation or by continuity with the plates of adjacent floors, is more assimilable to elastic embedment and not to simple articulations with free rotations and also, the location of the free vertical borders, which is rarely in practice and that sustancially changes de nature of the second order loads to be verified in the plate, which are, after all determinant.

A wall´s behaviour to compression corresponds more accurately to that of a rigid plate supported by its four borders. And to that respect we limit ourselves to mention that the critical loads of that configuration exceed by at least **more than double** those corresponding to the same element loaded as rod, as is the case of the trials used.

We should not forget to take into account, in the real cases, the existence of perpendicular walls that contribute greatly to increasing the rigidity, and therefore the global load capacity.

10.6 OBSERVATIONS ON FLEXION TESTS

The referred trials use their own stem supports to analyse the capacity to flexion of the elements and to that respect it is necessary to point out that the transversal deformations are not impeded in them, so the vertical displacement configurations must be affected by the corresponding reductions to assimilate them to the behaviour of a plate supported on its four borders.

Another fundamental feature when evaluating the results of the flexion trials is that in every case the panel conserved an enormous capacity of elastic recovery, even in the

ultimate or exhaustion state. More so, when the plastified section was not in condition of absorbing more load, when removing it one could consistently verify that most of the energy absorbed by the section was stored as deformation elastic energy, with the piece tending to its original position of equilibrium in a more than significant manner.

10.7 10.7 CAPACITY AT SIMPLE FLEXION OF UNIDIRECTIIONAL M2 PLATES

PANEL TYPE	Mcal Tm/m	Admissible loads (Ton/m2) / deformations (cm)							
		2,50	3,00	3,50	4,00	4,50	5,00	5,50	6,00
PR-40	0,49	0,62	0,43	0,32	0,24	0,19	0,16	0,13	0,11
		0,06	0,08	0,11	0,15	0,19	0,23	0,28	0,34
PR-50	0,53	0,68	0,47	0,35	0,27	0,21	0,17	0,14	0,12
		0,05	0,08	0,10	0,13	0,17	0,21	0,25	0,30
PR-60	0,58	0,74	0,51	0,38	0,29	0,23	0,18	0,15	0,13
		0,05	0,07	0,09	0,12	0,15	0,19	0,23	0,27
PR-70	0,62	0,80	0,55	0,41	0,31	0,25	0,20	0,16	0,14
		0,04	0,06	0,08	0,11	0,14	0,17	0,21	0,25
PR-80	0,67	0,85	0,59	0,44	0,33	0,26	0,21	0,18	0,15
		0,04	0,06	0,08	0,10	0,13	0,16	0,19	0,23
PR-90	0,72	0,92	0,64	0,47	0,36	0,28	0,23	0,19	0,16
		0,04	0,05	0,07	0,09	0,12	0,15	0,18	0,21
PR-100	0,78	0,99	0,69	0,51	0,39	0,31	0,25	0,21	0,17
		0,03	0,05	0,07	0,09	0,11	0,14	0,17	0,20
PR-110	0,84	1,07	0,74	0,55	0,42	0,33	0,27	0,22	0,19
		0,03	0,05	0,06	0,08	0,11	0,13	0,16	0,19
PR-115	0,86	1,11	0,77	0,56	0,43	0,34	0,28	0,23	0,19
		0,03	0,05	0,06	0,08	0,10	0,13	0,15	0,18
PR-120	0,89	1,14	0,79	0,58	0,45	0,35	0,29	0,24	0,20
		0,03	0,04	0,06	0,08	0,10	0,12	0,15	0,18
PR-130	0,95	1,22	0,85	0,62	0,48	0,38	0,30	0,25	0,21
		0,03	0,04	0,06	0,08	0,10	0,12	0,14	0,17
PR-140	1,01	1,30	0,90	0,66	0,51	0,40	0,32	0,27	0,22
		0,03	0,04	0,06	0,07	0,09	0,11	0,14	0,16
PR-150	1,07	1,37	0,95	0,70	0,54	0,42	0,34	0,28	0,24
		0,03	0,04	0,05	0,07	0,09	0,11	0,13	0,16
PR-160	1,13	1,45	1,01	0,74	0,57	0,45	0,36	0,30	0,25
		0,03	0,04	0,05	0,07	0,08	0,10	0,13	0,15
PR-170	1,19	1,52	1,06	0,78	0,60	0,47	0,38	0,31	0,26
		0,02	0,04	0,05	0,06	0,08	0,10	0,12	0,14
PR-180	1,25	1,60	1,11	0,82	0,63	0,49	0,40	0,33	0,28
		0,02	0,03	0,05	0,06	0,08	0,10	0,12	0,14
PR-190	1,31	1,68	1,16	0,86	0,66	0,52	0,42	0,35	0,29
		0,02	0,03	0,04	0,06	0,07	0,09	0,11	0,13
PR-200	1,37	1,75	1,22	0,90	0,69	0,54	0,44	0,36	0,30
		0,02	0,03	0,04	0,06	0,07	0,09	0,11	0,13

The column that corresponds to the calculation Momentum is the greatest among the calculated ones, whether it's by ELU or by E I, and the loads shown on the table are total, and should be compared with the maximization actions with the corresponding safety coefficients.

10.8 EXAMPLES OF PRACTICAL APPLICATIONS

10.8.1 Example 1: Case of an 8 story building

First of all, in a simple manner an eight story building of 2.80 m per floor (total height 22.40 m) is verified under the action of its permanent loads, regulation overloads and an earthquake of extreme severity with a maximum acceleration of 0.3 g.
The parameters concepts of calculation are the following:
Plant of rectangular building of 30 m by 10 m with normal architecture.
Eigenweight of the walls = 1.20 kN/m2 (incidence of opening is not deducted).

Slabs of 4 m average light between support, with Eigenweight of 1.80 kN/m2, permanent overload of 1.20 kN/m2 and accidental overload of 2.00 kN/m2.Sismic action is considered on all permanent loads and on 30% of the accidental ones.
Structural collaboration of all interior partitioning for the absorption of horizontal loads is negligible and this must be taken into account in a real case. This is to the effect of maximise the loads on the exterior partitions. Only 30 m longitudinal party walls are considered to absorb loads originated at the total momentum due to earthquake.
With these unfavourable and conservative hypothesis, the permanent load on these walls was 107 kN/m.

Maximum load, including the action of the earthquake reaches 205 kN/m, of which the simple expanded polystyrene M2 PN 04 de 4 cm thick panel and with 3 cm cement mortar on each side has, with regards to the trial values a safety coefficient of **4.5**.

10.8.2 Example 2: **Calculation of a slab with PR 80 panel.**

A rectangular slab (3 m x 4 m) is verified, simply supported on its four borders, subjected to a uniformly distributed vertical load. The calculated load is 5 kN / m2 total that provokes a main flexor momentum equal to 308 kNm / m.

The theoretical capacity is 1061,7 kNm / m (theoretical safety coefficient 3.44).
The capacity reached through testing is 1200 kNm / m (security coefficient**3,9**)
The theoretical capacity is found in the following manner:
Resultant of traction of the existing reinforcement is:
Section of a rod ø 5 (0.196 cm2) times the amount of rods per meter of panel (5.33) plus the section of a rod 2,5 (0,049 cm2) times the amount of rods per meter of panel (12.44) multiplied by the ultimate stress established (500 Mpa) and the lever arm formed by the thickness of the panel times 2/3 of the thickness of the compression layer and plus 1.5 cm (12.83) gives the value shown in the previous paragraph. To this respect we should mention that the hypothesis of location of the

resultant from compression loads at 2/3 of the height of the compression layer is more than conservative, since the loads in that material are so low for the rupture momentum that this resultant is really located in the superior quadrant.

That hypothesis is endorsed by cracking charts observed in the trials and by the magnitudes of the real ultimate momentums obtained in them.
Even though the shear in the plates is not determinant, its accepted that for the calculated case its maximum value reaches 5.74 kN/m.

It's important to mention the possibility of strengthening the flexion reinforcements with the addition of more meshes, in virtue of the predominance of the flexion and the excellent adherence provided by the meshes, achieved by the rational distribution thanks to the mesh openings and to the reduced diameters of the reinforcements.

10.8.3 Example 3: Functioning as a stem of great height
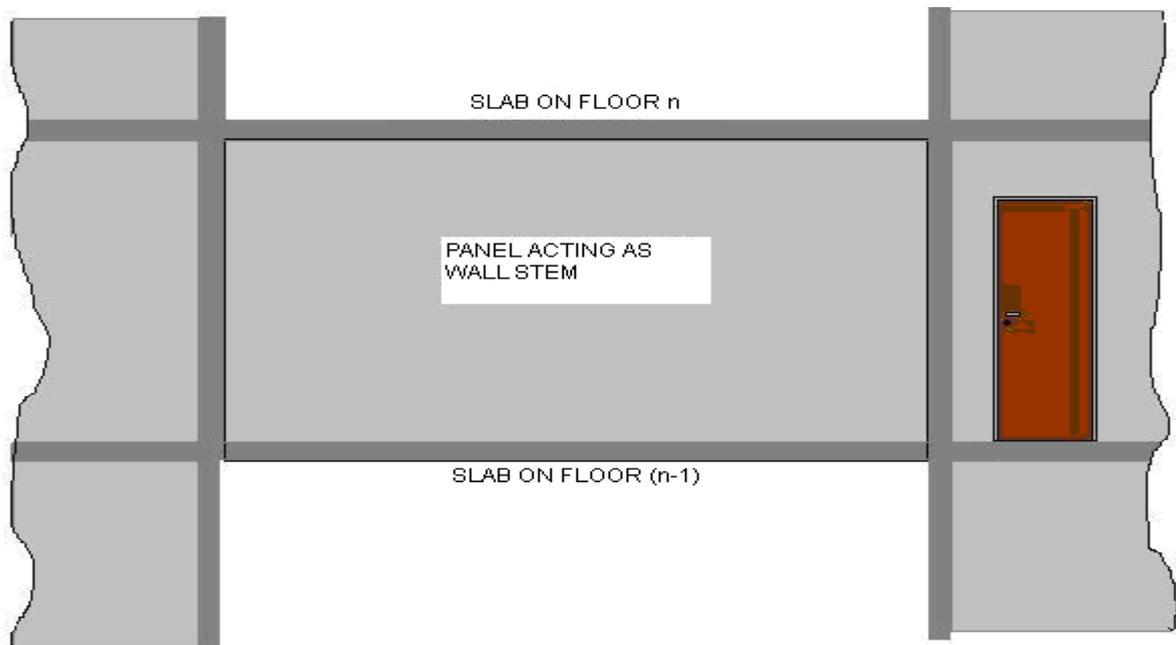
We will verify all loads in a stem wall located in a hypothetical high story of a building, and that supports the mezzanine of the rooms it divides in its inferior part.
Parameters:

Height		=	2,80 m
Length		=	5,00 m
Area of the slabs that support the stem wall	=	20	m2
Total load on the slabs	=	5,00	kN/m2
Total load on the stem wall		=	24,00 kN/m

Equivalent flexor momentum = 75,00 kNm
Internal arm (supposed 0.7 h) = 1,96 m
Resultant of total compression / traction = 40,00 kN

The resultant compression value must be compared with the capacity of centred compression since that is the load on the panel in this case.

Regarding the traction value, we only mention that it is absorbed by eight reinforcement bars, located at a height of 30 cm (h/9), which results specially adequate in sight of the loads verified in this type of structural elements.

It is also useful for verifying the capacity against this s load, the result of the load trials contained in the plane, in which values of 350 kN were reached in 2.40 m high panels, that are compared with half the total load of the case under study, that is, 60 kN (safety coefficient **6).**

In the former calculations we have not taken into account the collaboration of the inertia of the slabs that influence on the stem, that transform it in a section composed of M2 elements, due to the didactic purpose of the analysed case.

10.8.4 Example 4: **Failure in the foundations**

We will verify Total undermining of the foundation of a one floor construction of dimensions (5,00 m x 6,00 m and height 3,00 m), such that an entire area of 2.00 by 5.00 will remain without supporting ground. It is verified that the action of the walls as a stem of great height supports the weight of all the elements linked to them, including foundation and covering.
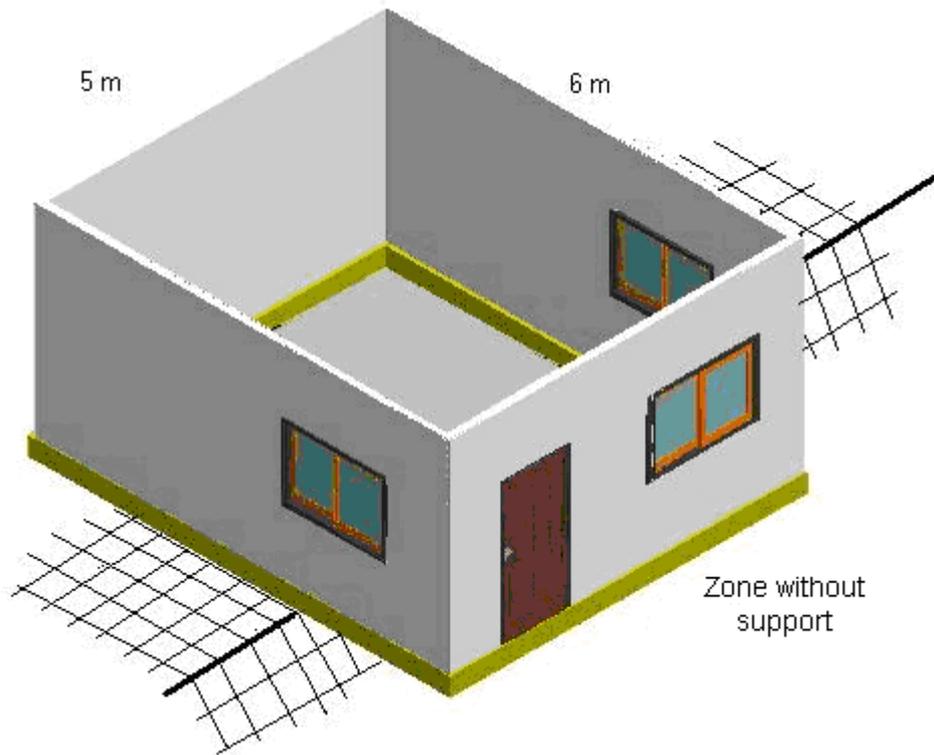
Weight per m2 of the foundation slab   kN/m2
Weight of the walls   kN/m2
Floor overload   kN/m2
Weight of the covering   kN/m2
Vertical shear in wall   = 48 kN (less than 350 kN / m)
Flexor momentum acting on wall   = 50 kNm
See form case verified for a flexor Momentum of 75 kNm

10.8.5 Example 5: **Stem done with panel segment**

Stem simply supported on 7.00 m long panel placed vertically used as slab rib.
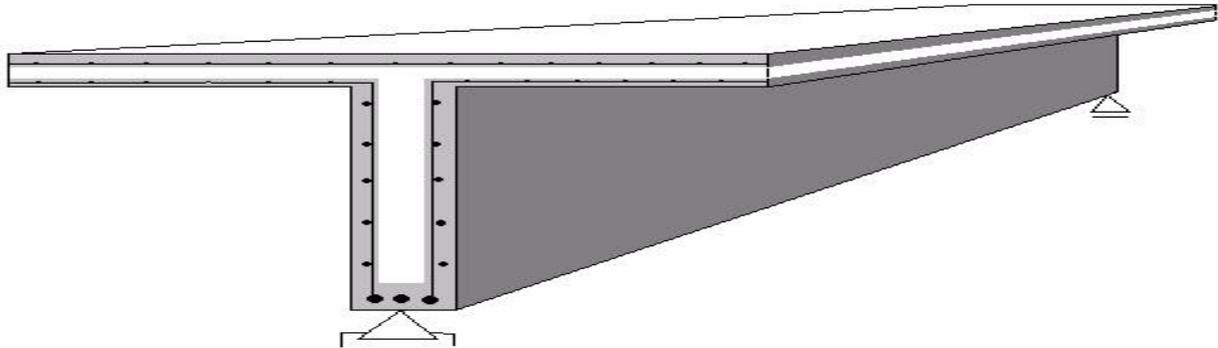
Influence width = 2.50 m
Total load   kN/m2
Uniform load on rib = 12.50   kNm/m
Maximum momentum   = 76 kNm
Elastic arm (0.85 h) = 60 cm
Traction to be absorbed   = 126 kN (3,30 cm2 of fyk = 440 MPa ; 3 Ø 12)
Maximum shear = 41kN
Comparison shear stress = 1,1 MPa (to obtain in you divide the maximum shear stress by the elastic arm and by the sum of the thickness of cement mortars, that is, 6 cm

This stress is compared with the one corresponding to conventional concrete (τ_{02} = 1,8 MPa) and you proceed with the verification using the reinforcement meshes as stirrups, considering that a mesh absorbs a stress equal to:

for the main direction τ = (0,093 cm2 x 500 MPa x 2) / (0,06 m x 0,059 m) = 2,63 MPa

for the secondary direction (valued in the shear tests carried out)
τ = (0,049 cm2 x 500 MPa x 2) / (0,06 m x 0,065 m) = 1,26 MPa
Minimum result obtained in trials = 1,50 MPa

10.8.6 Example 6:   Verification of the efficacy of the starter bars between M2 plates and a continuous foundation.

The link between a continuous foundation of the strip footing type and the composing elements of the M2 system is done through the irons bars of appropriate diameter embedded in the footing.
This length emerging from these iron bars is tied to the meshes of the vertical panels and then stays embedded in the cement mortar with which pneumatic projection is done.

This union is verified at tear-off verifying that it supports the weight of the footing with a safety coefficient of 1.75.

The present calculation memory must be adapted to the appropriate conditions in relation to each building site, and constitutes a model in which for different hypothesis the most unfavourable cases were adopted.

Linkage Reinforcement
Steel rods of diameter 6 mm where considered in the calculation.
Steel is considered with fluence stress 420 MPa and 500 MPa to rupture.

Adherence stress
Instructions from Standard DIN 1045 and its equivalents are followed.
In function of the water cement relation of the cement mortar with which pneumatic projection (0.52) is done, a characteristic resistance of 21 Mpa is conservatively estimated. The rods in question, when they are in vertical position, must be considered, according to classification of that standard as in position 1 (favourable zone of adherence).
Admissible Adherence stress for the described case is 1.80 MPa

t_{adm} = 1,8 MPa

Note: Admissible adherence stress is referred to in DIN 1045 to an ultimate conventional valued corresponding to a displacement of 0.1 mm of an anchored rod in a normalized trial. The safety coefficient of the stress described is 3. With regards to the real ultimate stress or failure stress the safety coefficient is 5.

Estimation of the weight of the foundation
We consider a field with an admissible capacity of 0.10 Mpa minimum, and a ground floor construction and two high floors.

Load calculation
Total height	= 7,80 m
Eigenweight of the walls (a 1,20 kN / m2)	= 9.36 kNm/m
Unloading of adjacent slabs with overload (at 5 kN/m2)	= 15.00 kNm/m
(Influence width 1.5 m)	
Vertical action due to horizontal load	= 1.00 kNm/m

Total adopted   **= 25.36 kNm/m**

Calculation of the width of the footing

A = 25,36 kN / m / 0,10 MPa = 25 cm
b adopted = 25 cm

Calculation of the eigenweight of the footing
G = 1.39 kN / m
Calculation for the tear-off (1.7 times the weight)
G calc = 2.44 kN / m

Note: the global safety coefficient, taking into account the one mentioned in adherence stress, rises to 5 with respect to the reference conventional value and to 9 with respect to the rupture value.

Calculation of the length necessary to support G calc
Considering, as a function of t_{adm}, that one centimetre in length of a 6mm bar resists a force of 0.34 kN by lateral adherence, that is:

F = 3,14 x 0,60 cm x 1,8 MPa
f = 0,34 kN / cm

And considering that two rods per linear meter of foundation are placed, each rod should absorb:
F = G calc / 2 = 1,22 kN

So the length necessary to absorb it, whether its anchored in the foundation or in the projected cement mortar, is equal to:
Length= F / f = 3,60 cm

Conclusion
We recommend placing a minimum reinforcement link consisting of straight bars of 6 mm diameter separated by 50 cm embedded in the footing, that will stick out 20 cm and will be tied to the panel's own mesh.

Verification at horizontal stress or relative horizontal displacement
The capacity of a 6 mm rod results:
Section x admissible stress = 0.28 cm2 x ($\sigma_{fluencia}$ / 4)   = 2.94 kN / rod
Therefore for a one meter union, with two rods   = 5.88 kNm/m
We should point out that this recommended minimum anchorage is capable of absorbing a shear stress at the base equivalent to 23 % of the total vertical load.

For greater stress the separation is decreased adequately.

11 FIXATION TO M2 WALLS

From the structural resistance point of view, M2 walls are designed to resist loads under dominant compression, which are represented in the M-N interaction diagrams particular to each type of panel according to its EPS thickness.

For cases of loads concentrated on isolated points, the calculation criterion is the verification of the contact pressure between bolt and walls, not exceeding the stress of the Concrete calculus, that for fck = 25 N/mm2 corresponds a value of fcd = 0.85 x fck = 14.2 N/mm2.
This is exactly the same for the verification of a fixing on a traditional reinforced Concrete wall.

The load capacity of the bolt anchored with bits shall be limited to the thickness of the concrete layer on the inclusion area, which is equal to 35 mm for M2 walls.

For fixings to a side, the maximum capacity for each one shall be given by the following chart:

Fixation Diameter mm	N adm Kg
8	102,00
10	127,50
12	153,00
14	178,50
16	204,00
18	229,50
20	255,00
22	280,50
25	318,75
30	382,50

The formula used is: N = fcd x e x Φ / 4, corresponding to the compression on the projection of the bolt area over the side of the concrete plus the translation torque of such cutting to the barycentre of the section.

If the loads were accidental, the admissible values could be increased up to the maximum stress on the edge equal to the concrete design resistance; in this case, the corresponding chart shall be as follows:

Fixation Diameter	N adm
mm	Kg
8	120,00
10	150,00
12	180,00
14	210,00
16	240,00
18	270,00
20	300,00
22	330,00
25	375,00
30	450,00

For greater concentrated loads, we may recur to the passing bolt that can be designed to uniformly compress the section of each side into the calculus stress; in this case, the fixing capacity chart changes, for example, for an EPS thickness of 90 mm (PN 90) into:

Fixation Diameter	N adm
mm	Kg
10	390,92
12	469,11
14	547,29
16	625,48
18	703,66
20	781,85
22	860,03
25	977,31
30	1172,77

Analogously to the fixing of only one side, the load capacity expression results from the combination of the cutting, as normal stress on the bolt section, plus the stress originated by the translation torque of the cutting force to the barycentre, in this case, of whole wall, that is to say, with its total thickness.

For greater levels of localized efforts, those areas coinciding on the fixing may be filled up so as to increase the cutting capacity of the bolts, limiting the contact pressure to the values indicated. Likewise, and similarly to what is applied for fixings on one side, for extraordinary or accidental loads, the calculated values may be increased on the 1 / 0.85 = 1.176 ratio, i.e. 17.6 %.

12 BI-DIRECTIONAL SLABS

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When M2 plates are leaned on their four edges and the ratio between the smallest side and the biggest side is between 0.5 and 2, they constitute plates that function as thin bi-directional sheets that transfer link reactions to the support perimeter; and, therefore, that generate flexor momentums on the two directions, x and y. They may be solved applying the elasticity theory for the equation of the thin sheets for the outline conditions corresponding to the external link conditions; or also, by means of simplified methods emerging thereof.

The criterion used is to arrange the same bars section of the master direction for the secondary direction.
If considering only the corrugated bars, it is as follows:
Fe x (cm2/m)   =   1.05 cm2/m
Fe y (cm2/m)   =   1.13 cm2/m (applying 1Φ 6 per each 25)

12.1 BI-DIRECTIONAL PLATES AS ENCLOSURE WALLS

If in the calculus of the useful load, the admissible Momentum of the symmetric double section of 3.5 cm thickness of the mortar is taken into account and the eigenweight of the plate is not discounted because the structural element is arranged vertically; the admissible horizontal loads are obtained for the M2 elements used as enclosure walls that include the safety coefficients.
Similarly to the previous case, only the instantaneous deformation is limited to the L / 250 value.

13 CALCULATION CRITERION

In order to obtain the loads and dimensioning of structural elements, the CYPECAD computer information program is used.

The calculation of **M2 supporting walls** has been assimilated to the performance of a loading wall of the CYPECAD program, which is defined by the manual as follows: "They are vertical elements of any transversal section, formed by rectangles between each floor, and defined by an initial level and a final level. The dimension of each side may vary in each floor, and its thickness may be decreased in each floor. […]. Both beams and slabs

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and pillars are joined to the walls along their sides in any position and direction. The thickness taken into account for the calculation is that effective value for the concrete, which is of 7 cm (3.5 cm each side) in our walls.

All joints correspond to some node of the triangles.

The discretization made is for thin elements like three-dimensional thick sheet, considering the deformation by cutting. They are formed by six nodes, on the vertexes and on the midpoints of the sides, with six degrees of freedom for each one. They have triangular shape and a wall mesh is made according to the dimensions, geometry, and openings, resulting on a mesh with perfecting on critical zones, which reduces the size of the elements around the angles, edges and singularities."

CYPECAD allows the modification of mechanical parameters of manufacturing walls, so as to introduce them according to the values of the M2 Panels as shown herein below.
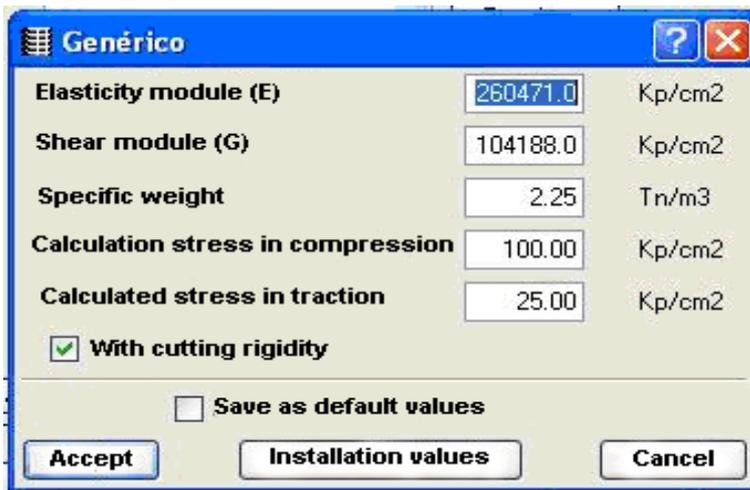
Slabs with single M2 panels are assimilated to the "solid slab" element of the CYPECAD program with thickness equal to the mortar and concrete amount included in the panel, for the slab to have a weight similar to that of the M2 panel in the calculation process.

This assimilation is made to consider slabs as elements that transfer different loads to the walls forming the structural framework, and not to dimension or calculate their frameworks and deformations.

According to the program, "the discretization of solid slabs stretches is performed on meshes of rod-type elements with maximum size of 25 cm, and a static condensation (exact method) is made on all degrees of freedom. The deformation of the cutting is taken into account and the hypothesis of the rigid diaphragm is sustained. The torsion rigidity of elements is considered."

As mentioned in the text of the Technical Aptitude Document, slabs support the actions described on the charts submitted by the manufacturer.

13.1 CYPECAD

Regarding Cypecad, we may state that it is a structural calculation program that analyses loads through a 3D spatial calculus, by rigidity matrix methods, forming all the elements that define the structure: Pillars, reinforced concrete curtains, walls, beams and slabs, and that have been selected because they are widely spread among the Spanish professional community. Therein, the deformations compatibility of all joints is stated, considering 6 degrees of freedom, and the non-deformability hypothesis of the plane on each story is created to simulate the critical performance of the slab, avoiding relative movements between joints thereof (rigid diaphragm). Therefore, each story may rotate and move as a whole only (3 degrees of freedom).

The consideration of the rigid diaphragm per each independent area of a story is sustained, even if beams, but not slabs, are introduced on the story.

Whenever there are independent areas on a same story, each one shall be considered as a different part for the non-deformability of that area, and the whole shall not be taken into account. Therefore, stories shall perform like independent non-deformable planes. A not connected pillar is considered as independent area.

For all cases of load conditions, the static calculation is made (except when dynamic actions are considered due to earthquakes, in which case, the spectral modal analysis is used); and it supposes a lineal performance of materials, and, thus, a first-order calculus to obtain movements and loads.

13.1.1 Structural schematisation and calculation criterion of loads

The program schematises the structure from the foundation, admitting different supporting planes, foundation plates, even with foundation ribs, footing and beams on solid elastic by Winkler's method, of reinforced concrete vertical elements, pillars and walls, also with openings, of floor plates made of horizontal and inclined slabs (gable roof) with floor beams; prismatic elements may be also be inserted, made of mezzanine reinforced concrete with the option to be connected on the inclined plane to slabs placed at different levels.
Regardless of the calculation algorithm used, structural joints may be connected only to beams, pillars and walls, simulating infinitely deformable slabs on the plane; or to plate elements with the thickness selected by the user, simulating finite rigidity slabs.

If SAP80, SAP90, and the INTERNAL SOLVER are used, joints placed on horizontal slabs may be rigidly connected to a master joint on the slab plane that normally coincides with the centre of mass; this option allows reducing the manufacturing times and eliminates the numeric approximation given in the use of plate elements when the infinitely rigid plane analysis is selected.

For loads, on data entry stage, the user selects the building over-loads and eigenweight conditions, which combined with seismic actions of wind and thermal changes, applying the corresponding load increase and resistance decrease coefficients, result on the necessary verifications.

The eccentricity effect of horizontal loads, by Rule or by the presence of torsion momentum at the plane by constructions on the seismic hazardous area, is simulated introducing loading conditions from the introduction of eccentricities and added to the previous ones, and combined with the rest according to the criterion stated on the preceding item.

Uniformly distributed vertical loads and trapezoidal loads can be inserted on beams and walls; on joints of unions of "beam" elements, components of stress and torque concentrated on any direction on the space are also definable. Temperature distribution may be inserted, with the intensity selected by the user, also on parts of the structure.

The loads calculation designed by Cypecad is based on the following hypothesis and types:
- foundation beams on elastic ground by Winkler's method are divided on stretches (minimum of 4). Joints are connected to the ground by means of springs with rigidity to vertical translation;
- footing on elastic ground constitute, structurally, elements of points with springs that show rigidity to the vertical translation and rotation around horizontal axis of global reference;
- foundation plates are discretized on a finite number of plate elements, where joints are connected to the ground by means of springs with rigidity to vertical translation.
The calculation of the seismic effects is solved by means of the EQUIVALENT HORIZONTAL STRESS METHOD or ELASTIC DYNAMIC ANALYSIS METHOD according to NSR '98 and by the percentage control of excited masses which, in the case of solids declared rigid, are concentrated on the master joint ; in the case of ground declared flexible, masses are considered with diffusion on joints located on the same ground.

In the case of the seismic analysis, mezzanine movements are also controlled.
User may also select the earthquake with the American Standard according to UBC '94.

13.1.2 Verifications of the Structural Elements

Walls are always designed by skewed flex-compression. Footing is designed by the static scheme of projections with embedding on the side of the pillar or on the axis of the pillar. For foundation plates verifications, calculation momentums may be inserted, modified according to the Eurocode Standards, Appendix A.2.8.

Anchorages of structural reinforced concrete elements are designed considering the normal effective stress of every rod on the verification section, dividing the anchorage areas of good and bad bond. Particularly, the program assesses the normal stress every rod may absorb on a section, developing the bond, the cylindrical surface placed at the left or the right of the given section; if on one section a rod absorbs by effect of the bond of a normal stress lower than the admissible one, its contribution to the total area is reduced by the program by means of the ration between the normal stress the rod may absorb by effect of the bond and the one admissible.

Verifications are made as from the equivalent steel areas so designed, that shown on the calculation memory.

Verifications of steel structural elements (only for STEEL CYPECAD users) are made according to the Italian Codes CNR 10011 and CNR 10022, the European Eurocode EC3, and the American Standard AISC ASD/LRFD. Instability and resistance verifications may be performed.

Verifications are distinguished between normal and exceptional stress conditions (I and II) or according to the various selected Codes.

The program performs verifications of connection elements as bridle-square-sheet of reticular or lap-joint base.

Special attention required on execution areas of doors and windows. These are to be avoided on enclosure corners (except supporting calculation thereof) and their maximum dimension shall be limited to the calculation, properly reinforcing these areas by means of additional frameworks.

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13.2 CHARTS SUPPLIED BY THE MANUFACTURER: SLABS.

Slabs are calculated as a continuous solid of reinforced concrete, where the section at highest or exhaustion limit condition has reached a deformation of the most compressed fibre of the concrete of a value equal to 2‰ and the steel has reached the deformation corresponding to its highest limit of 10‰. Therefore, the section shows a breakage by frameworks traction and a great deformation.

In order to control this deformation, it is considered for the calculation that the longitudinal elasticity Module of the compound section is equal to 3000 MPa, although in fact, it has a greater value that naturally increases as the solidity index increases on the compound plates up to values close to 8000 MPa.
The highest momentum corresponds to the result of the frameworks tractions multiplied by the elastic z arm of the section. Values corresponding to the exhaustion momentums of each type of panel are perfectly indicated on the charts.

Manufacturer's charts allow knowing, in each type of panel and for each case of light between supports and bay openings shape, the values of total maximum stress that verifies the deformation conditions imposed by the EHE (Structural Concrete Code), the values of the cutting stress, the admissible total load, and even the values of the normal traction and compression stress on the fibre most remote from the neutral axis, both in cases of slabs with **unidirectional** performance and on the case of slabs with **bi-directional** performance. (Reinforcements with corrugated rods of 6mm may be used on the secondary direction to obtain bi-directional plates that may be verified on the corresponding charts).

The thickness of the compression layer may be of 5 cm minimum and may be changed according to the calculation requirements.

14 MECHANICAL CAPACITY OF NORMAL PANELS

Although EPS normal panels are not used for structural uses because of issues inherent to the EHE's provisions, they have a mechanical capacity that is a function, like on reinforced panels, of the industrial mortar section and of the frameworks amount.

Generally, these panels are finished on the site with industrial mortar featuring a fck = 16 MPa resistance, called Normal M2 mortar, with the following hardening curve:

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Normal MK2 mortar hardening curve
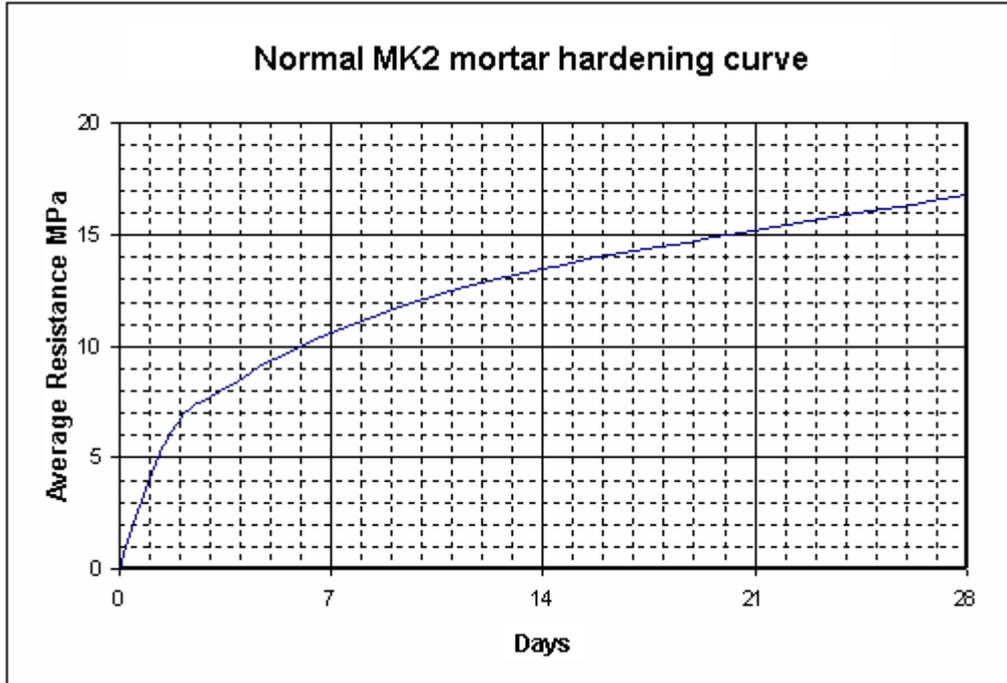
Since frameworks are constituted by galvanized flat rods of 2.5 mm diameter and a fyk = 650 MPa resistance, we can draw their respective interaction diagrams with the same criterion used for drawing the reinforced panels diagrams.

Therefore,

$$N\,u = \quad 0.85 \times b \times h \times f\,cd + As \times f\,yd$$
$$x\,\text{lím} = \quad 0.259 \times d$$

f ck =	160,00 Kg/cm2		f cd =	106,67 Kg/cm2
f yk =	6500,00 Kg/cm2		f yd =	5652,17 Kg/cm2

A s = 0,87 cm2/m

δ = d' / h
A total 1,75 cm2/m

Effective rec = 3,50 cm
Calculation rec = 3,50 cm
d' = 2,4 cm

Safety coefficients adopted for this analysis:

γ G =	1		
γ c =	1,5	1,5	1,6
γ s =	1,15		

γ tot = 1,725

AXIL v	α1	α2	α3
0,10	-0,09	2,01	2,00
0,20	-0,15	1,99	2,06
0,30	-0,19	2,00	2,00
0,40	-0,20	1,96	2,19
0,50	-0,18	2,05	2,17
0,60	-0,15	2,15	2,03
0,70	-0,11	2,26	1,89
0,80	-0,05	2,30	1,76
0,90	0,03	2,31	1,62
1,00	0,12	2,31	1,49
1,10	0,21	2,32	1,38
1,20	0,30	2,32	1,27
1,30	0,39	2,33	1,18
1,40	0,48	2,33	1,10
1,50	0,58	2,33	1,03

PANEL TYPE	eps cm	rec cm	b cm	h cm	d cm	δ	ω
PN 40	4	3,50	100	11	8,60	0,22	0,084
PN 50	5	3,50	100	12	9,60	0,20	0,077
PN 60	6	3,50	100	13	10,60	0,18	0,071
PN 70	7	3,50	100	14	11,60	0,17	0,066
PN 80	8	3,50	100	15	12,60	0,16	0,062
PN 90	9	3,50	100	16	13,60	0,15	0,058
PN 100	10	3,50	100	17	14,60	0,14	0,054
PN 110	11	3,50	100	18	15,60	0,13	0,051
PN 120	12	3,50	100	19	16,60	0,13	0,049
PN 130	13	3,50	100	20	17,60	0,12	0,046
PN 140	14	3,50	100	21	18,60	0,11	0,044
PN 150	15	3,50	100	22	19,60	0,11	0,042
PN 160	16	3,50	100	23	20,60	0,10	0,040
PN 170	17	3,50	100	24	21,60	0,10	0,039
PN 180	18	3,50	100	25	22,60	0,10	0,037
PN 190	19	3,50	100	26	23,60	0,09	0,036
PN 200	20	3,50	100	27	24,60	0,09	0,034

Advanced Building System

Interaction Diagrams PN 40 to PN 100

Nd (T/m)

Md (Tm/m)

— PN 40 — PN 60 — PN 80 — PN 100

Interaction Diagrams PN 120 TO PN 200

Nd (T/m) vs Md (Tm/m)

Legend: PN 120 — PN 140 — PN 160 — PN 180 — PN 200
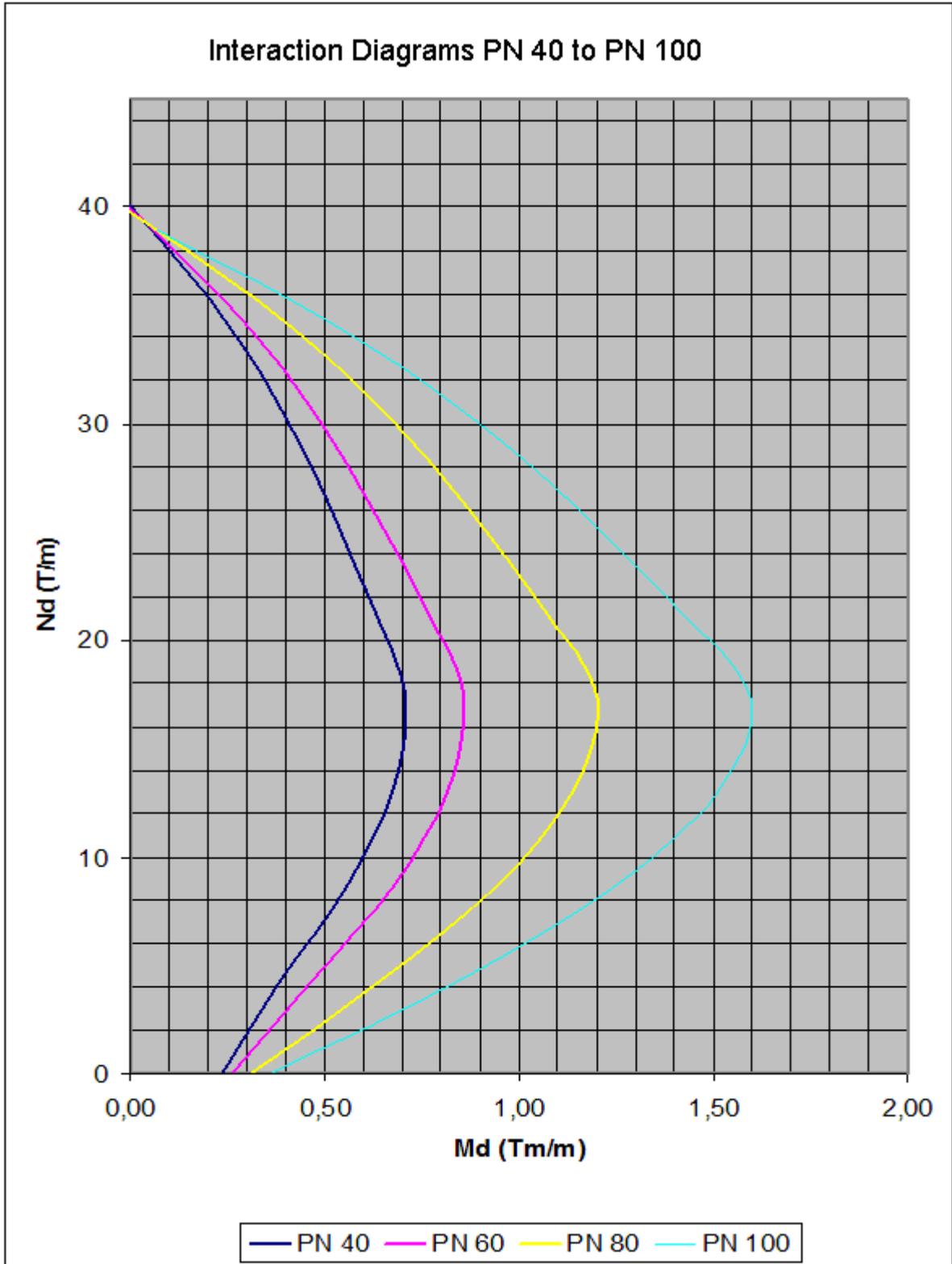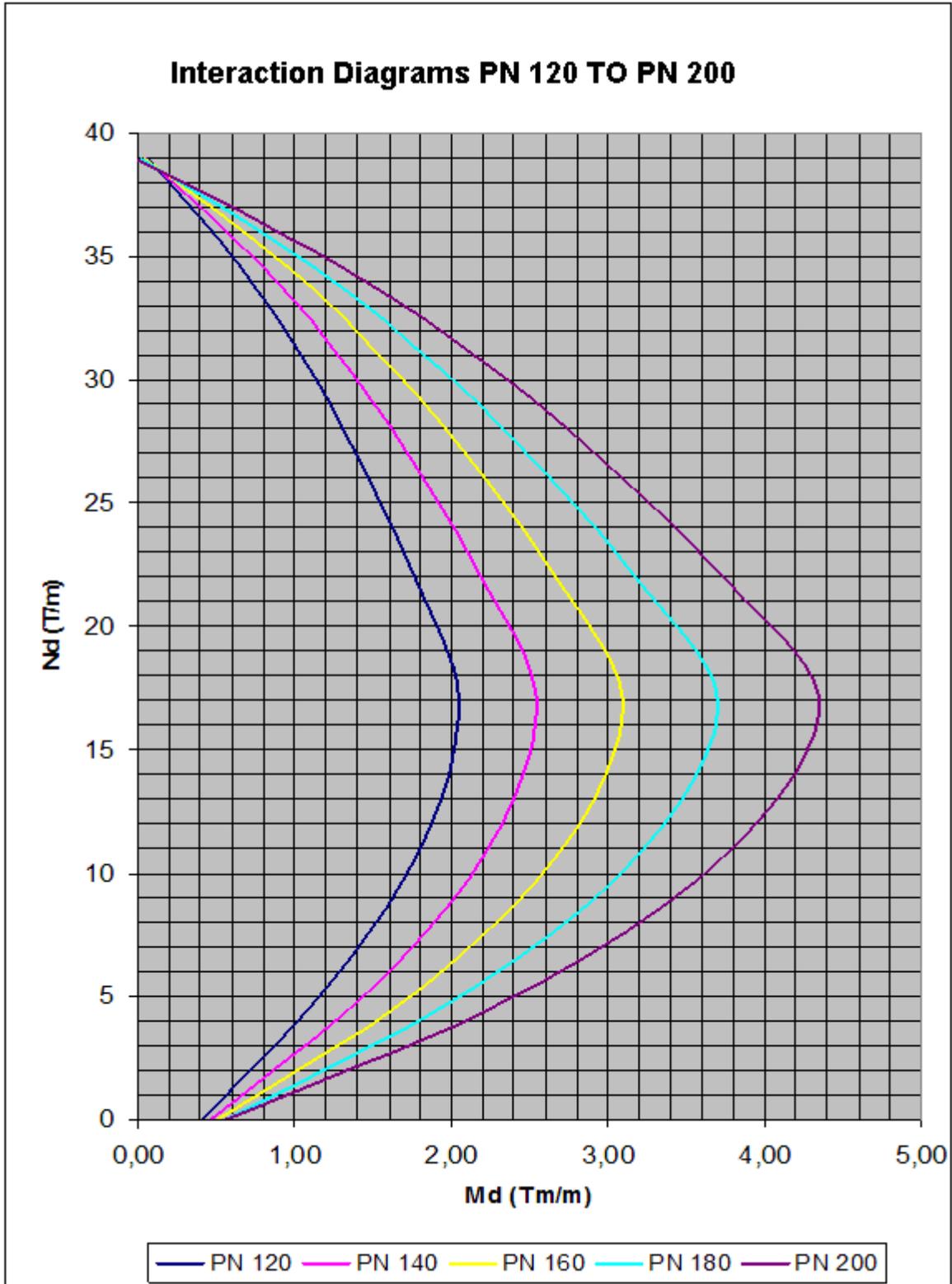
15 LABOUR FORCE YIELD IN THE M2 SYSTEM

Labour force yield on the M2 system are correctly adjusted to the following scheme, where secondary tasks constituting each activity have been disintegrated.

We have divided them into two basic types, which are the use as simple vertical enclosure within structures performed by the pre-manufactured or traditional system, or the integral use as supporting system contemplating resistant elements, both vertical and horizontal.

These yields are quite rough estimates of the reality and enough for the works planning. Naturally, on repetitive works, the labour force shall be trained and the indicated yields may decrease between a 30 and a 40%, although those characteristics peculiar to each type of work may be always evaluated.

It is very important to take into account the volume of the work regarding the times of the work. It is highly convenient to divide workers on operating groups like modules that shall be increased proportionally to the working plan.

These teams shall be fixed (as long as possible, and regarding their performance and yield), obtaining this way automation based on the repetition of tasks.

The partial use as single enclosure element results on a yield of 0.208 mh/m2 or its inverse of 4.8 m2/mh. Whenever the enclosure is on continuous blind walls of up to 12 m height, as in the case of the industrial premises division, yield values increase up to 0.10 mh/m2, that is to say, 10 m2/mh

Tasks inherent to the placement of M2 panels as enclosure may be disintegrated on 4 activities:

15.1 PARTIAL USE AS VERTICAL ENCLOSURE

Panels assembly

Personnel required	1	official
	2	assistants
Yield	9	m/hora
	23,4	m2/hora
	0,128	**hh/m2**

Reinforcement meshes placement

Personnel required	2	assistants
Yield	16,875	m/hora
	43,875	m2/hora
	0,046	**hh/m2**

Plumbing and alignment

Personnel required	1	official
	1	assistant
Yield	22,5	m/hora
	58,5	m2/hora
	0,034	**hh/m2**

0,208 hh/m2

Mortar projection and surface leveling

Personnel required	1	official
	1	assistant
Yield	25	m2/hora
	0,080	**hh/m2 cara**

TOTAL M.O.	0,368	hh/m2

When the M2 systems is used integrally, above-mentioned assembly yields decrease due to the need of greater bracing and shoring because of the lack of elements of the existing structure.

It is highly important the perfect setting-out of walls, and it must be taken into account that the shoring and alignment elements shall be correctly grounded and designed to properly support wind and assembly loads.

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15.2   TOTAL USE LIKE CLOSING AND STRUCTURE

Vertical panels assembly

Personnel required	1 official	
	4 assistants	
Yield	11,25 m/hora	
	29,25 m2/hora	
	0,171	h h/m2

Reinforcement meshes placement

Personnel required	2 assistants	
Yield	4,5 m/hora	
	11,7 m2/hora	
	0,171	h h/m2

Plumbing and alignment

Personnel required	1 official	
	1 assistant	
Yield	9 m/hora	
	23,4 m2/hora	
	0,085	h h/m2

}   0,501   hh/m2

Assembly of forged

Personnel required	1 official	
	4 assistants	
Yield	6,75 m/hora	
	27 m2/hora	
	0,185	h h/m2

Mortar projection, forged bottom side – 1st layer

Personnel required	1 official	
	1 assistant	
Yield	6,75 m/hora	
	27 m2/hora	
	0,074	h h/m2

Mortar projection, forged bottom side – 2nd layer

Personnel required	1 official	
	1 assistant	
Yield	4,5 m/hora	
	18 m2/hora	
	0,111	h h/m2

Compression layer concrete casting

Personnel required	1 official	
	5 assistants	
Yield	25 m/hora	
	100 m2/hora	
	0,060	h h/m2

Mortar projection and surface leveling

Personnel required	1 official	
	1 assistant	
Yield	25 m2/hora	
	0,080	h h/m2 cara with continuous machine

TOTAL M.O.	0,759	h h/m2

16 CONTROL PROTOCOL OF M2 WORKS

16.1 AUTHORIZATION VERIFICATION OF THE COMPANY EXECUTING THE BUILDING

It shall be verified that the company executing the assembly and mortars applications works has the written authorization issued by Emmedue in compliance with the local regulations. The commencement of works shall not be authorized without the corresponding authorization issued for a work of similar type.

16.2 VERIFICATION OF SETTING OUT

The approval of the record of setting out executed between the construction company and the project and site management shall be verified, with the walls thickness corresponding to each of their positions.

The final thickness of structural walls shall be equal to the thickness of the expanded polystyrene core (EPS) of the panel, plus the measure of screeds and plus 2.5 mm, which is the diameter of the transversal reinforcement of the wire mesh.

With 25 mm guides, the wall shall have an average thickness of total coating equal to 33.5 mm per each side; while with 30 mm guides, the average thickness shall be 38.5 mm per each side. This way, the final thickness of walls shall be:

25 mm guide: TOTAL WALL THICKNESS = EPS + 67 mm
30 mm guide: TOTAL WALL THICKNESS = EPS + 77 mm

16.3 PLACEMENT OF REBARS

Rebars shall be placed in front of wire meshes of each side. Therefore, the space between rebars sides shall be equal to:

EPS + 1.7 cm. It shall be better rounding down to 1.5 cm for those to be fixed against the wire meshes.

The longitudinal space between rebars is not fixed and the verification of the calculations recommended is to take up the maximum cutting at the base through them, considering a calculations resistance of steel f yc = 100MPa. In most cases, 50 cm can be used with staggered layout, since the cutting taken up by this section would always exceed the expressed condition. The penetration in the foundation shall be of 20 cm, and 35 cm shall protrude to be tied to the panels.

16.4 WALLS PLUMBING AND SHORING

It is convenient for longitudinal alignment to place a crossbeam of proper stiffness according to the wall length, and to shore it up to the ground. Steel square section pipes are recommended, which shall be verified for their correct line before placing

them in their positions, by leaning them on a flat surface so as to dismissed those with bends, that shall be transferred to the panels.

Crossbeams shall allow the placement of reinforcement meshes arranged at 45° on the arris of openings.

Crossbeams shall be always tied to the areas where double connectors are placed; if it is not possible, the panel with the ties shall be crossed to hold the crossbeam from the wire mesh of the opposite side.

Always verify that the braces be hammered to the ground, to support the wind load.

Plumbing tolerance shall be of 8 mm.

Panels may be mounted on the ground in groups of 3, 4, or 5 units, and after tying the flaps of the meshes and cutting the bay openings corresponding to the openings of the windows, they may be placed in its place.

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Internal partition walls shall be arranged preferably after placing the door frames, so that the load beams be settled with an etched panel that may be arranged both horizontally and vertically.

16.5 PLACEMENT OF ANGULAR AND FLAT CONTINUITY AND REINFORCEMENT MESHES OF ASSEMBLY

Auxiliary meshes are wire meshes stretches, manufactured in the same steel than the panels wire meshes, with rods diameter of 2.5 mm. These parts are used to obtain the necessary continuity of the EPS enveloping reinforcement, where it is interrupted by cut or change of direction.

They are manufactured with wire drawing and galvanized steel of high resistance:
    Yield limit > 600 MPa
    Breakage stress > 680 MPa

After aligning and plumbing all walls, angular continuity meshes may be placed covering all horizontal and vertical arris of the resulting dihedrons.
Note that after placing the angular reinforcement meshes, wall alignments and plumbing may not be corrected, due to the rigidity given by the transversal panels to the system, even during the stage prior to the assembly.
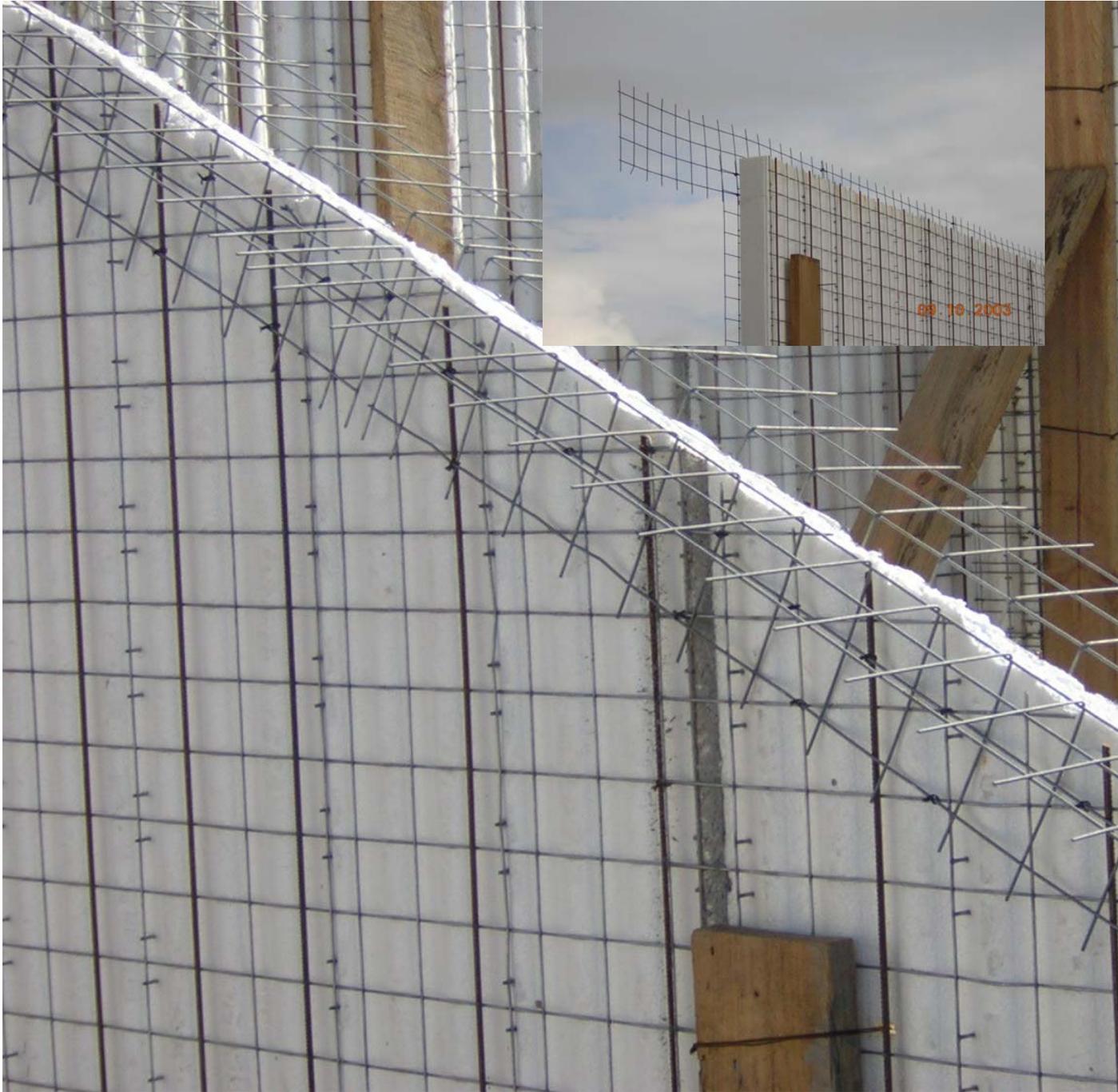
Angular meshes for slab sheets may be left in stand-by. Likewise, meshes for the continuity of the façade's vertical walls may be also left in stand-by.

16.6 PRODUCTION BINDING METAL BANDS

It is essential to follow the vertical continuity of concrete layers applied to walls, floor by floor, through the so-called "metal bands" that shall be settled according to indicated in the Technical Aptitude Documents No. 431, figures 5 and 6 of page 19, and No. 455, figures 6 and 7 of page 19.

No cementing of the compression layer shall be authorized without the verification of the correct execution of such "metal bands", with the reinforcement frameworks, as indicated in the above mentioned details.
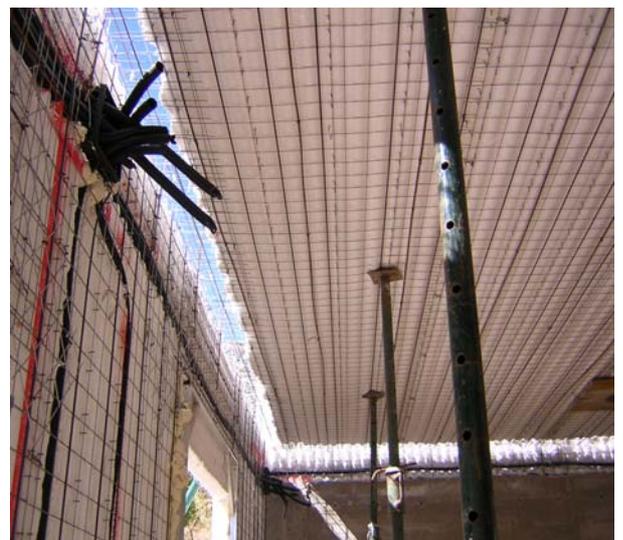
The picture shows the free space to be filled with concrete in the joint between the vertical panel and the slab. It just remains to place the 1 Φ 6 passing reinforcement separated according to the calculations of the cutting in the joint.
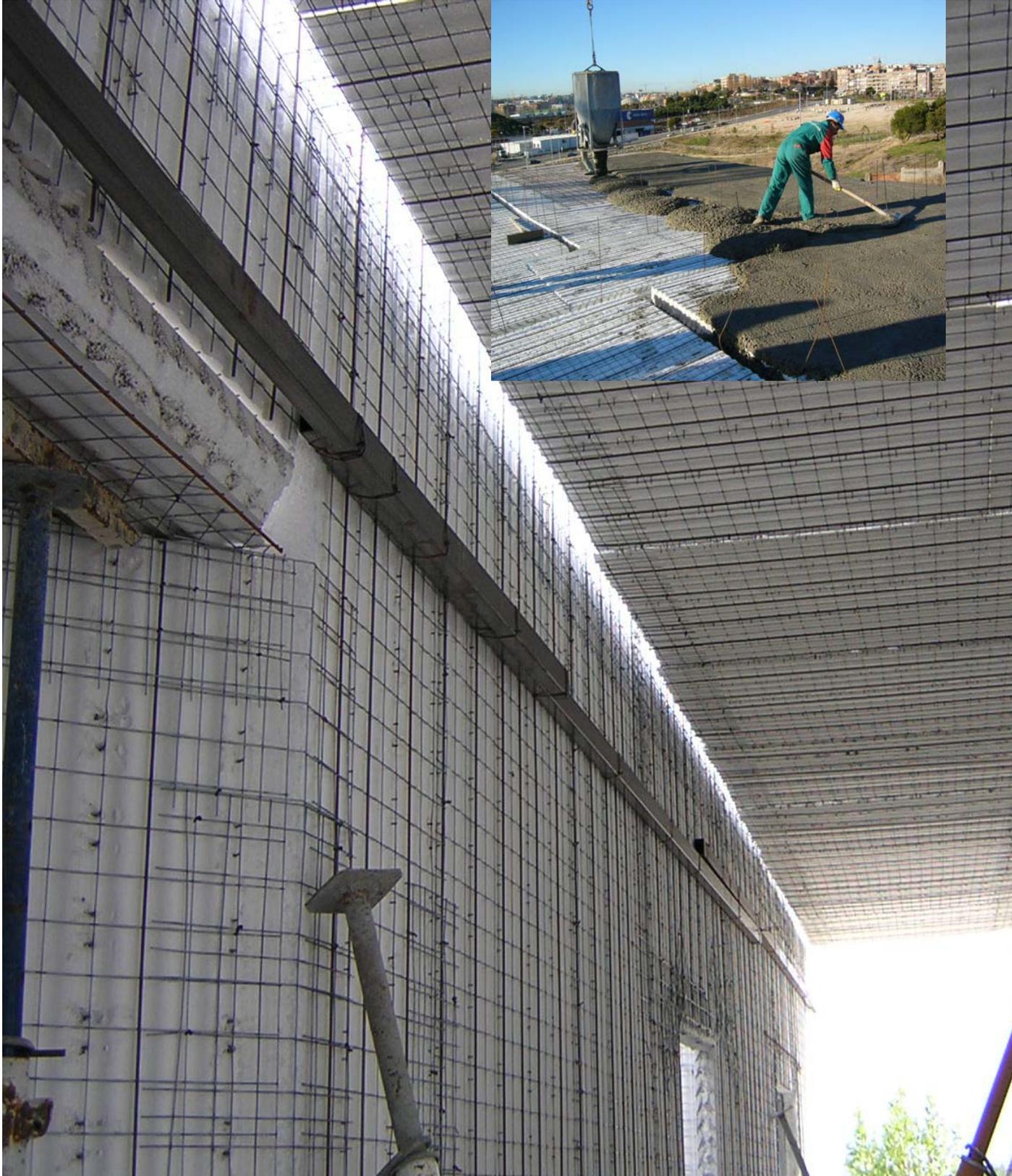
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The free space shall be at least of 60 mm, and it is recommended to be made with a greater looseness (between 80 and 100 mm) to guarantee no interruption of the load side on the EPS.

The angular connection mesh of the compression layer may be replaced with the wall of the upper story through straight passing rods from the lower floor, as shown in the previous picture, with a geometric amount equivalent to the steel section of the angular wire mesh.

16.7 PREPARATION OF INDUSTRIAL MORTAR

Before proceeding with the application of the structural mortar, a final verification shall be performed to control the correct placement of all and every panel, verifying the alignment and plumbing of them and the complete placement of all reinforcements of flat and angular meshes and corrugated steel reinforcing rods, according to what is stated in the previous items.

At this moment, an approval record shall be issued and the stage of micro-concrete application shall be authorized.

It is very important to guarantee that the built-in installations are placed in such a way that no groove opening be needed after application.

The first issue to be dealt with is the verification of the industrial mortar.
This must be manufactured by factories awarded with an officially recognized quality seal.

The supplier of the industrial mortar shall be required to submit the hardening curve of the material, which shall be had a breakage resistance of 28 days, greater than 20 MPa, and a certificate of inspection of the material covering the quality testing corresponding to the current month. The certificate of inspection shall include the sieve analysis curve of aggregates, compression testing on standard prismatic test tube of 40x40x160 mm, and the flex traction testing.

Upon approval of the material, there follows the gauging of the projection machine, according to the features of the industrial mortar available on site. This gauging consists of the regulation of the water content applied by the machine per time unit, and shall depend on the following characteristics:

1- Machine volume of flow
2- Apparent dry mortar weight
3- Water content recommended by the manufacturer
4- In case of using machines of double mixing, it shall be considered the amount of mortar the dosifier shaft can dragged from it.

In case of using the industrial mortar, the following expression shall be applied:

Water (litres/hour) = 12 x volume of flow (litres/minute)

For the double mixing machines with dosifier shaft of:

Volume of flow	Water
35 litres/minute	420 litres/hour
50 litres/minute	600 litres/hour

For single mixing machines:

Volume of flow	Water
18 litres/minute	216 litres/hour
20 litres/minute	240 litres/hour
22 litres/minute	264 litres/hour

For single mixing machines, PFT type G54 version, the indication shall be strictly followed with a tolerance o ± 5%. It is convenient to measure the volume of flow on the work with a bucket of known capacity so as to obtain the volume of flow expressed in litres per minute, which after being multiplied by the 12 constant shall allow obtaining the volume of flow in litres per hour to be used to adjust the machine hydrometer. This hydrometer is generally a graduated glass tube with a floating weight. A valve operates and regulates the water flow, as shown in the following picture:

Advanced Building System

Once this is regulated, it shall be controlled permanently. Every control visit must control the strict compliance with the stipulated regulation.

This way, the applied material shall have similar characteristics than the theoretical ones of the material produced in the central plant.

Every change of the regulation shall be expressly authorized by the M2 monitor assigned to the work. Said changes may depend on conditions of temperature, humidity, sun exposure, and winds on the site where works are being performed, and shall be aimed at maintaining the applicability conditions of the product regarding consistence and time of hardening.

It is normal that the change of manometric height of the application place in front of the machine position modifies the volume of flow of the mixed mortar, and thus the need of a new regulation that shall be always performed before an authorized technician.

The mortar mixed this way shall have a drainage measured at the vibrating table of 175 ± 5 mm.

16.8 APPLICATION OF INDUSTRIAL MORTAR

To guarantee the coating of reinforcement, metallic or PVC screeds are placed on the site, with measures according to the coating to be applied.
These screeds are generally steel square section pipes, with edges from 20 to 40 mm, according to the environmental Exposure Type corresponding to the works site.

Since the M2 technology is a pre-industrialized or pre-manufactured system, the totality of the panels used in the works are manufactured at the production plant under strict manufacturing controls and where the mortar application is only "on site", we may take into account the Chart 37.2.4 of the EHE (Structural Concrete Code), which clearly stipulates the coatings needed:

Coating margin: 5 mm
Minimum coating at Exposure Type I: 15 mm
Idem at Exposure Type IIa: 20 mm
Idem at Exposure Type IIb: 25 mm
Idem at Exposure Type IIIa: 30 mm
And so on, according to the order of the Chart.

Then, the nominal coating shall be equal to the sum of the minimum coating plus the margin:

Type I	20 mm
Type IIa	25 mm
Type IIb	30 mm
Type IIIa	35 mm
Type IIIb	35 mm
Type IIIc	40 mm
Type IV	35 mm
Type Qa	40 mm

Therefore, and taking into account the thicknesses applied on the wave of the panel, it results that for ordinary cases, and using 25 mm edge screeds leaned on the transversal base wire mesh (perpendicular to the wave), the 5 mm diameter coating of the master framework is equal to 20 mm, right up to Exposure Type I.
For Type IIa, 30 mm edge screeds are used, and so on, according to each case.

This way, the micro-concrete thickness to be applied is guaranteed, since the worker fills until cutting against the screed (screeded) with a working procedure totally familiar for any worker, even for the untrained.

The picture shoes the mark left by the screed and the thickness of the first layer on the right and of the second layer finished on the left.

The following picture shows a wall prepared with screeds of steel square section pipes:

85

++

The following is the application procedure after placing the screeds:

1- Before beginning one has to know all about the surface to be applied since the projection must be done without interruptions whenever possible.
2- The application at 3 or 4 cm shall be performed in 2 coats, leaving an opening in both cases to receive the finish product from time to time.
3- In the first coat, the product must be applied as much as possible without falling, for which a compressor of 400 litres per minute air flow is recommended, so the polystyrene "bites" and the product be as compacted as possible.
4- The second coat until the desired thickness is reached is done within a 48 hour interval. After 48 hours without doing so, a bond bridge must be applied.

Of the machinery available in the market, for the application of the product, because of its technical and design features, the MALTECH Plasterjet or PFT Cayman 30 are recommended.

As in all concrete, the hardening to which walls surface are subject is of vital importance. Correct curing consists in allowing for the process of hydration of the cement, avoiding evaporation of the remaining water, for which it is necessary to maintain superficial humidity by means of spraying with water, particularly during the first 24 hours after the second and definite micro-concrete coat is applied, and specially on those areas of greater exposure.

The mortar may be applied by complete sides, i.e. the two coats of the same side without applying the mortar on the opposite side, up to a maximum height of 5.50 metres.

For taller walls not braced to rigidity elements, it shall be proceeded by side up to 5.50 m so as to automatically balancing the loads of the eigenweight. On hot climates, and given the faster hardening speed, the application height of each side may be increased according to the criterion stated by the M2 monitor.

On slabs, it shall be shored using beam supports leaned on braces, which shall have a maximum space of 1.20 m between them.
Before shoring, mortar splatter shall be applied to the bottom side, as mordant.
The shoring shall secure a 2% light camber between supports.

After shoring, the first mortar coat shall be applied to the bottom side, which shall be enough to coat the reinforcements with average thickness of 20 mm.

Once this task is performed, the concrete may be applied to the compression layer, which shall be cured following the guidelines stated in previous paragraphs for walls curing.

According to the hardening curve of the applied mortar or concrete, and upon previous structural verification, the stripping of slabs may be performed to complete the second coat of the bottom coating, pursuant to the required coating specifications. Only for indicative purposes and for moderate lights, it may be stripped after 14 days.

The commencement of the mortar application shall not be authorized under room temperature below 5°C or whenever the person in charge of the M2 deems there is risk of freezing. No anti-freeze products and, in general, no type of additive may be used without the express approval of the manufacturer of the industrial mortar, because of the risk of a chemical reaction with any of the additive elements thereof.

Remember that slabs, during their assembly stage, may be exposed to suction forces of the wind and, therefore, they shall be correctly fixed to the floor, tying properly the beam supports to them. To calculate this fixing, there shall be considered a suction load of 40 Kg/m2 uniformly distributed.

16.9 CEMENTING OF COMPRESSION LAYER OF SLABS

The compression layer of slabs may be made in the same industrial mortar applied to the walls, or with the traditional concrete of the plant, which shall have an officially recognized quality seal.
It shall have a minimum thickness of 50 mm on the EPS wave. To guarantee this thickness, guide rules with this measure shall be placed during the cementing process.

16.10 QUALITY CONTROL AT THE BUILDING SITE

Concrete, both made at the works site and supplied from a central station that shall have the AENOR quality seal, shall be controlled according to the criterion established by statistical control. Upon concrete and mortar reception, the corresponding delivery note shall be required, being the testing performed by an independent authorized laboratory. For the control, the following parameters are set:

- Lot: Concrete provided or made at the works site during a week.
- Lot extension: 50 m3
- Quantity of mixings to be controlled: 2 mixings per lot.
- Quantity of test tubes per mixing:
3 test tubes for breakage at 24 hours.
3 test tubes for breakage at 7 days.
3 test tubes for breakage at 28 days.

Test tubes shall be moulded at the works site. Transportation of fresh concrete or mortar to external laboratory shall not be admitted, but samples shall be compulsory taken at the works site moulding the cylindrical test tubes of 15x30 or prismatic test tubes of 4x4x16, according to the concrete or mortar respectively, which shall be carefully cured and preserved until their breakage. This is to avoid segregation of components and hardening during transportation of the mixing to the mechanical testing laboratory.

Moulds of test tubes, particularly the prismatic ones, shall be dimensionally verified and shall belong to brand names with quality seal, for the moulded samples to be representative.

Taking of concrete samples shall be performed pursuant to UNE 83300:84.
Control testing shall be performed by laboratories complying with the stipulations of the Real Decree 1230/89 and enforceability provisions.

If concrete is supplied by a factory bearing an officially recognized Quality Seal, the reception control of their material components at the works site shall not be necessary. Otherwise, the following shall be verified:

- SAND
It shall be controlled at least once during execution of works or if supply conditions vary:
Granulometry
Maximum grain size
Fines content
Organic matters content
Other impurities.

- WATER
Mixing water shall comply with the stipulations.

- CEMENT
Cements shall comply with the Instruction RC-97 Standard for the reception of cement, and it shall be also certified by a quality brand.
Testing tubes for mortar shall be standardized of 40x40x160.
Consistence may be measured either in Abrams Cone or at the vibrating table.

Steel corrugated rods to place on the works shall be controlled according to the criterion set forth for the control at normal level. Upon concrete and mortar reception, the corresponding manufacturer's Guarantee Certificate shall be required, being the testing performed by an independent authorized laboratory. For the control, the following parameters are set:

- Batch:
Material supplied to the works once, from the same name and origin.

- Lot:
20 tons of steel of 6 mm diameter

- Lot extension:
20 tons

The following tests shall be performed on each lot:
Two verifications of equivalent section
Two comparisons of geometric features of ledges
Two verifications of bending-unbending
During the works, the following shall be determined at least in two cases, in a test tube of each supply:

Elastic limit
Breakage load
Breakage extension.

16.11 BUILDING SITE CONTROL PARTS

Each control visit to the building site performed by the M2 system monitor shall be certified by means of the "Works Revision Report".
Said report describes the essential aspects of the execution control with a rating. It shall be signed jointly by the Chief or Person in Charge of the Works and the M2 Monitor, who shall leave the original and take a duly signed copy. The company executing the works shall repair the defects marked, according to the special instructions or notes recommended by virtue of the corresponding records. These records are correlatively enumerated during each inspection to the work.

The company executing the works shall keep the totality of the records corresponding to the visits performed by the person in charge of Emmedue permanently in the technical office of the building site.

17 GENERAL CONSTRUCTIVE DETAILS

17.1 SECTION OF THE ENTIRE BASE PLATE
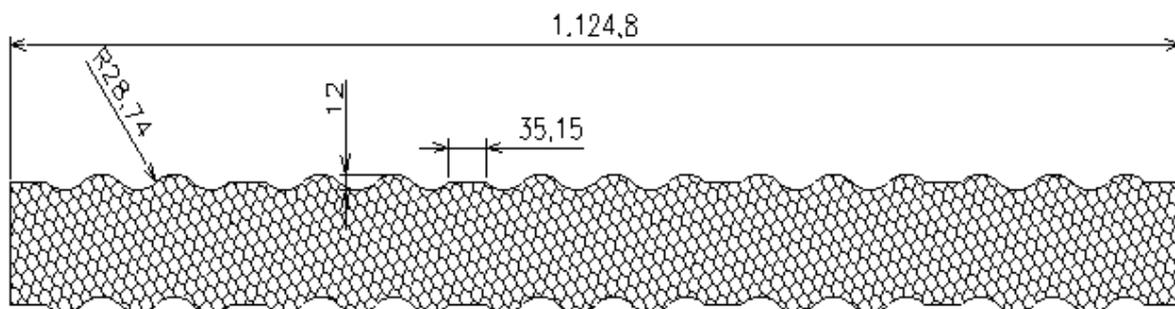
(Limits   in mm)

17.2 UNION BETWEEN WALL AND SLABS
The type of panel represented in the picture is merely indicative.
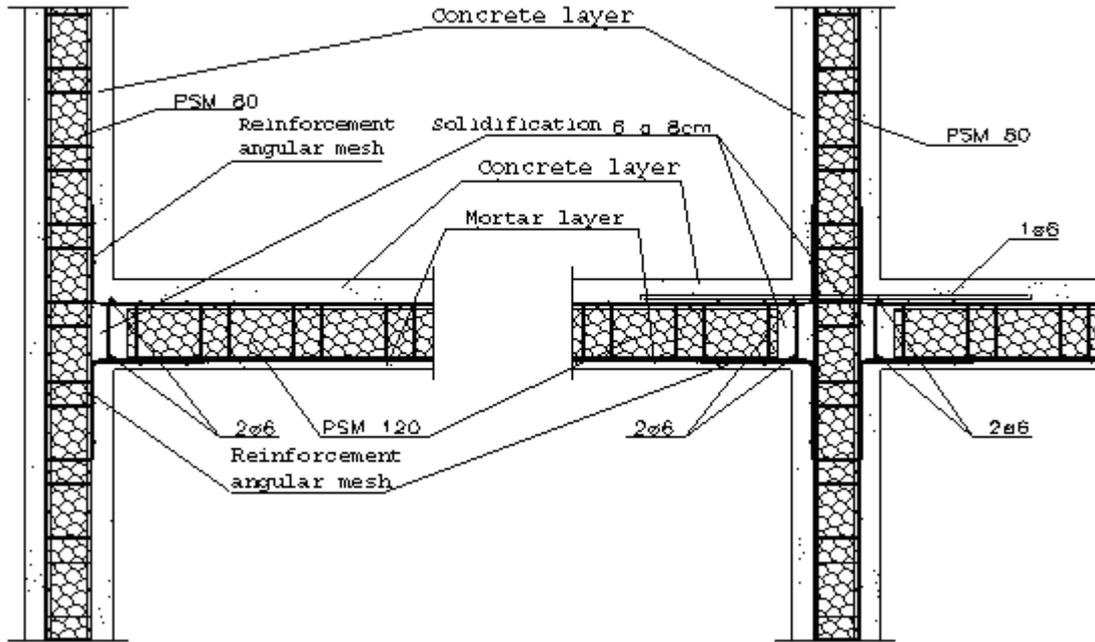
17.3 UNION BETWEEN WALL AND INCLINED DECK
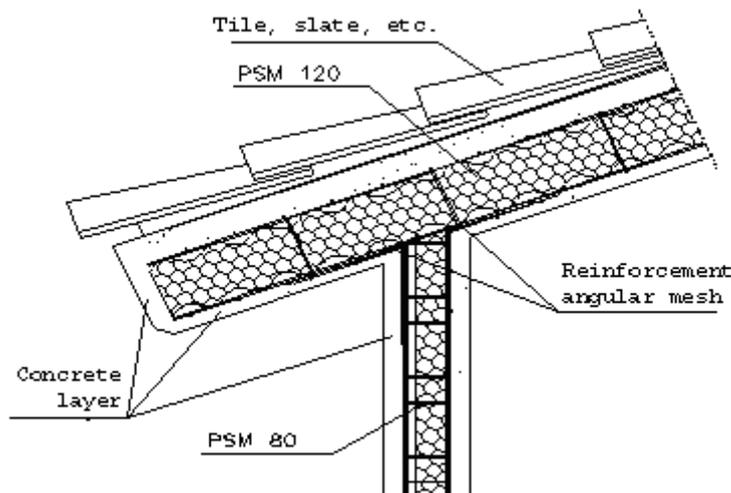
17.4 HORIZONTAL SECTION
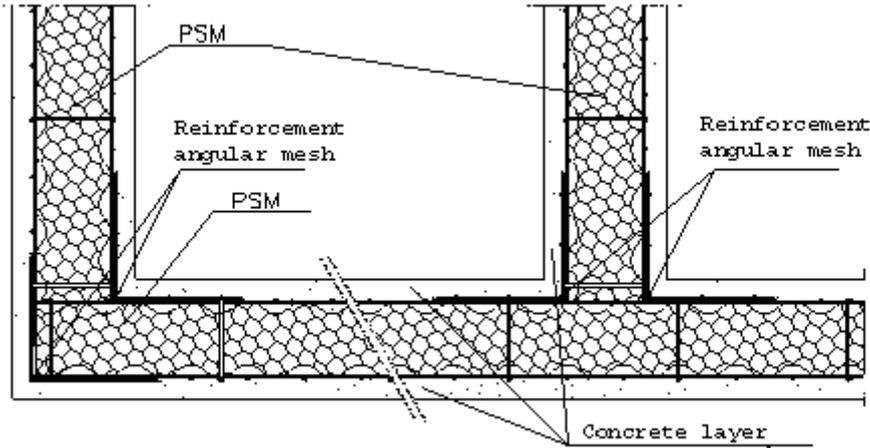
17.5 WINDOW OPENINGS

17.6 BLINDS

Concrete Layer

Solidi-
fication≥ a 8cm

Concrete Layer

Mortar layer

Reinforcement
angular mesh

PSM 80

Reinforcement
angular mesh

2ø6

Preframe
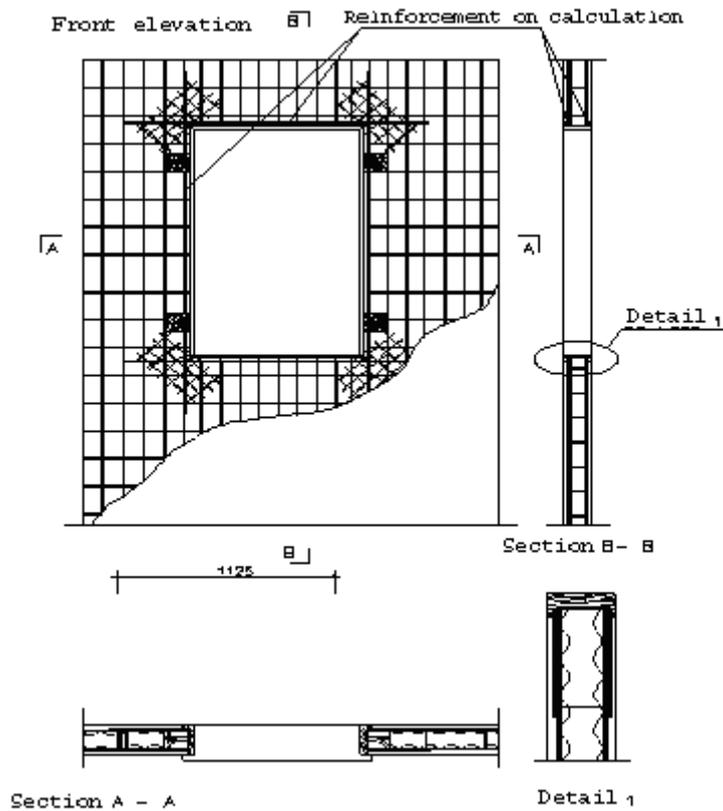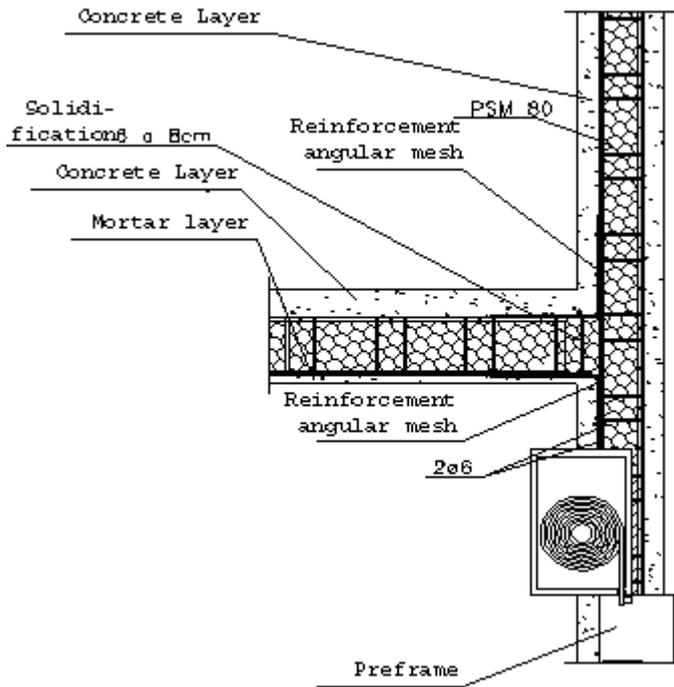
17.7 UNION TO THE FOUNDATION
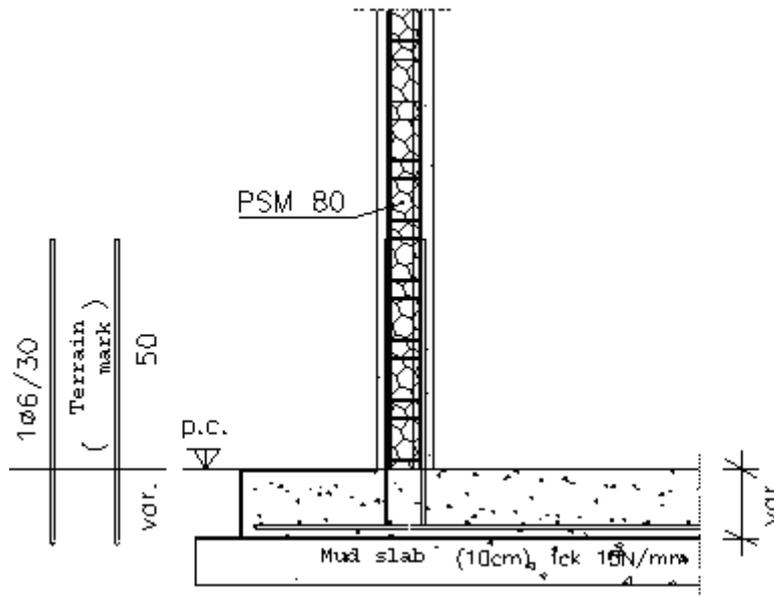
17.8 FOUNDATION WITH BUTTRESS
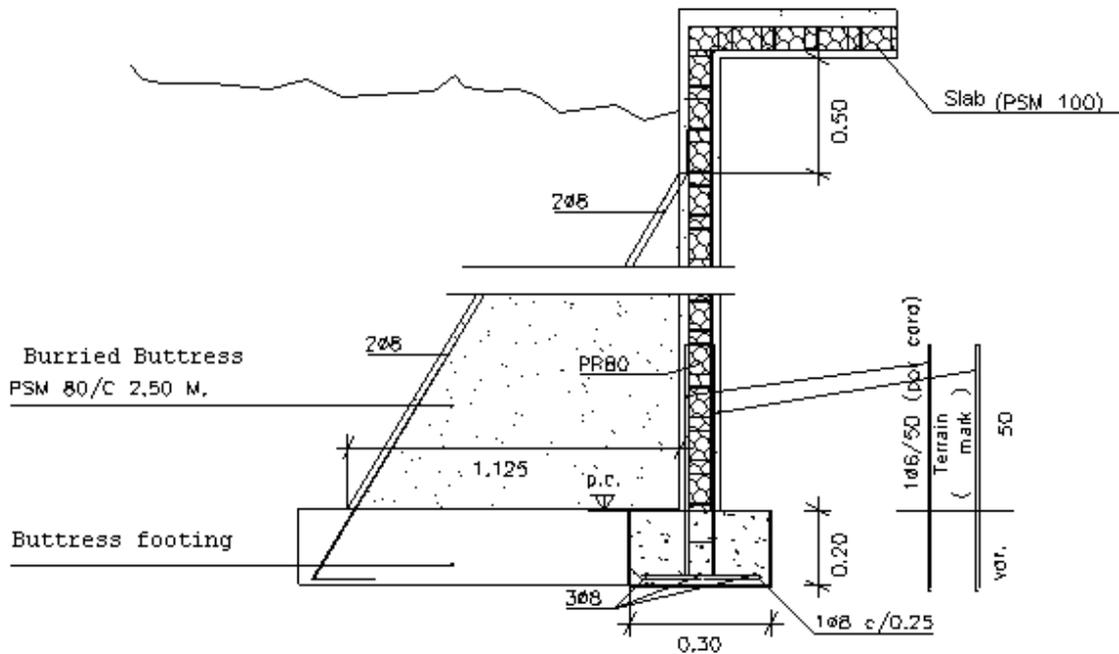
17.9 ANCHORAGE BETWEEN WALL AND FOUNDATION

800

800

PSM 80

400

1ø6 AL
Terrain mark
CADA 40 cm

350

550

200

250

Floor

Mass footing
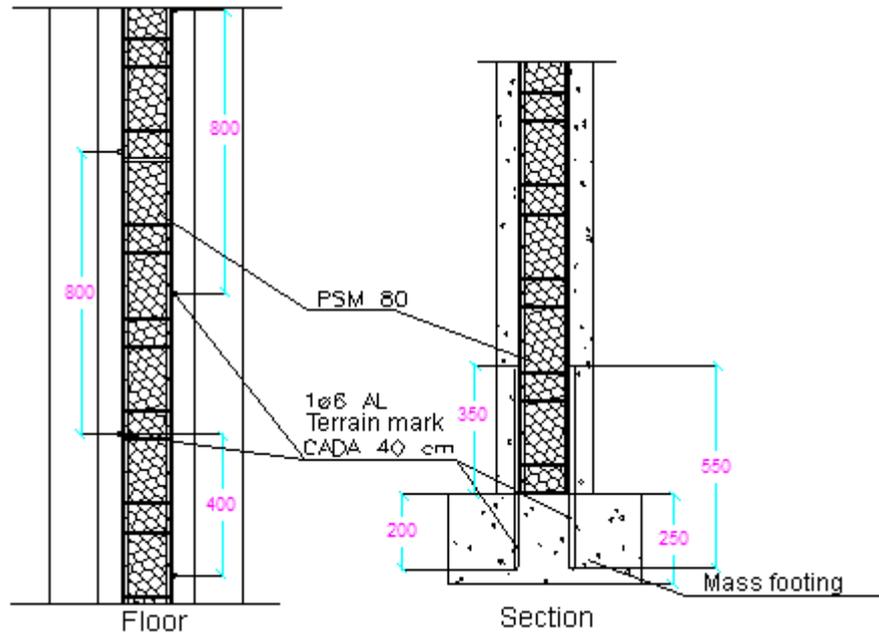
Section

17.10 DETAILS WITH ATTACHED HºAº CONTENTION WALL

EMMEDUE PANEL

Electro welded mesh
6 Ø 5 mm.

Electro welded mesh
6 Ø 5 mm.

Reinforcement with reinforced
concrete curtain e=15 cm

EMMEDUE PANEL

0.10

0.10

0.25
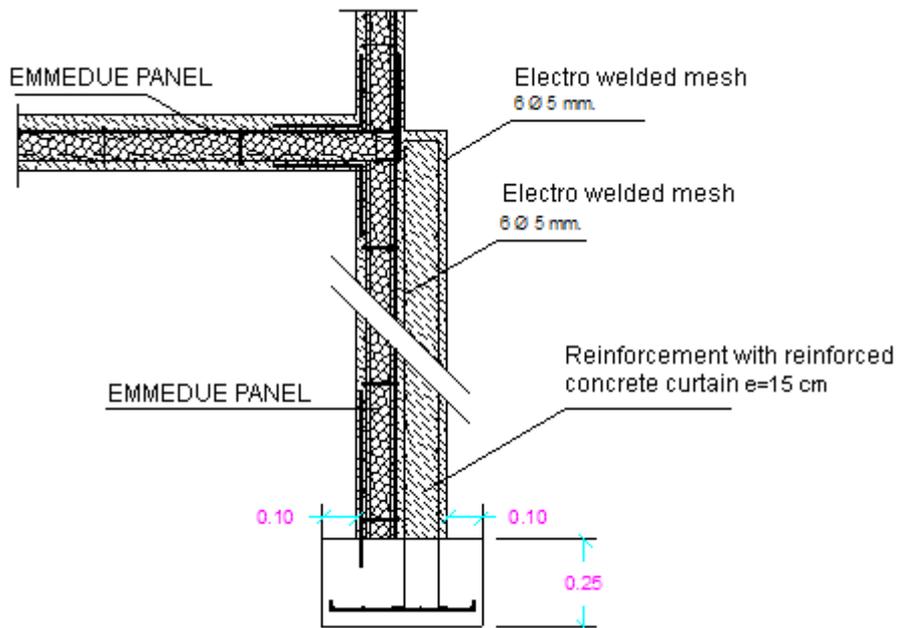
17.11 DETAIL OF CONSTRUCTIVE JOINT

PSM 60

Mono Layer

Mortar

2ø6

Extruded polystyrene or roofmate

100

Block 1

Block 2

Joint
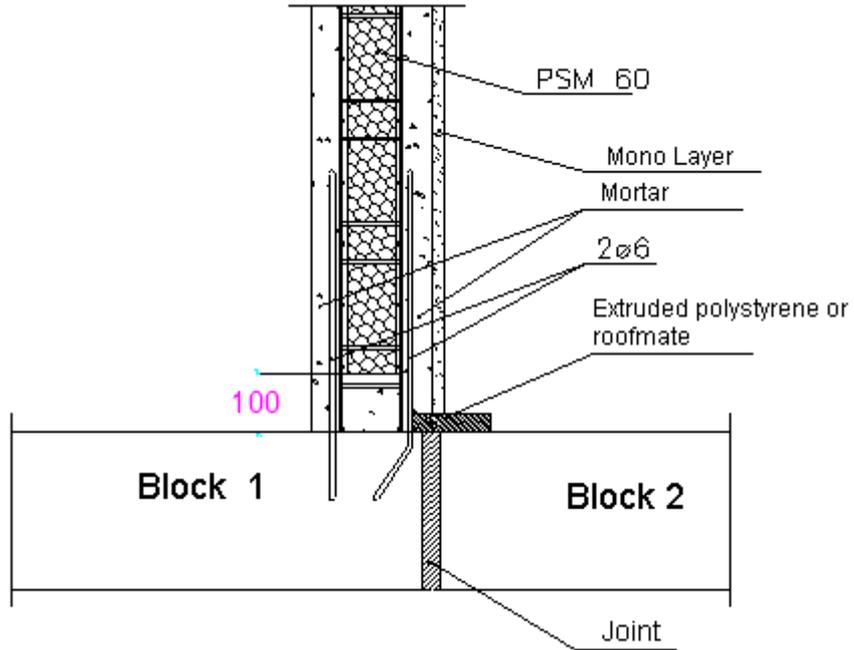
TYPE 1 UNION STAIRS WITH WALL

Concrete layer
Solidification from 6 to 8 cm
Concrete layer
PSM 80
Reinforcement angular mesh
Stairs panel
Concrete layer
Reinforcement angular mesh
Reinforcement angular mesh
2ø6   PSM 40
Mortar layer

Section by polystyrene

Concrete layer
Solidification from 6 a 8cm
PSM 80
Reinforcement angular mesh
Concrete layer
Stair rib Solidified to the top
Concrete layer
Reinforcement angular mesh
Reinforcement angular mesh
2ø6   PSM 40
Mortar layer

Section by stair rib

17.12 SLAB SUSPENDED FROM WALL ACTING AS BEAM

PSM 80

1ø6 c/30 cm

Angular mesh

PSM 150

1ø6 c/30 cm

400

2ø6

2ø6

Plane mesh

Solidification zone

Shear by the jamb of the door
(limits in cm)

PSM 80

Angular mesh

1ø6

1ø6 c/30 cm

2ø6

PSM 150

1ø6

(according to calculation)

2ø8 (according to calculation)

Plane mesh

Solidification zone
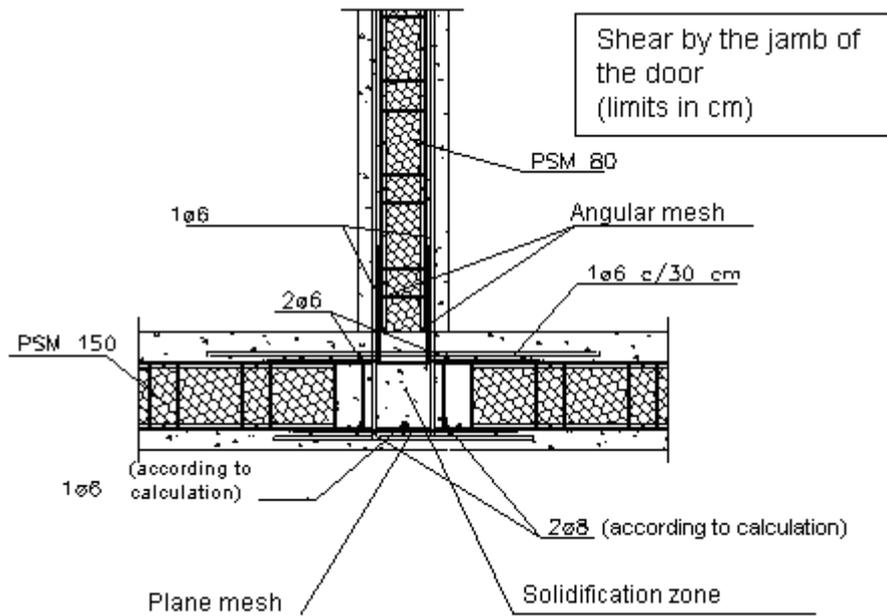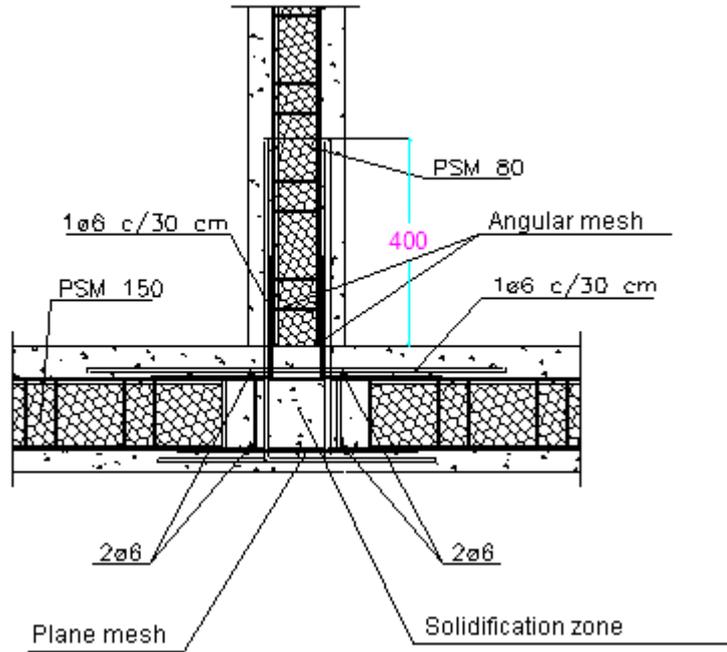
17.13 PANEL SUSPENDED FROM SLAB

Spheres
(Ø6 C/50)

Reinforcement mesh

Slab

Mortar

Supplementary EPS

Slab edge

(Limits in centimeters)
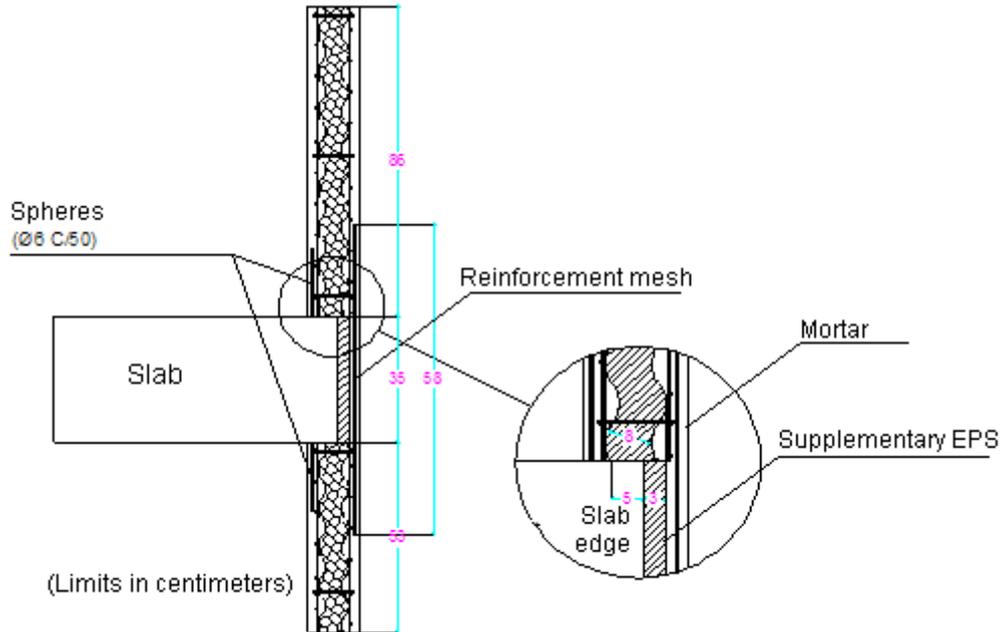
17.14 FIXING OF PANEL TO METALLIC PILLAR

2 cm.

30 cm.

17.15 PANEL PASSING THROUGH SLAB 1

(2Ø8)

15 cm.

Separator (3 cm.)

Slab

17.16 PANEL PASSING THROUGH SLAB 2

PANEL PSM 80

15 cm.

(Ø8 c/50 cm.)*

Slab

Separator (3 cm.)
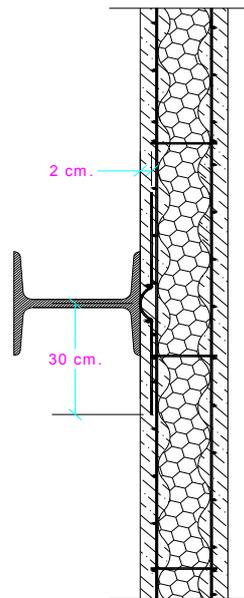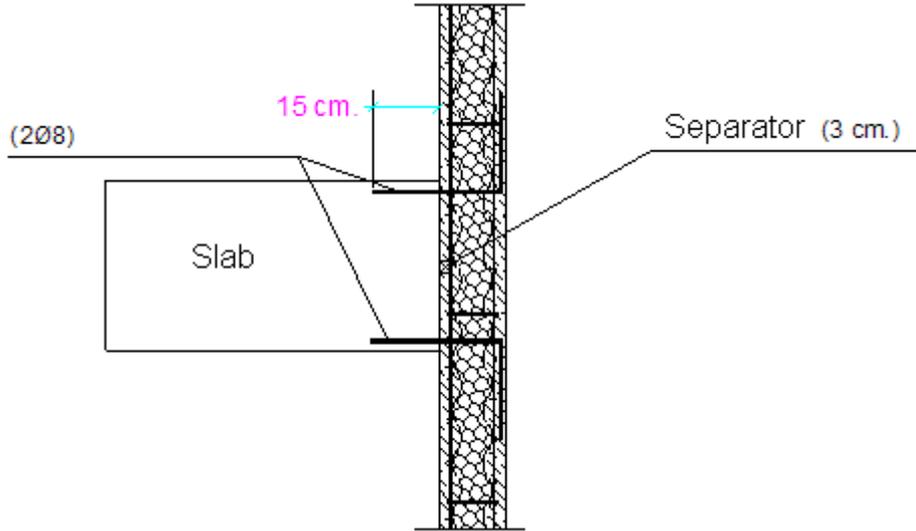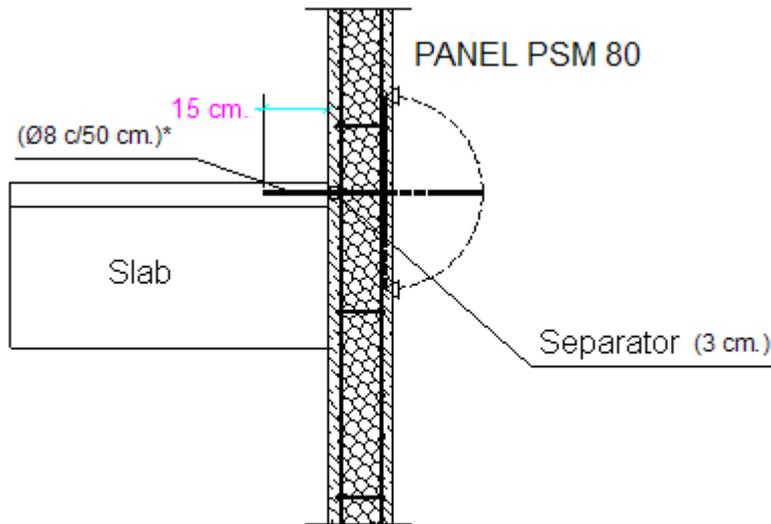
*They will bend alternatively upwards and downwards as
the one is in the detail.

17.17 PARTITION WALL BEGINNING IN SLAB

ø6   Terrain mark

PN 40

PR 150
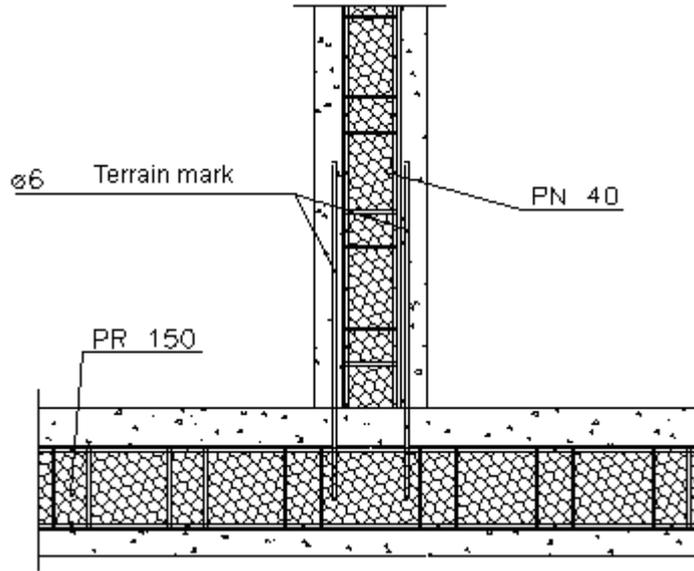
17.18 WALL PROJECTION WITH CONTINUITY

PSM 80

Angular mesh

Projecting
reinforcement

ø6

ø6

ø6

PSM 120

Angular mesh
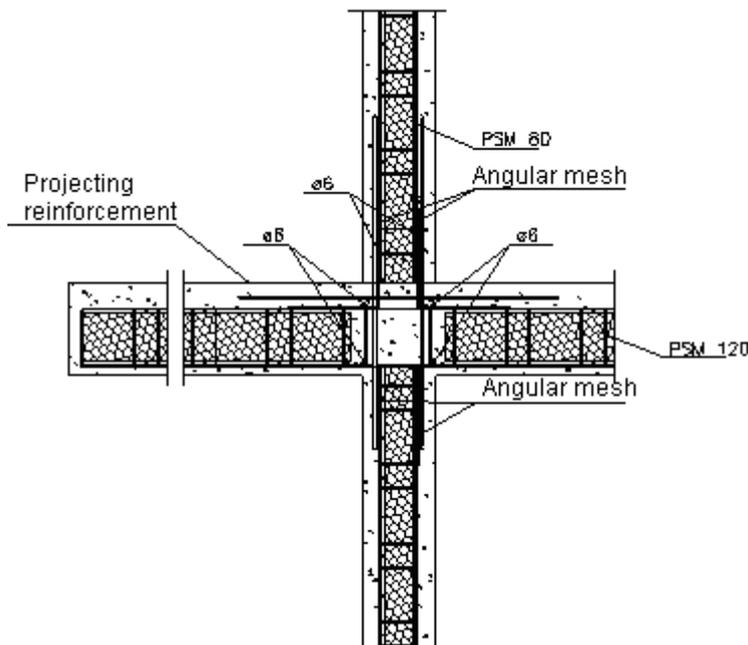
17.19 LOAD BEAM ON INCLINED DECK

Tile, slate, etc.

PSM 120

Reinforcement angular mesh

Concrete layer

PSM 80

"U" Mesh

20

2ø8   2ø10

17.20 UNION BEAM – WALL

2ø10

Lower EPS 4 cm

Zone to solidify

Panel stem

600
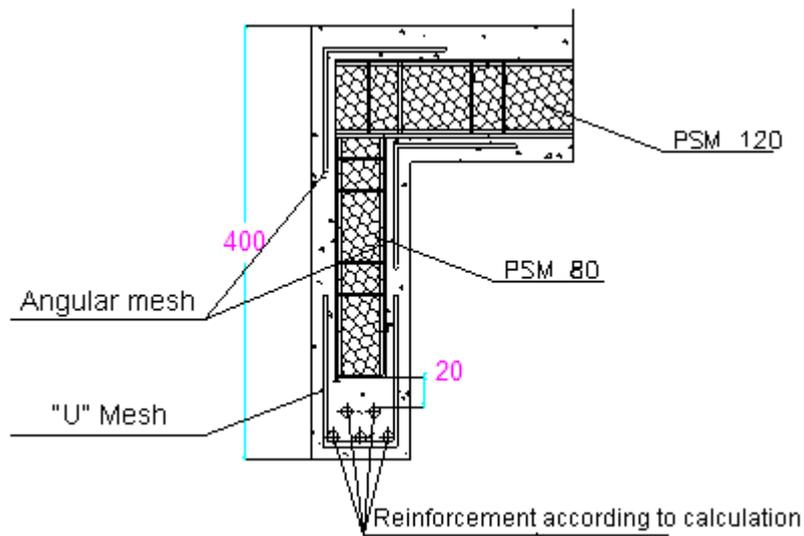
PSM 120

Angular mesh

100

3ø12

PSM 80
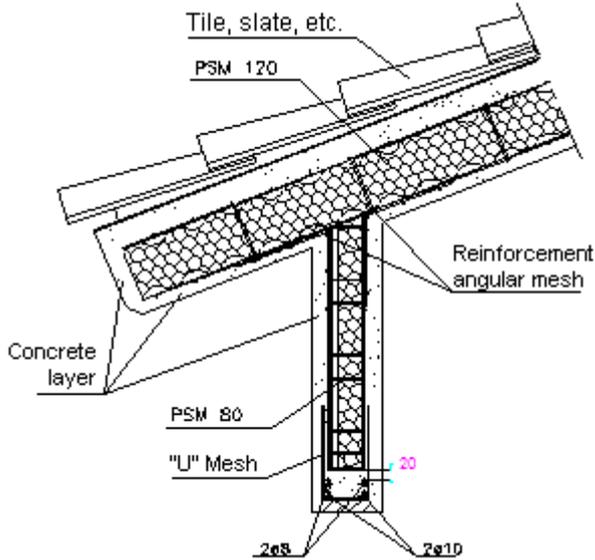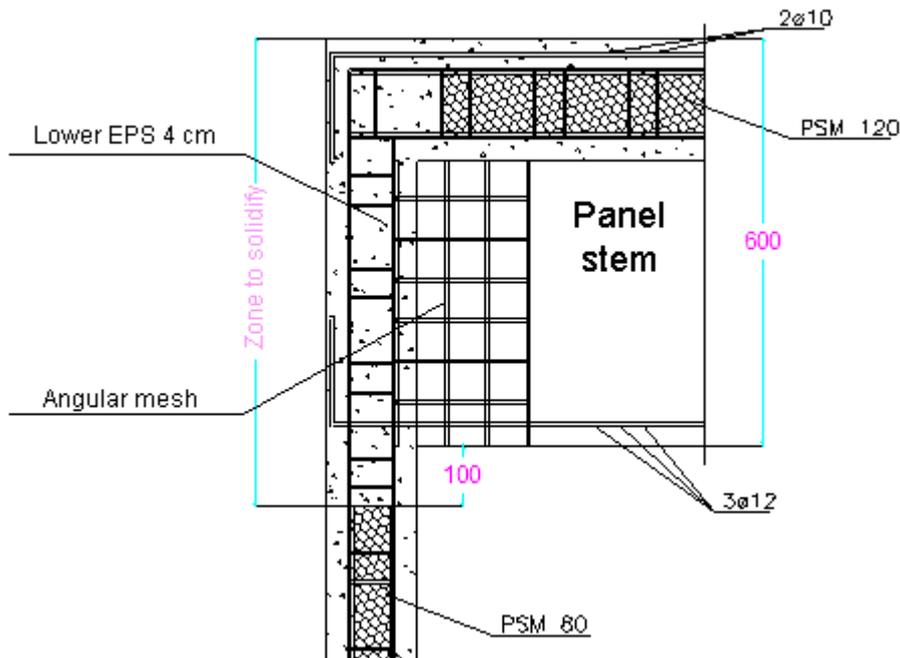
17.21 UNION BEAM – WALL 2
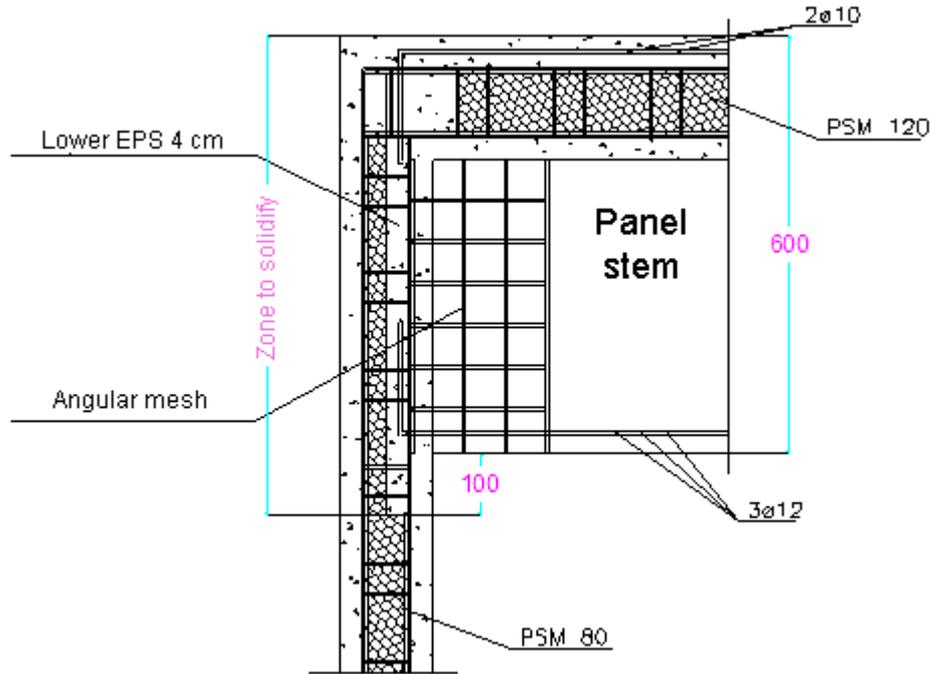
17.22 FLAT BEAM ASSEMBLED TO POSITIVES
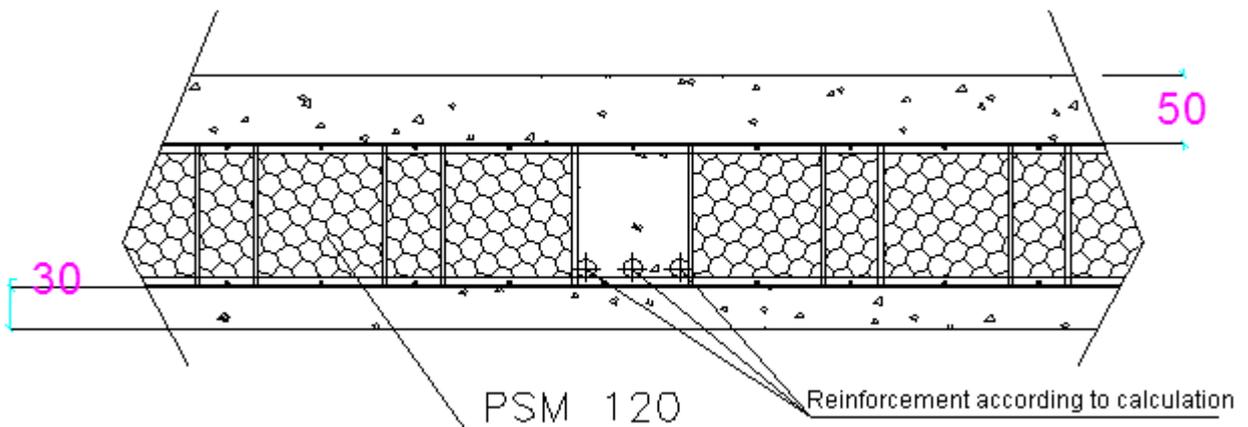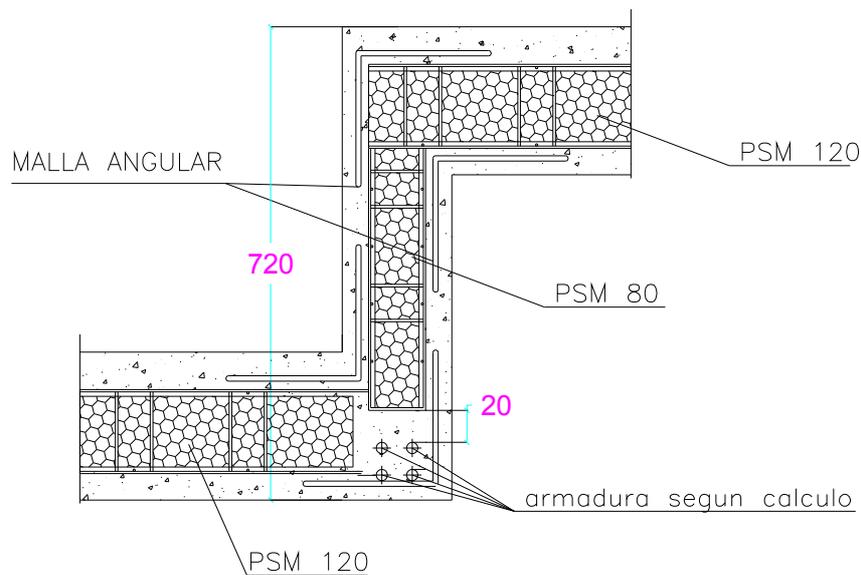
17.23 FLAT EDGE BEAM ASSEMBLED TO POSITIVES

50

30

PSM 120

armadura segun calculo

17.24 EDGE BEAM

PSM 120

400

PSM 80

Angular mesh

20

"U" Mesh

Reinforcement according to calculation

17.25 RIDGE BEAM

2ø10
Angular mesh
50
PSM 120
30
Angular mesh
PSM 80
20
"U" Mesh
Reinforcement according to calculation

17.26 SLOPING BEAM

PSM 120
MALLA ANGULAR
720
PSM 80
20
armadura segun calculo
PSM 120

17.27 INTERIOR EDGE BEAM

Reinforcement according to calculation

PSM 120

Angular mesh

PSM 80

"U" Mesh

20

Reinforcement according to calculation
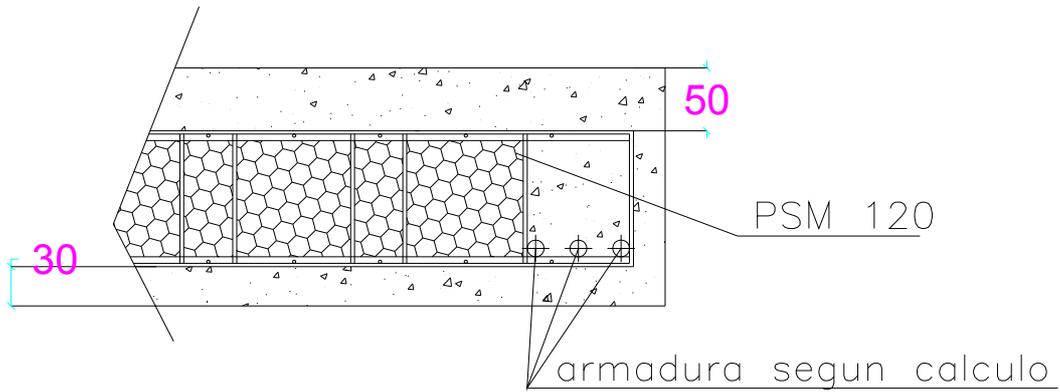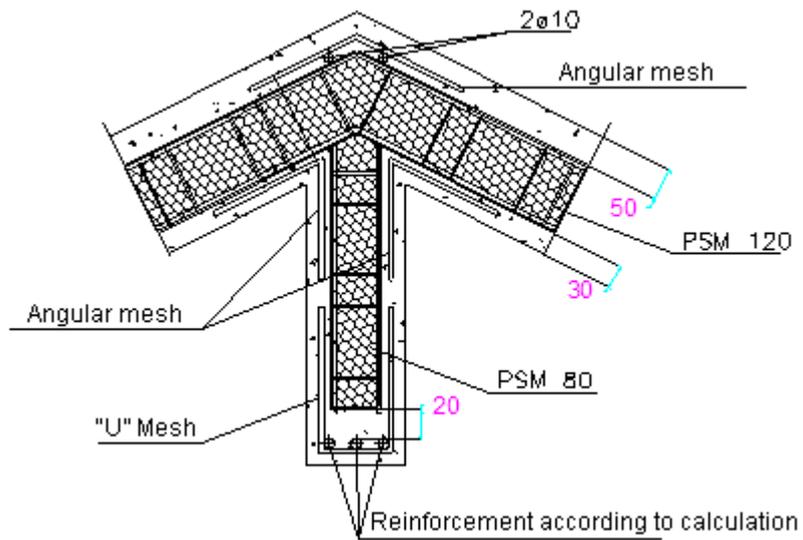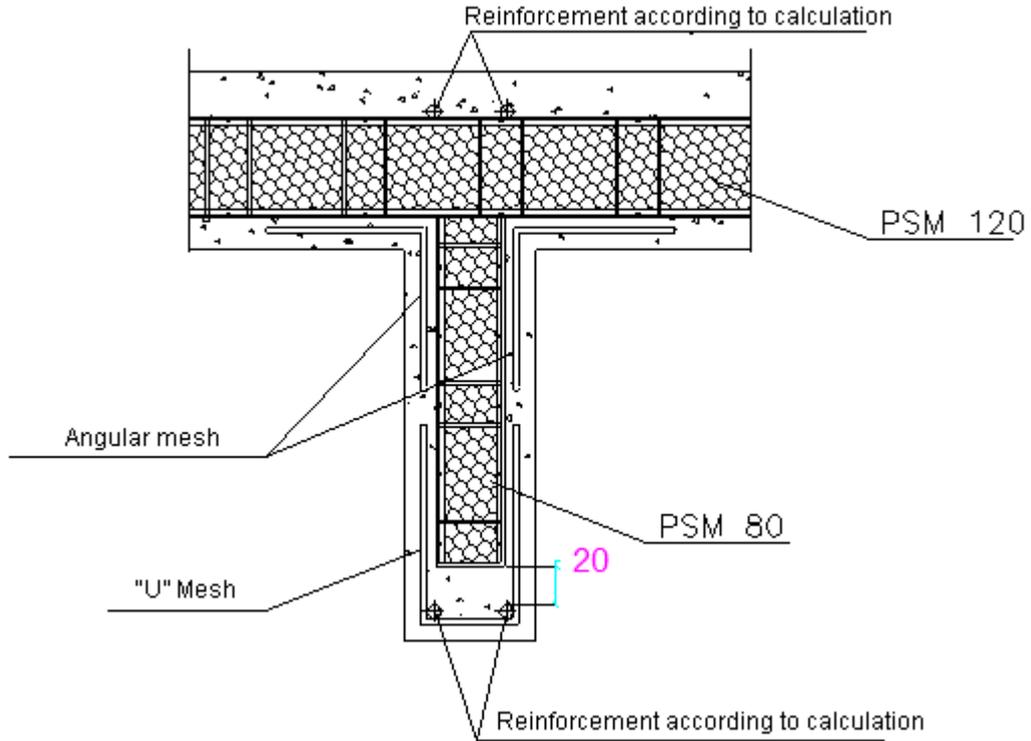
Important: The types of panels, reinforcements and frameworks shown in previous details are only examples. The types and reinforcements of union of each Project are determined according to the corresponding calculations and verifications.