Slab on ground crawl space foundation
MODULO / MULTIMODULO /

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Technical Dossier
established by the applicant
Avis Technique request n°_______

A. Description

1 *Principle*

Method for producing crawl space foundation raised paving produced by casting of concrete into a mold obtained by interlocking of polypropylene lost formworks.

The design of the formwork create a sanitary void beneath the slab.

The void created under the slab is used as a ventilated crawl space or as a technical space for pipes and plumbing. Other uses are possible but specific studies are needed.

Structure created by the use of formwork MODULO is not part of the load bearing structure of a building, a function that belongs to the foundation beams or slab foundation, but only serves to create a crawl space.

The MODULO system must be able to transmit vertical compression loads from the slab to the underlying structure, which must withstand the vertical loads transmitted.

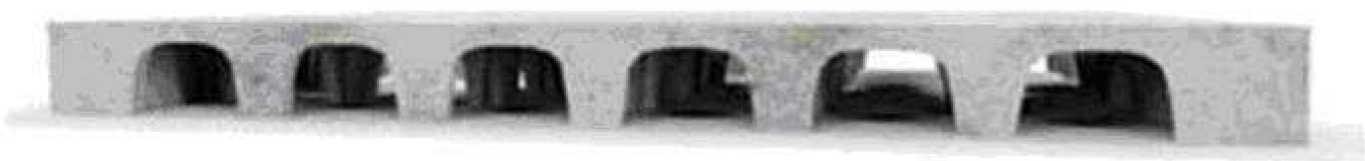

Figure 1

2 *Application field*

This document is intended to describe completely the MODULO system its physical composition, characteristics of use, method of calculation and finally being completed by a description of accessories.

MODULO the system is usable in a variety of building types:
homes
hospitals
industrial buildings
logistics buildings
parking, etc. ...

This document is limited to study the use of Modulo in the case in which the containment structure (foundation beams curbs etc) has been carried out at a previous time, so the function of the Modulo system is only to obtain a lightweight filling.
Structure created by Modulo is subject only to the action of vertical loads, according to the hypothesis that all horizontal actions are absorbed by the supporting structure.
The intensity and shape of loads (concentrated or distributed) taken into consideration are provided by the tables contained in this document.

MODULO can be used for any other application and type of building, but must be accompanied by a specific calculation.

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3 *Production method*

MODULO formworks are realized with an injection process. The production process and the verifications are certified according to ISO 9001.

3.1 Dimensions

MODULO is made of a regenerated copolymer named polypropylene and it is available in several dimensions in height and several plan size to best adapt to the constraints of job site.
The MODULO formworks may undergo variations in size up to maximum 3%. These tolerances are due to the production process.

3.2 Characteristics of resistance for MODULO formworks

MODULO elements once correctly laid have a breaking strength of 150 kN applied at the top of the dome using an imprint load with a surface of $64cm^2$ (8x8cm).
This resistance is confirmed by an independent body.
We carry out regular internal punching tests on our plastic products, tests are archived after an internal procedure.
Quarterly, we can get a copy of the CSTB.

3.3 Definition of the material

The materials composing MODULO system are:

REGENERATED POLYPROPYLENE COPOLYMER
C.A.S. No
9010-79-1 (Polypropylene Random).
Depending on the specific requirements of fire resistance, MODULO formworks can be manufactured with flame retardant plastic material according to the classification P.92.507 NF M1 / UL Standard 94 V0. The producer of plastic granulate will provide Geoplast the certificate of fireproof material for the batch of pellets with additives.

CONCRETE
Characteristics of the concrete slab must refer to Eurocode 2 part1.1 Chapter 3.1

STEEL
The steel reinforcement shall refer to the standard Eurocode 2 part1.1 Chapter 3.2

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4 Description of the installation

4.1 Phases of installation

Description of working phases for achieving a ventilated crawlspace paving with the MODULO system.

- Excavation and site preparation as a traditional solution.

  Prepare the media if the soil has load bearing capacity, level the ground, if the ground has not enough bearing capacity, you must make a backfilling to obtain a soil resistance equal to 50 MPa/m (Westergaard module).

  The leveling of the base is used to create a laying plan for the correct inter connection of the formworks.

  The thickness of the preparation surface is a function of the applied loads.

  It is possible to install drainage and ventilation systems, installation procedures are described in Chapter 4.2.1 and 4.2.2.

- After installation of welded mesh, we proceed to the installation of Geoplast Modulo formworks as shown.

  All MODULO formworks posed, represents a walkable platform after the lay of the mesh

  The design of the reinforcement must be consistent with the loads as described in Chapter 5.

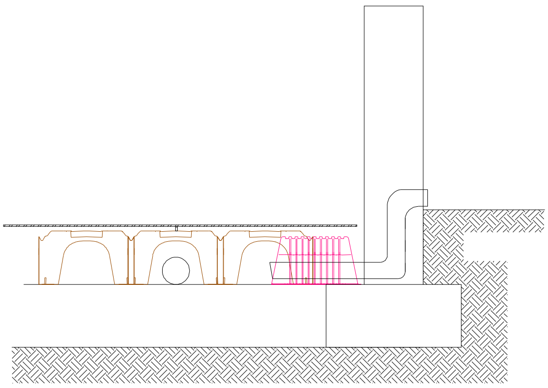

Figure 2

- The final stage contemplate the pouring of concrete to the level of MODULO formworks and to realize the upper slab.

The thickness of the top slab is a function of operating loads.

- 24 to 48 hours after casting the slab above the formwork is walkable.

For a complete description of the method of installation, see Annex 1.

4.1.1 Concrete consumption

Depending on the height of the MODULO formwork installed and accessory elements GeoBlock, we expect different concrete consumption.
The consumption of concrete over MODULO formwork is calculated in m^3 per m^2.
Consumption for pouring concrete with GeoBlock is calculated in m^3 per ml of foundations and we evaluated three possible extension of GeoBlock. Intermediate values can be calculated by linear interpolation.

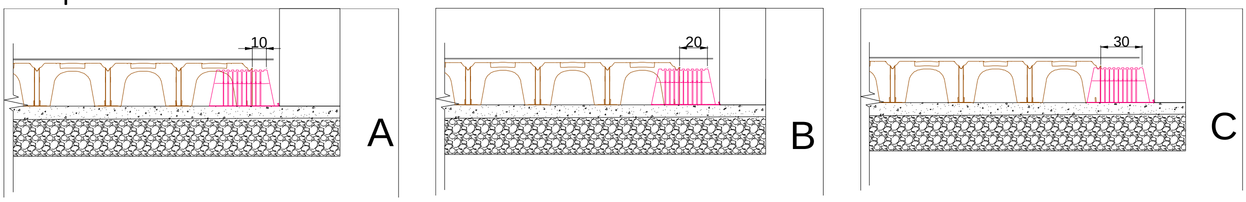

Figure 3

CONCRETE CONSUMPTION MODULO				
HEIGHT	CONCRETE CONSUMPTION FORMWORK **[m³/m²]**	**A** CONCRETE CONSUMPTION GEOBLOCK **[m³/m]**	**B** CONCRETE CONSUMPTION GEOBLOCK **[m³/m]**	**C** CONCRETE CONSUMPTION GEOBLOCK **[m³/m]**
H3	0.004	N.A.	N.A.	N.A.
H6	0.009	N.A.	N.A.	N.A.
H9	0.010	N.A.	N.A.	N.A.
H13	0.028	0.004	0.008	0.012
H15	0.030	0.004	0.008	0.012
H17	0.035	0.006	0.012	0.018
H20	0.037	0.008	0.014	0.024
H25	0.038	0.010	0.020	0.030
H27	0.040	0.010	0.020	0.030
H30	0.045	0.012	0.024	0.036
H35	0.053	0.014	0.028	0.042
H40	0.056	0.016	0.032	0.048
H45	0.064	0.011	0.022	0.033
H50	0.072	0.014	0.028	0.042
H55	0.073	0.021	0.042	0.063
H60	0.085	0.021	0.042	0.063
H65	0.077	0.022	0.044	0.066
H70	0.090	0.023	0.046	0.069

table 1

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CONCRETE CONSUMPTION MULTIMODULO				
HEIGHT	CONCRETE CONSUMPTION FORMWORK [m^3/m^2]	A CONCRETE CONSUMPTION GEOBLOCK [m^3/m]	B CONCRETE CONSUMPTION GEOBLOCK [m^3/m]	C CONCRETE CONSUMPTION GEOBLOCK [m^3/m]
H13	0.020	0.003	0.006	0.009
H15	0.027	0.004	0.008	0.012
H17	0.028	0.005	0.010	0.015
H20	0.032	0.006	0.012	0.018
H25	0.033	0.007	0.014	0.021
H27	0.035	0.009	0.018	0.027
H30	0.042	0.010	0.020	0.030
H35	0.045	0.012	0.024	0.036
H40	0.050	0.013	0.026	0.039

table 2

example : Concrete consumption calculation for GeoBlock MODULO H40.
We consider a 10m wall on which we can have 20 GeoBlock for an extension of 17cm, the use of concrete for each GeoBlock be as follows:

$$0.032\ m^3/\text{Geoblock} : 0{,}20\ m = x : 0.17\ m$$
$$x = 0.0272\ m^3/\text{Geoblock}$$

4.2 Details of installation

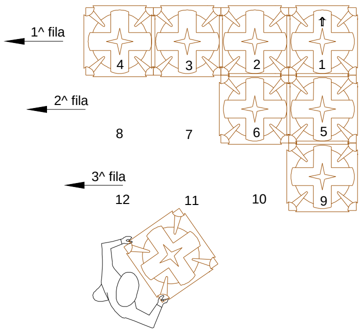
4.2.1 Laying of formwork

MODULO formwork must be installed in a horizontal line from right to left usually begins with the laying MODULO to the wall till the opposite, where it is possible use an element GeoBlock to compensate for the missing distance.
During installation, it is necessary to pay special attention to the male/female interlocking between two elements, thus hermetically seal the two elements from intrusion of concrete

male / female locking
Figure 4

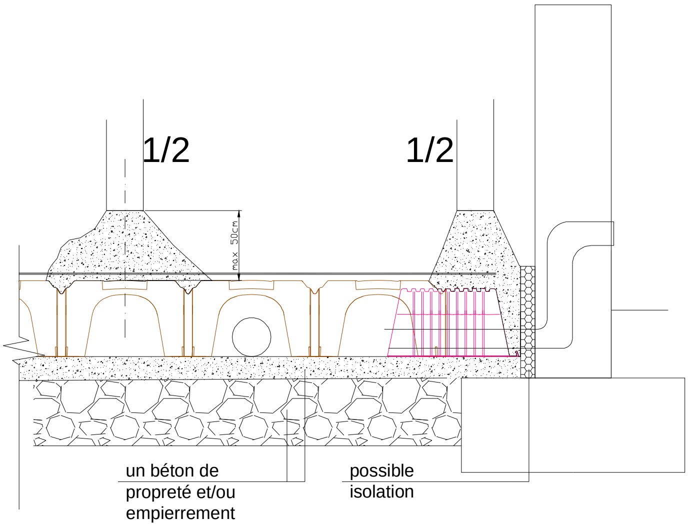
details H55 – H70
Figure 5

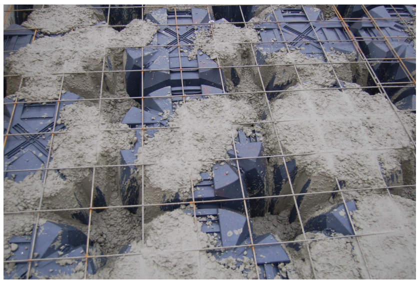
The resistance of MODULO creates a walkable support for installers



Laying direction
Figure 6

The concrete must be at least class C25/30 with a consistency in S3 or S4.
It is possible to make the pouring with a class of concrete strength and consistency different according to a study case.
The pouring of concrete must be done primarily on the dome of MODULO and then directed toward the feet or to the GeoBlock and the foundation.
Concrete should not be poured on MODULO formworks at a height greater than 50cm.

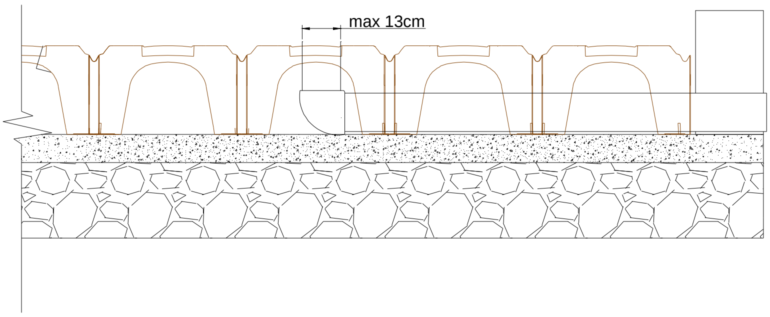




Example of pouring over MODULO formwork
Figure 7

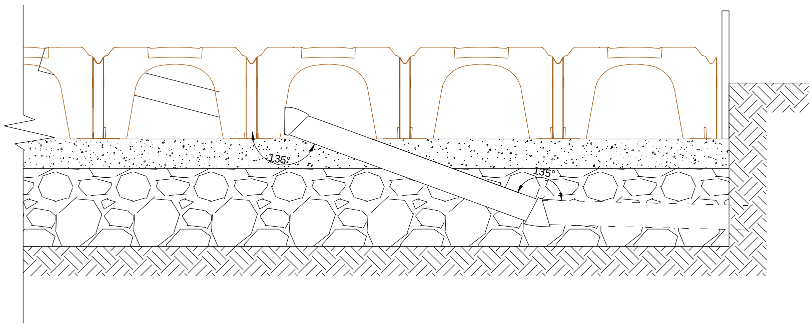
4.2.2 Welded mesh installation

In the sanitary void created with MODULO system, there is the possibility to lay the ducts and tubes of services.
It is possible to pierce the center of formwork MODULO for a maximum diameter of 13 cm in any case is not to exceed the highest step of the mesh.



Example of pipes laying
Figure 8

In the case of a realization of a discharge pipe, when the slope of the pipe is greater than the height h of the MODULO formwork it is possible to punctually cross the layer of lean concrete, and to bury the pipe.
In no event the pipe shall cut thickness of the blinding concrete.



Example of pipe laying
Figure 9

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5 *Structure*

5.1 Definition

The structure created with the Modulo lost formwork can transfer vertical compression loads from the slab to the base structure. The stratigraphy underlying Modulo must provide a module of Westergaard 50MPa as indicated by law (DTU13.3).
The formwork Modulo allows you to form a series side by side of domes supported by unarmed pillars. The building science, and in particular the statics of structures indicates that the vault or arched shape allows the transfer of vertical forces, from top to bottom, using the compressive strength of the material.
Concrete characterized by a high resistance to compression, gives the system of domes created with Modulo the necessary resistance to the transmission of forces.

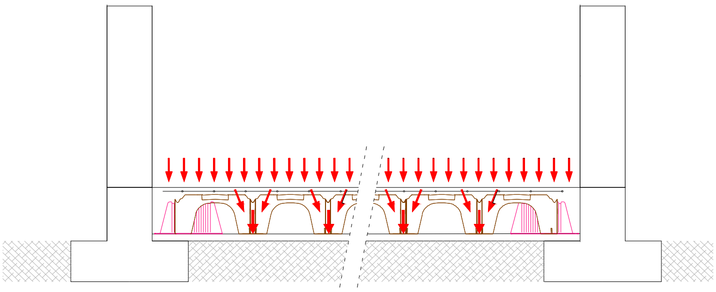


Figure 10

In order to associate the Modulo to a system calculable by the method proposed by legislation DTU 13.3 the system of domes must be transformed in a full slab equivalent

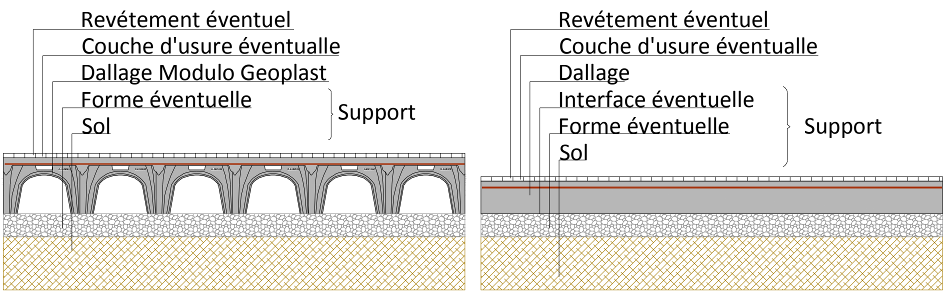


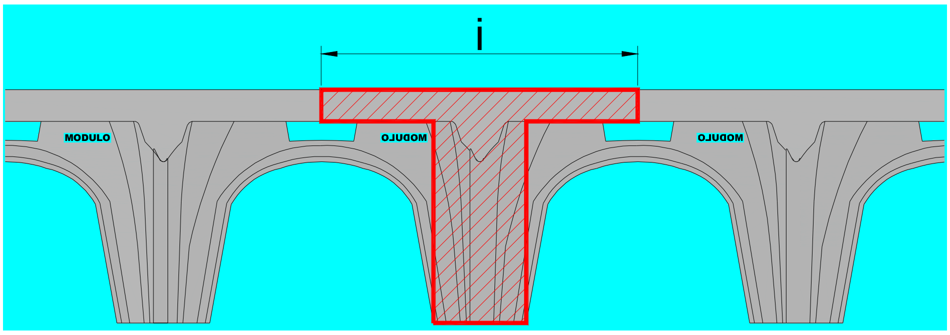
Figure 11

This type of comparison must be carried out according to a well-defined parameter that defines the resistance characteristics, taking into account the increased stiffness due to the presence of the feet and in general three-dimensional geometry of the formwork. The parameter taken into account is the inertia, it is the property which determines the opposition to the variations of the state of motion and depends on the geometrical characteristics.

Below ss provided, for each combination of Modulo and slab thickness, the respective full slab structure.

MODULO	Slab thickness								
H	5	6	7	8	9	10	12	15	20
	Equivalent full slab								
3	6.3								
6									
9									
13									
15									
17									
20									
25									
27									
30									
35									
40									
45									
50									
55									
60									
65									
70									
MULTIMODULO									
13									
15									
17									
20									
25									
27									
30									
35									
40									

The practical procedure to identify the thickness of the slab is to calculate the equivalent inertia of the section of the system Modulo I_m simplified as a T section, this section refers to the diagonal of the formwork

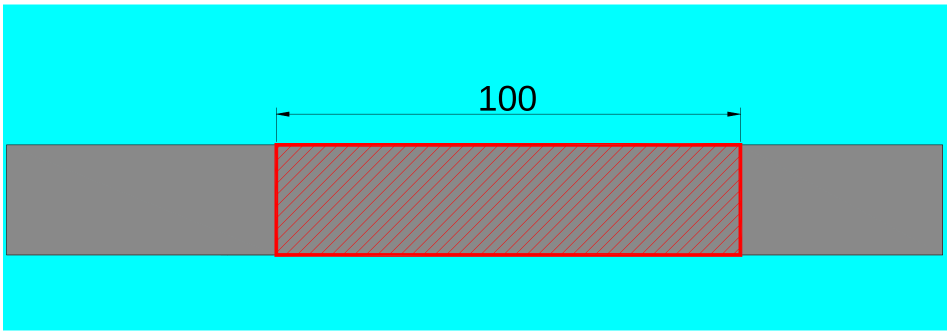


It thus identifies the value of inertia per linear meter by dividing the inertia just calculated for the diagonal

$$I = I_m / i$$ **Equation 1**

Obtained the inertia per linear meter via the inverse formula of calculating the inertia of a rectangular section is obtained the thickness of the equivalent slab.

$$s = \sqrt[3]{\frac{I \cdot 12}{100}}$$ **Equation 2**



5.2 Method of calculation

At the time of this writing, no standard law provides a method for calculating crawlspace system realizes with formwork.
The objective of the method of calculation described below is to propose a system for proper sizing and compatible with the results of laboratory tests.
The aim is to demonstrate that the structure created with Modulo is suitable to the application concerned by this technical document. The following checks will be performed:

- Bending verification ;
- Punching verification ;
- Contact pressure on the ground;
- Compression test of the feet.

The following sections show how the simplified calculation proposed by Geoplast is correct and supported by laboratory tests.

5.2.1 Laboratory Test

The laboratory test involves the application of a concentrated load on a reinforced concrete structure realized with MODULO and brought to maturation.
The characteristics of the materials are as follows:
Concrete C25/30
Steel mesh Ø6/20x20 (1.414cm^2/m) placed directly on the formwork.

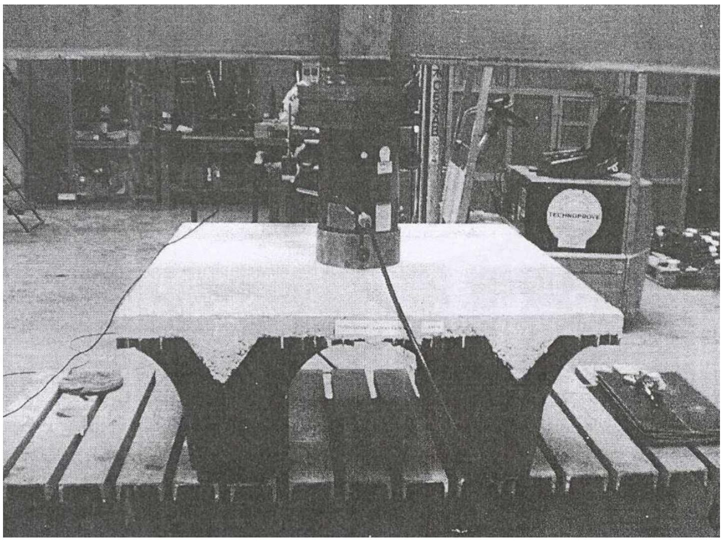
The range of formworks Modulo is characterized by different plan dimensions and different distances between the feet.
For carrying out the tests were created using formworks seven specimens that correspond to two different geometric configurations in plan:

1. **the most burdensome**: represented by formwork 71x71cm in plan corresponding to the maximum span between the feet.
2. **The most resistant**: represented by formwork 71x71cm in plan, but having a central foot corresponding to the minimum clearance between the feet.

These two geometric configurations correspond to the extreme values of resistance of the specimen realized with Modulo.

Foot height is not a significant influence on the test results as they are subjected to simple compression.

The tests were carried out using a load imprint, concentrated load, of Ø25cm at the center of the dome, which corresponds to the point of intersection of the diagonals of the square defined by the feet.
During the test, a linearly increasing load was applied until reaching at break of the element.
For each of the two configurations have been realized specimen with different thicknesses of slab in such a way as to have a wider range of values: the values obtained are summarized in the following table.



MULTIMODULO H25 Diagonal foot to foot 50 cm	slab	load
		F_p
	cm	daN
	5	15770
	10	29300
	15	39550
MODULO H45 Diagonal foot to foot 100 cm	slab	load
		F_p
	cm	daN
	5	6400
	8	10400
	10	12880
	15	20000

table 3

Laboratory tests were performed by certified laboratories.
All these documents is attached (all.1).

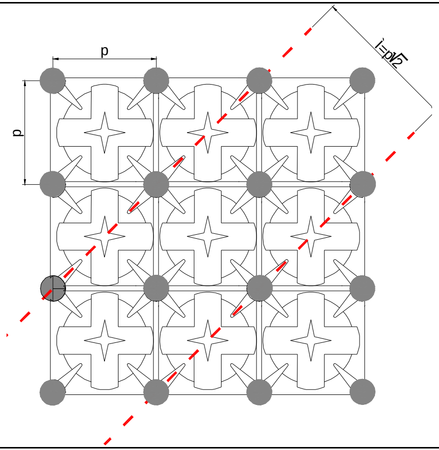
5.2.2 Hand calculations

The hand calculations proposed by Geoplast has the aim of providing a fast and simplified calculation method for dimensioning the compression on the slab.
The results provide the maximum loads applicable and will be compared obtaining a coefficient of comparison, so that demonstrate the efficacy and safety of the proposed calculation.
The hand calculations of the Modulo system occurs operating some simplifications that are described below. These simplifications lead back the MODULO system to a system calculated with the classical methods proposed by the Building Science.

5.2.2.1 Structural simplification

The structure created from formworks MODULO is a monolithic structure formed by vertical elements squat and by a horizontal slab of constant thickness function of the load bearing capacity.
Being difficult to find a quick and easy procedure for the design of a structure of this type, it is necessary to separate the system into basic elements that can be studied with the classical methods of its Building Science.
The subdivision occurs in this way:

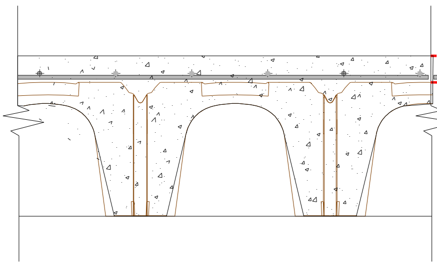
• SLAB, which is element subjected to a deformation and the object of study: it will verified a bending and punching.
The study of compression of the slab occurs by identifying a portion of the slab having width equal to the diagonal distance between two feet and a thickness equal to the height of the slab.



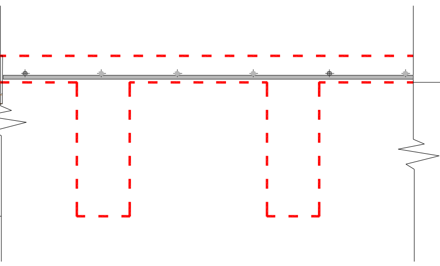
MODULO	p [cm]	i [cm]
H3	8,3	11,8
H6	10,0	14,1
H9	16,7	23,6
H13-H40	50,0	71,2
H45-H70	71,0	100,0
MULTIMODULO	35,0	50,0

table 4

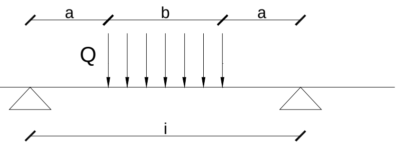
In light of this specification is identified the static scheme that will be used in subsequent calculations.



Real section
Figure 12



Simplified section
Figure 13



$$M_{max} = \frac{Q \cdot b}{8} \cdot (2 \cdot i - b)$$

Static scheme
Figure 14

As can be seen in correspondence of the feet it has been suggested to reproduce a hinge , this choice was made for two reasons:
- Assume a different type of restraint would not be correct: in fact, the interlocking would not be appropriate given the lack of connection reinforcement.
- The adoption of support simple maximizes the stress on the span: therefore these stresses will lead to results more burdensome than the reality thus in favor of safety.
Finally, in the calculation will be held into consideration as distance between the feet the diagonal between them in such a way as to maximize the stresses.

• FEET, able to transmit vertical loads from the structure below: they are responsible for simple compression, so that their performance depends on the characteristic compressive strength of concrete used.

With regard to the feet, the simplification to set them free from the horizontal structure (floor), makes it easy to check them, as it is sufficient verify them to simple compression.
Even in this case, to be in favor of safety it is assumed that the foot is a cylinder whose diameter is represented by the base of the same, are summarized below base areas Ac of each element.

table 5

MODULO 50x50	Ac [cm^2]
H3	6
H6	16
H9	18
H13	350
H15	420
H17	300
H20	350
H25	250
H27	185
H30	250
H35	170
H40	140

MODULO 71x71	Ac [cm^2]
H45	330
H50	300
H55	275
H60	275
H65	240
H70	240

MULTI MODULO	Ac [cm^2]
H13	100
H15	130
H17	90
H20	155
H25	70
H27	90
H30	100
H35	70
H40	70

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5.2.2.1 Verification of bending and comparison with load test

To compare the results of load tests with the results of hand calculations we proceed by calculating the resisting moment of the section of beam taken into consideration.
The resistant section for evaluating the resisting moment will be identified by:

i base of inter axes between the feet;
S height equal to the thickness of the slab.

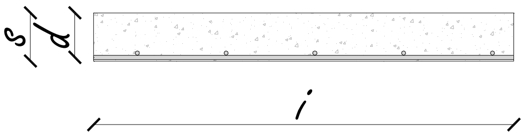
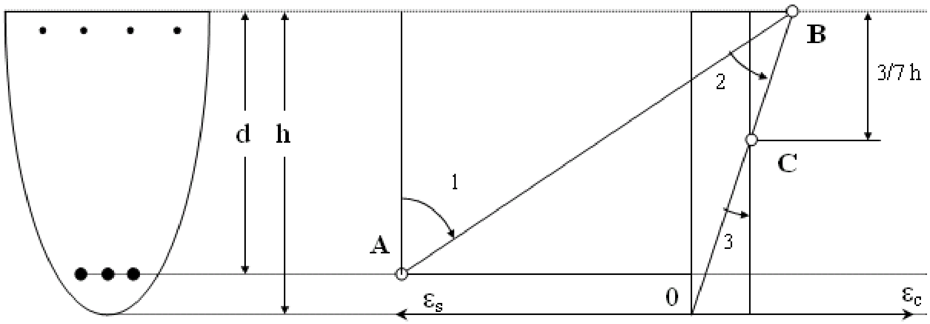


Figure 15

The maximum resisting moment of the section is calculated assuming that the break occurs within the "field 2" of the figure below.



A.4.3,3 diagram of the deformations at the boundaries of the section (Rules BAEL 91 revised 99)

Point B on the 2 field is a function of the shortening of concrete, represents the limit of compressive strength of concrete subjected to bending (simple or compound), Point A represents the maximum value of the stretched fibers, composed of the sums of the lower reinforcement (from point A to point 0) and by a small part of the concrete tense (from point 0 to point B).
The calculation of the moment of resistance occurs according to the following formula:

$$M_{Rd} = A_s \cdot f_{yd} \cdot d \left(1 - \frac{A_s \cdot f_{yd}}{2 \cdot i \cdot d \cdot f_{cd}} \right) \qquad \textbf{Equation 3}$$

where:

A_s reinforcement of the slab [mm^2];
f_{yd} yield strength of the steel reinforced concrete [Mpa] ;
d effective height of the section [mm];
i width of the section [mm];
f_{cd} value to calculate the compressive strength of concrete.

Achieved the resisting moment of the section, the maximum load is obtained by the inverse formula to calculate the moment, based on the static scheme of Figure 13.

$$M_{max} = \frac{Q \cdot b}{8} \cdot (2 \cdot i - b) \quad [kNm]$$ **Equation 4**

$$Q_{max} = \frac{8 \cdot M_{max}}{(2 \cdot i - b) \cdot b} \quad [kN/m]$$ **Equation 5**

The value obtained turns out to be a linear load, in order to be compared with the loading tests should be led back to concentrated load by multiplying it by the imprint load "b", which for all cases will be 0.25m.
Moreover in order to have an effective comparison between the calculation and load tests at rupture of the specimen, must be applied to the Q value just calculated the coefficient of amplification of load defined by EC2 for live loads, coefficient set equal to 1.5.
In this way the calculated maximum load refers to a load situation (ULS) similar to that of the test (specimen rupture).

$$F = Q_{max} \cdot b \cdot 1.5 \quad [kNm]$$ **Equation 6**

In order to make the comparison between the load value F and the just calculated value Fp, the latter it must be divided into two directions, because the simplifying assumption that identifies a continuous beam on several supports is valid for two orthogonal directions:

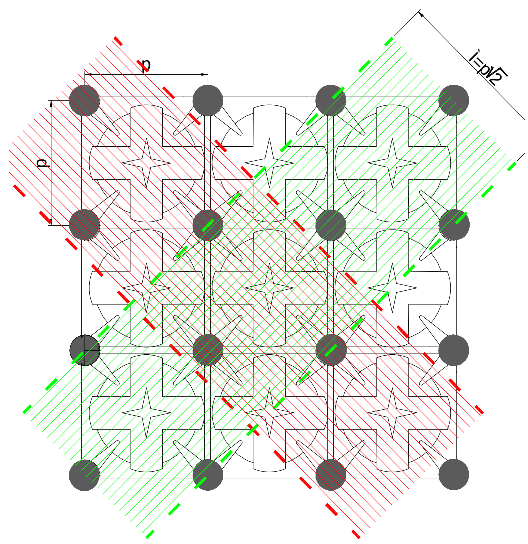


Figure 16

Therefore, the load is divided equally in two directions, and the final value of the load to be compared with the calculation method proposed by Geoplast will be halved with respect to that resulting from the tests. Below is a summary table with the values to compare

$$Fp' = Fp / 2 \quad [kNm]$$ **Equation 7**

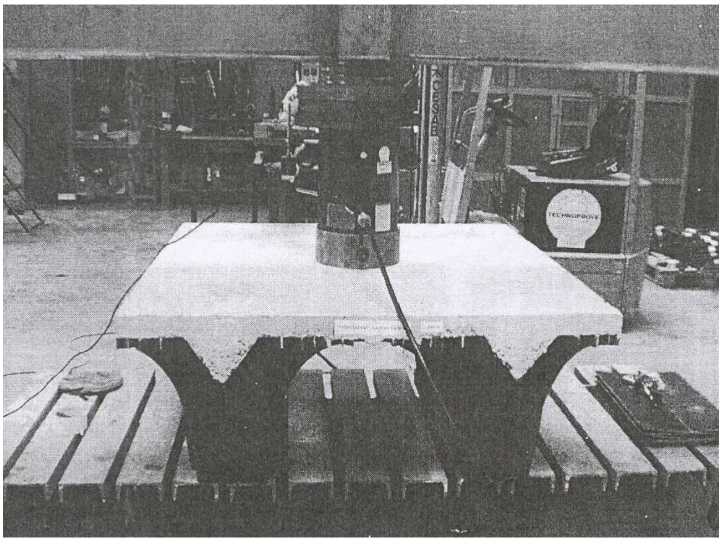
<table>
<tr><td rowspan="12"></td><td>MULTIMODULO H25
Diagonal distance between the feet
50 cm</td><td>slab</td><td>Load</td></tr>
<tr><td rowspan="5"></td><td></td><td>F_p'</td></tr>
<tr><td>cm</td><td>daN</td></tr>
<tr><td>5</td><td>7885</td></tr>
<tr><td>10</td><td>14650</td></tr>
<tr><td>15</td><td>19775</td></tr>
<tr><td>MODULO H45
Diagonal distance between the feet
100 cm</td><td>slab</td><td>Load</td></tr>
<tr><td rowspan="6"></td><td></td><td>Fp</td></tr>
<tr><td>cm</td><td>daN</td></tr>
<tr><td>5</td><td>3200</td></tr>
<tr><td>8</td><td>5200</td></tr>
<tr><td>10</td><td>6440</td></tr>
<tr><td>15</td><td>10000</td></tr>
</table>

table 6

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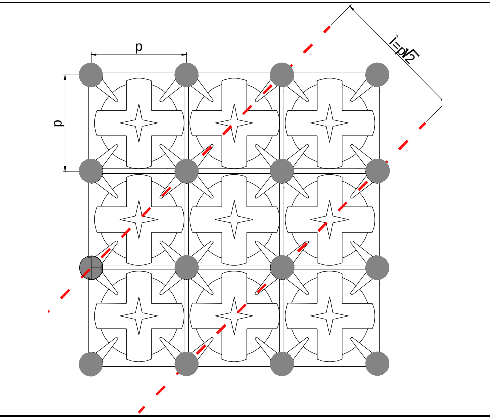
EXAMPLE 1: MULTIMODULO H25 – SLAB THICKNESS 5 cm

Below is an example calculation for the system H25 MULTIMODULO with slab 5cm.
The geometrical characteristics are the following:
plan dimension 71x71cm with center foot place to 35cm, as can be seen from the table below, with reference to MULTIMODULO the center distance for calculating is equal to 50cm



MODULO	*p [cm]*	*i [cm]*
H3	*8,3*	*11,8*
H6	*10,0*	*14,1*
H9	*16,7*	*23,6*
H13-H40	*50,0*	*71,2*
H45-H70	*71,0*	*100,0*
MULTIMODULO	***35,0***	***50,0***

table 7

The thickness of the slab chosen for the calculation is equal to 5cm, and the useful height of the section, considering a welded mesh Ø6/20, results to be equal to 4cm.
Therefore, the resistant section is as follows:
Considering the following parameters:

A_s = 70.50 mm^2;

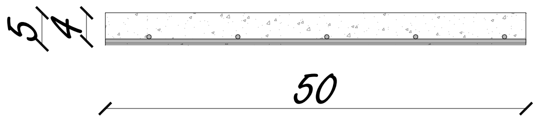
f_{yd} =391 Mpa ;

d = 40 mm;

i = 500 mm;

f_{cd} = 14.17 MPa;

b = 250 mm



The calculation of the resisting moment leads to the following value:

$$M_{res} = A_s \cdot f_{yd} \cdot d \left(1 - \frac{A_s \cdot f_{yd}}{2 \cdot i \cdot d \cdot f_{cd}}\right) = 1{,}049 KNm$$

The value of the maximum load that can be applied to the section to match the resisting moment is obtained from the inverse formula:

$$Q_{max} = \frac{8 \cdot M_{res}}{(2 \cdot i - b) \cdot b} = \frac{8 \cdot 1.049}{(2 \cdot 0.5 - 0.25) \cdot 0.25} = 44.7 kN/m$$

$$F = Q_{max} \cdot b \cdot 1.5 = 16.76 kN$$

The value obtained is lower than the value of the load test, this is due to the simplifications previously indicated, but provides a value that appears to be on the safe side according to a coefficient equal to

$$F_s = \frac{Q}{Q_{max}} = \frac{78.85}{16.76} = 4.70$$

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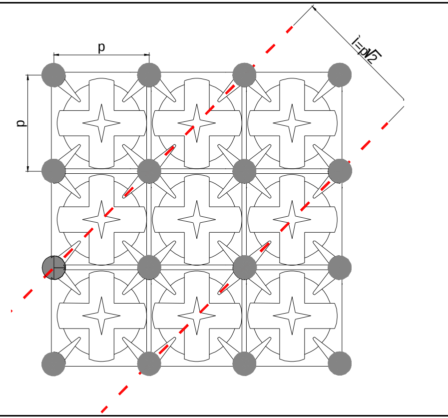
EXAMPLE 2: MULTIMODULO H25 – SLAB THICKNESS 10 cm

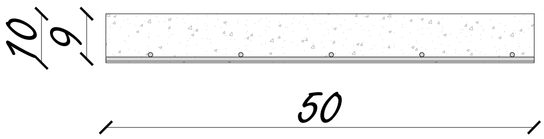
Below is an example for calculating for the system MULTIMODULO H25 with slab thickness 10cm. The geometrical characteristics are the following:
plan dimension 71x71cm with center foot place to 35cm, as can be seen from the table below, with reference to MULTIMODULO the center distance for calculating is equal to 50cm



MODULO	*p [cm]*	*i [cm]*
H3	*8,3*	*11,8*
H6	*10,0*	*14,1*
H9	*16,7*	*23,6*
H13-H40	*50,0*	*71,2*
H45-H70	*71,0*	*100,0*
MULTIMODULO	***35,0***	***50,0***

table 8

The thickness of the slab chosen for the calculation is equal to 10cm, and the useful height of the section, considering a welded mesh Ø6/20, turns out to be equal to 9cm.
Therefore, the resistant section is as follows:
Considering the following parameters:



A_s = 70.50 mm^2;

f_{yd} =391 Mpa ;

d = 90 mm;

i = 500 mm;

f_{cd} = 14.17 MPa;

b = 250 mm

The calculation of the resisting moment leads to the following value:

$$M_{Res} = A_s \cdot f_{yd} \cdot d\left(1 - \frac{A_s \cdot f_{yd}}{2 \cdot i \cdot d \cdot f_{cd}}\right) = 2.437KNm$$

The value of the maximum load that can be applied to the section to match the resisting moment is obtained from the inverse formula:

$$Q_{max} = \frac{8 \cdot M_{res}}{(2 \cdot i - b) \cdot b} = \frac{8 \cdot 2{,}437}{(2 \cdot 0.5 - 0.25) \cdot 0.25} = 104kN/m$$

$$F = Q_{max} \cdot b \cdot 1.5 = 39kN$$

The value obtained is lower than the value of the load test, this is due to the simplifications previously indicated, but provides a value that appears to be on the safe side according to a coefficient equal to

$$F_s = \frac{Q}{Q_{max}} = \frac{146.5}{39} = 3.75$$

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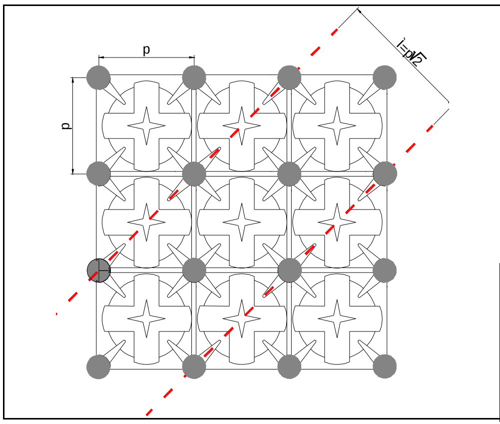
EXAMPLE 3: MULTIMODULO H25 – SLAB THICKNESS 15 cm

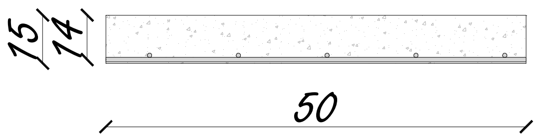
Below is an example for calculating for the system MULTIMODULO H25 with slab thickness 15cm. The geometrical characteristics are the following:
plan dimension 71x71cm with center foot place to 35cm, as can be seen from the table below, with reference to MULTIMODULO the center distance for calculating is equal to 50cm



MODULO	p [cm]	i [cm]
H3	8,3	11,8
H6	10,0	14,1
H9	16,7	23,6
H13-H40	50,0	71,2
H45-H70	71,0	100,0
MULTIMODULO	**35,0**	**50,0**

table 9

The thickness of the slab chosen for the calculation is equal to 15cm, and the useful height of the section, considering a welded mesh Ø6/20, turns out to be equal to 14cm.
Therefore, the resistant section is as follows:
Considering the following parameters:



A_s = 70.50 mm^2;
f_{yd} =391 Mpa ;
d = 140 mm;
i = 500 mm;
f_{cd} = 14.17 MPa;
b = 250 mm

The calculation of the resisting moment leads to the following value:

$$M_{res} = A_s \cdot f_{yd} \cdot d\left(1 - \frac{A_s \cdot f_{yd}}{2 \cdot i \cdot d \cdot f_{cd}}\right) = 3.805KNm$$

The value of the maximum load that can be applied to the section to match the resisting moment is obtained from the inverse formula:

$$Q_{max} = \frac{8 \cdot M_{res}}{(2 \cdot i - b) \cdot b} = \frac{8 \cdot 3.805}{(2 \cdot 0.5 - 0.25) \cdot 0.25} = 162.3kN/m$$

$$F = Q_{max} \cdot b \cdot 1.5 = 60.9kN$$

The value obtained is lower than the value of the load test, this is due to the simplifications previously indicated, but provides a value that appears to be on the safe side according to a coefficient equal to

$$F_s = \frac{Q}{Q_{max}} = \frac{197.75}{60.9} = 3.25$$

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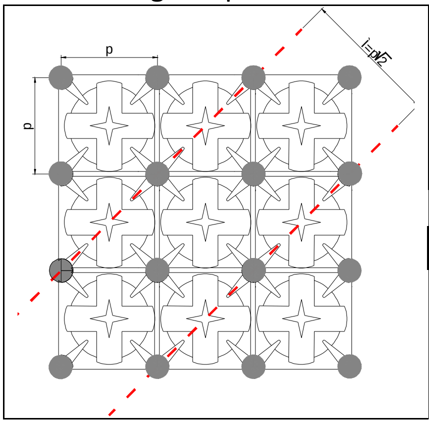
EXAMPLE 4: MODULO H45 – SLAB THICKNESS 5 cm

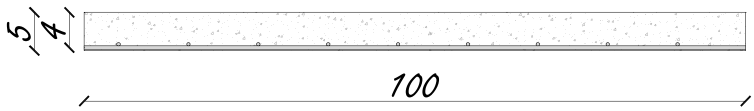
Below is an example for calculating for the system MODULO H45 slab with 5cm:
The geometrical characteristics are the following:
71x71cm plan dimension, as can be seen from the table below, with reference to the MODULO the center distance for calculating is equal to100cm



MODULO	p [cm]	i [cm]
H3	*8,3*	*11,8*
H6	*10,0*	*14,1*
H9	*16,7*	*23,6*
H13-H40	*50,0*	*71,2*
H45-H70	***71,0***	***100,0***
MULTIMODULO	*35,0*	*50,0*

table 10

The thickness of the slab chosen for the calculation is equal to 5cm, and the useful height of the section, considering a welded mesh Ø6/20, results to be equal to 4cm.
Therefore, the resistant section is as follows:
Considering the following parameters:



A_s = 141 mm^2;
f_{yd} =391 Mpa ;
d = 40 mm;
i = 1000 mm;
f_{cd} = 14.17 MPa;
b = 250 mm

The calculation of the resisting moment leads to the following value:

$$M_{Res} = A_s \cdot f_{yd} \cdot d \left(1 - \frac{A_s \cdot f_{yd}}{2 \cdot i \cdot d \cdot f_{cd}}\right) = 2.098\text{KNm}$$

The value of the maximum load that can be applied to the section to match the resisting moment is obtained from the inverse formula:

$$Q_{max} = \frac{8 \cdot M_{res}}{(2 \cdot i - b) \cdot b} = \frac{8 \cdot 2.098}{(2 \cdot 1 - 0.25) \cdot 0.25} = 38.4\text{kN/m}$$

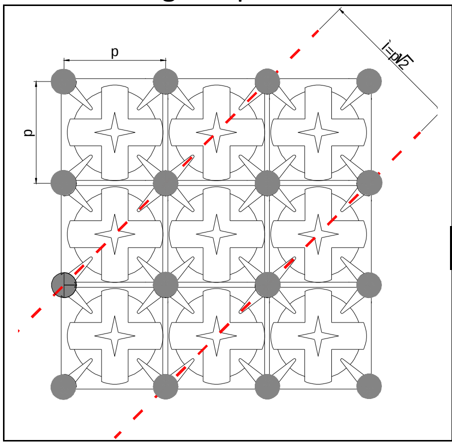
$$F = Q_{max} \cdot b \cdot 1.5 = 14.4\text{kN}$$

The value obtained is lower than the value of the load test, this is due to the simplifications mentioned above but provides a value that appears to be on the safe side according to a parameter equal to

$$F_s = \frac{Q}{Q_{max}} = \frac{32}{14.4} = 2.22$$

EXAMPLE 5: MODULO H45 – SLAB THICKNESS 8 cm

Below is an example for calculating for the system MODULO H45 with slab thickness 8cm:
The geometrical characteristics are the following:
plan dimension 71x71cm, as can be seen from the table below, in reference to the Modulo the center distance for calculating is equal to 100cm



MODULO	*p [cm]*	*i [cm]*
H3	*8,3*	*11,8*
H6	*10,0*	*14,1*
H9	*16,7*	*23,6*
H13-H40	*50,0*	*71,2*
H45-H70	***71,0***	***100,0***
MULTIMODULO	*35,0*	*50,0*

table 11

The thickness of the slab chosen for the calculation is equal to 8cm, and the useful height of the section, considering a welded mesh Ø6/20, turns out to be equal to 7cm.
Therefore, the resistant section is as follows:
Considering the following parameters:

$A_s = 141\ mm^2$;

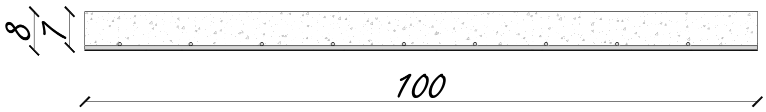
f_{yd} =391 Mpa ;

d = 70 mm;

i = 1000 mm;

f_{cd} = 14.17 MPa;

b = 250 mm



$$M_{Res} = A_s \cdot f_{yd} \cdot d \left(1 - \frac{A_s \cdot f_{yd}}{2 \cdot i \cdot d \cdot f_{cd}} \right) = 3.752 KNm$$

The value of the maximum load that can be applied to the section to match the resisting moment is obtained from the inverse formula:

$$Q_{max} = \frac{8 \cdot M_{res}}{(2 \cdot i - b) \cdot b} = \frac{8 \cdot 3.752}{(2 \cdot 1 - 0.25) \cdot 0.25} = 68.6 kN/m$$

$$F = Q_{max} \cdot b \cdot 1.5 = 25.7 kN$$

The value obtained is lower than the value of the load test, this is due to the simplifications mentioned above but provides a value that appears to be on the safe side according to a parameter equal to

$$F_s = \frac{Q}{Q_{max}} = \frac{52}{25.7} = 2.02$$

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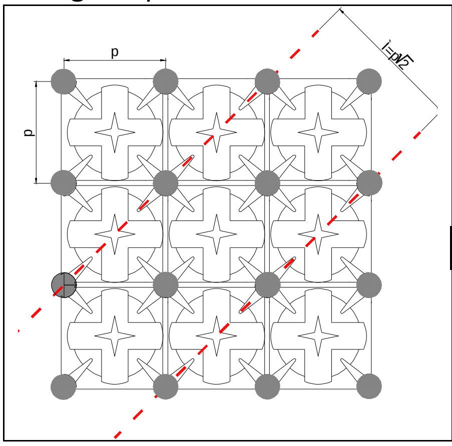
EXAMPLE 6: MODULO H45 – SLAB THICKNESS 10 cm

Below is an example for calculating for the system MODULO H45 with slab 10cm:
The geometrical characteristics are the following:
base size 71x71cm, as can be seen from the table below, in reference to the MODULO the center distance for calculating is equal to 100cm

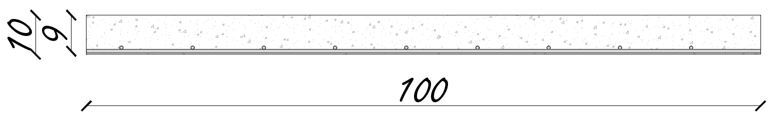


MODULO	p [cm]	i [cm]
H3	8,3	11,8
H6	10,0	14,1
H9	16,7	23,6
H13-H40	50,0	71,2
H45-H70	**71,0**	**100,0**
MULTIMODULO	35,0	50,0

table 12

The thickness of the slab chosen for the calculation is equal to 10cm, and the useful height of the section, considering a welded mesh Ø6/20, turns out to be equal to 9cm.
Therefore, the resistant section is as follows:
Considering the following parameters:

A_s = 141 mm^2;
f_{yd} =391 Mpa ;
d = 140 mm;
i = 1000 mm;
f_{cd} = 14.17 MPa;
b = 250 mm



$$M_{Res} = A_s \cdot f_{yd} \cdot d \left(1 - \frac{A_s \cdot f_{yd}}{2 \cdot i \cdot d \cdot f_{cd}}\right) = 4.854 KNm$$

The value of the maximum load that can be applied to the section to match the resisting moment is obtained from the inverse formula:

$$Q_{max} = \frac{8 \cdot M_{res}}{(2 \cdot i - b) \cdot b} = \frac{8 \cdot 4.854}{(2 \cdot 1 - 0.25) \cdot 0.25} = 89 kN/m$$

$$F = Q_{max} \cdot b \cdot 1.5 = 33.4 kN$$

The value obtained is lower than the value of the load test, this is due to the simplifications mentioned above but provides a value that appears to be on the safe side according to a parameter equal to

$$F_s = \frac{Q}{Q_{max}} = \frac{64.4}{33.4} = 1.93$$

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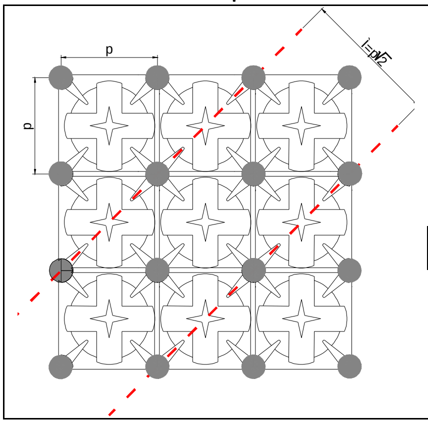
EXAMPLE 7: MODULO H45 – SLAB THICKNESS 15 cm

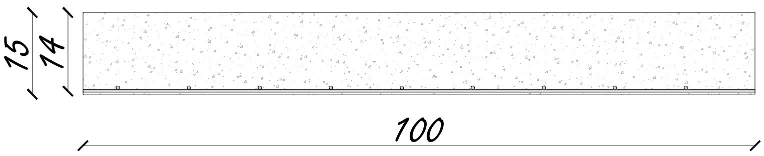
Below is an example for calculating for the system MODULO H45 with slab 15cm:
The geometrical characteristics are the following:
base size 71x71cm, as can be seen from the table below, in reference to the MODULO for calculating the center distance is equal to 100cm



MODULO	p [cm]	i [cm]
H3	*8,3*	*11,8*
H6	*10,0*	*14,1*
H9	*16,7*	*23,6*
H13-H40	*50,0*	*71,2*
H45-H70	***71,0***	***100,0***
MULTIMODULO	*35,0*	*50,0*

table 13

The thickness of the slab chosen for the calculation is equal to 15cm, and the useful height of the section, considering a welded mesh Ø6/20, turns out to be equal to 14cm
Therefore, the resistant section is as follows:
Considering the following parameters:



A_s = 141 mm^2;
f_{yd} =391 Mpa ;
d = 140 mm;
i = 1000 mm;
f_{cd} = 14.17 MPa;
b = 250 mm

$$M_{Res} = A_s \cdot f_{yd} \cdot d \left(1 - \frac{A_s \cdot f_{yd}}{2 \cdot i \cdot d \cdot f_{cd}}\right) = 7.611 \text{KNm}$$

The value of the maximum load that can be applied to the section to match the resisting moment is obtained from the inverse formula:

$$Q_{max} = \frac{8 \cdot M_{res}}{(2 \cdot i - b) \cdot b} = \frac{8 \cdot 7.611}{(2 \cdot 1 - 0.25) \cdot 0.25} = 139.2 \text{kN/m}$$

$$F = Q_{max} \cdot b \cdot 1.5 = 52.2 \text{kN}$$

The value obtained is lower than the value of the load test, this is due to the simplifications mentioned above but provides a value that appears to be on the safe side according to a parameter equal to

$$F_s = \frac{Q}{Q_{max}} = \frac{100}{52.2} = 1.92$$

Summary table

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		Laboratory test	Manual calculation Geoplast	
MULTIMODULO H25	Slab	Load	Load	
		Q	Q	Fs
	cm	daN	daN	
	5	7885	1676	4.70
	10	14650	3900	3.75
	15	19775	6090	3.25
MODULO H45	Slab	Load	Load	
		Q	Q	Fs
	cm	daN	daN	
	5	3200	1440	2.22
	8	5200	2570	2.02
	10	6440	3340	1.93
	15	10000	5220	1.92

Figure 14

In the light of laboratory tests and the calculations can be drawn from the following considerations:

1 - The data provided by laboratory tests relating to the system MULTIMODULO, show that the relationship between the thickness of the slab and the increased load applicable follow a logarithmic trend; this is due to the considerable amount of feet present (~ 9 per sqm) and the emphasized influence of arch effect of the dome, so it can be argued that the more the thickness of the slab the more the system is approaching a full solution.

The manual calculation instead follows a almost linear trend, this is due to the simplifications made.

The factor obtained from the relationship between the values of the laboratory test and the manual calculation turns out to be a large safety factor.

2 - The data provided by laboratory tests relating to the MODULO system demonstrate how the relationship between the thickness of the slab and the increased load applicable follow a trend a linear, and likewise the manual calculation follows the same trend, this is due to the fact that the simplification made turn out to be less invasive than the MULTIMODULO solution.

The factor obtained from the relationship between the values of the laboratory test and the manual calculation is almost constant and still provides a large safety factor.

Therefore, it is possible to assume the following values as safety factors:

MULTIMODULO		MODULO	
	3.00		1.90

figure 15

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5.2.2.2 *Verification to punching on the slab*

For verification to punching, no shear reinforcement and punching shear no reinforcement is necessary if:

$$v_{Ed} < v_{rd,c} \qquad \textbf{Equation 8}$$

Recall the formulas for calculating the punching resistance NF EN 1992-1-1 :2005-10 chapters 6.4.3.

The design value of the punching resistance of a slab without punching shear reinforcements along the control section:

$$v_{Rd,c} = C_{Rd,c} \cdot k \cdot (100 \cdot \rho_l \cdot f_{ck})^{1/3} \qquad \textbf{Equation 9}$$

$C_{Rd,c}$ $0.18/\gamma_c$

γ_c partial safety factor for concrete = 1.60 ;

ρ_l percentages of tensile reinforcement;

f_{ck} Characteristic compressive strength ;

d Effective height;

Values must be compared with v_{Ed} that represents the values of rupture per unit length.

$$v_{Ed} = \frac{V_{Ed}}{u_l \cdot d} \qquad \textbf{Equation 10}$$

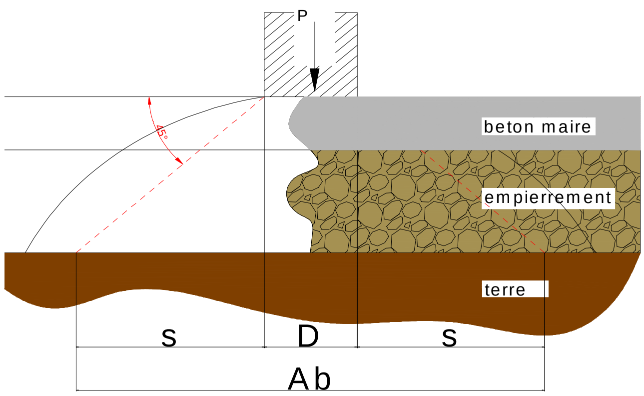
u_l perimeter of load;

If the inequality is not respected according to $v_{Ed} > v_{rd,c}$ should change the thickness of the slab until obtaining satisfactory result.

5.2.2.3 *Contact pressure on the ground*

Following the French standard DTU 13.3 (NF P 11-213-1) in Chapter 5.1.2.3, the ground must ensure Westergaard module not less than 50 MPa / m.

Thus the system MODULO can be placed directly on the prepared soil, following the excavation. However, in case the ground is not bearing, it should make a blocking composed generally of concrete and / or filling material.



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Contact pressure transmitted to the ground through the feet is calculated based on the assumption of a stress distribution with an inclination on of 45 ° (assuming the ground through the different layers is not subject to decompression).
In light of this observation is evaluated, at the desired depth, the imprint of the load of the single element column, then the contact pressure based on the simple relationship between applied load and area of interest.

$$\sigma = \frac{P}{A_b} < \bar{\sigma}_{am.ter.} \quad \textbf{Equation 11}$$

Therefore:
σ= Ground pressure;
P = Total load;
A_b= Base area calculated according to ((s +s + D)/2)π
$\sigma_{am.ter}$= Permissible ground pressure

5.2.2.4 Verification compression of the feet

The feet suffered only one type of stress in the vertical direction representing a compression on a equal footing. Verification to be performed is similar to that used for columns, neglecting in favor of safety the effect of the enlargement of the section.

The NF EN 1992-1-1 :2005-10 section 5.8.3.1 is assumed that the second order effects can be neglected if the slenderness ratio λ (as defined in 5.8.3.2) is less than a value λ_{lim}

$$\lambda_{lim} = 20 \cdot A \cdot B \cdot C / \sqrt{n} \quad \textbf{Equation 12}$$

The slenderness ratio is defined as follows:

$$\lambda = \frac{l_0}{i} \quad \textbf{Equation 13}$$

Therefore:
l_0 is the effective length, see 5.8.3.2 (2) to (7);
i represents the radius of gyration of the uncracked concrete section.

The compression verification of the feet for non-slender elements shall be calculated by reference only to the bottom surface of the unarmed concrete feet and must comply with the following formula (ref 6.2.2 EN 1992-1-1: 2005):

$$\sigma_{cp} = \frac{N_{Ed}}{Ac} \leq f_{cd} \quad \textbf{Equation 14}$$

Therefore:
N_{Ed} is the normal force acting in the cross-section;
σ_{cp} The compressive stress in the concrete due to a normal force or prestressing;
A_c is the area of the cross section of the concrete in mm^2;
f_{cd} Calculation value of the compressive strength of the concrete.

5.3 Conclusion

Based on the calculations, it can be argued that the adoption of static regime described in Section 5.2.2.1 seems appropriate, therefore, the calculation of the presence of distributed loads can be handled using the following formula:

$$M_{max} = \frac{Q \cdot i^2}{8} \qquad \textbf{Equation 15}$$

To calculate the maximum loads acting on the base:

$$Q = \frac{\frac{M_{Rd}}{i} \cdot 8}{i^2} \qquad \textbf{Equation 16}$$

be less than:

$$M_{Rd} = A_s \cdot f_{yd} \cdot d \left(1 - \frac{A_s \cdot f_{yd}}{2 \cdot i \cdot d \cdot f_{cd}} \right) \qquad \textbf{Equation 17}$$

5.4 Minimal reinforcement

To determine the minimum amount of reinforcement of the slab using the formula proposed by the legislation NF EN 1992-1-1 October 2005 - Eurocode 2 al punto 9.3.1.1.

$$A_{s,min} = 0.26 \frac{f_{ctm}}{f_{yk}} b_t d \qquad A_{s,min} \geq 0.0013 b_t d \qquad \textbf{Equation 18}$$

where:

b_t means the average width of the tension zone;

f_{ctm} Should be determined according to the appropriate strength class according to Table 3.1.

Example

For a slab of 50 mm is obtained 52mm^2 of transverse reinforcement corresponding to a mesh PAF C (80 mm^2).

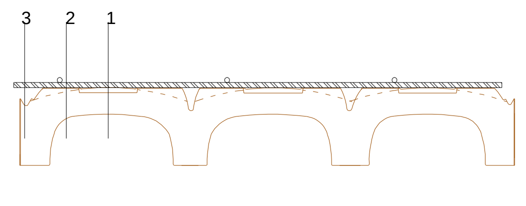
5.4.1 Coating of the reinforcement

For fire resistance, the French national standard DTU 7.4.2.1, stabilizes the minimum coating to ensure, depending on the duration, fire resistance.

Every type of MODULO formwork is characterized by a different form therefore the coating of the reinforcement.

MODULO H3-H6 in these heights only for use renovation of existing floor it is possible to make a slab with a thickness of at least 3 cm with a mesh PAF C or with polypropylene fibers according to the DTU.
To obtain a coating of 1 cm on a minimum area of 90%, it is necessary to provide a spacer when casting.

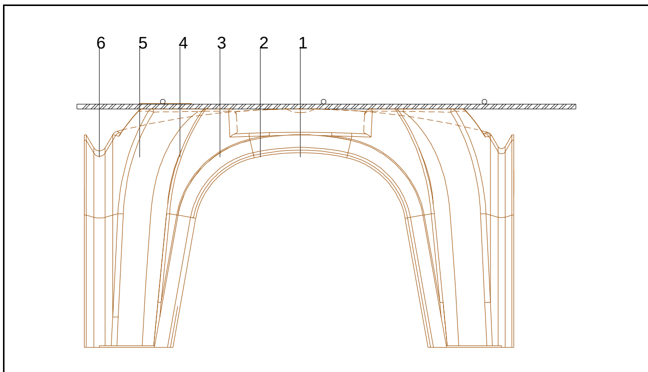
MODULO H9 the shape of the formwork, with several points of support and domes, allow the mesh to be placed directly on the formwork guaranteeing a minimum cover of 1 cm to a minimum of 93% of the surface.



Section	*Position*	*Covering*
1	0.00cm	0.00cm
2	5.00cm	1.04cm
3	10.00cm	2.76cm

figure 16

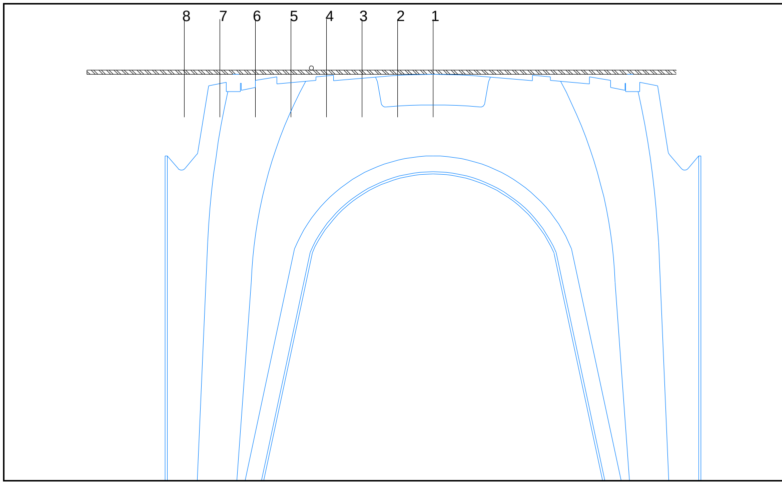
MODULO H13-40 the shaping of the dome very arched allows the mesh to be placed directly on the formwork ensuring a coating of at least 1 cm on a minimum of 95% of the surface.



Section	*Position*	*Covering*
1	0.00cm	0.00cm
2	5.00cm	0.74cm
3	10.00cm	1.12cm
4	15.00cm	1.80cm
5	20.00cm	2.82cm
6	25.00cm	5.90cm

figure 17

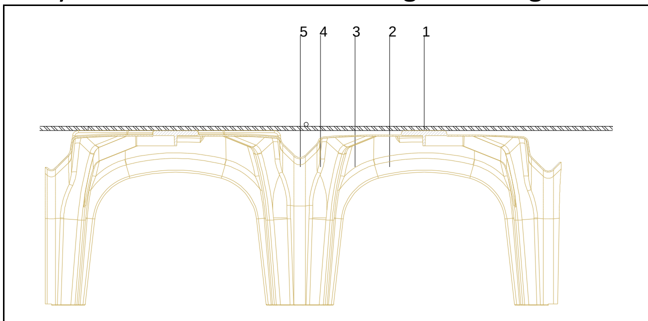
MODULO H45-70 The shape of the dome, little arched, allows the mesh to be placed directly on the formwork ensuring a coating of 60% of the surface. To obtain a coating of 1 cm on a minimum area of 90%, it is necessary to provide a spacer when casting.



Section	*Position*	*Covering*
1	0.00cm	0.00cm
2	5.00cm	0.73cm
3	10.00cm	1.15cm
4	15.00cm	1.81cm
5	20.00cm	2.02cm
6	25.00cm	2.43cm
7	30.00 cm	2.91 cm
8	35.00 cm	14.12 cm

table 18

MULTIMODULO H13-40 the dome shape despite being low arched, allows the mesh to be placed directly on the formwork ensuring a coating of minimum 1 cm to 95% of the area.



Section	*Position*	*Covering*
1	0.00cm	0.00cm
2	5.00cm	1.26cm
3	10.00cm	1.28cm
4	15.00cm	1.67cm
5	20.00cm	4.49cm

table 19

However, it is possible to obtain a coating greater than 1 cm to meet the required standards of fire resistance by positioning the mesh at an appropriate distance from the element.

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5.5 Joints

Failure of a structure can be multiple and they are not limited to exceeding the ultimate strength of sections.
Once the resistance of surfaces created with the system are defined, it is studied the condition of exercise and insufficient behaviour of the structure.
Depending on the geometry, a fundamental problem is the formation of cracks when shrinking, as well as for the realization of traditional paving.
Drying of concrete causes two types of contractions:
- "Plastic shrinkage" when the conglomerate is still fresh in the first hours after casting;
- "Hygrometric shrinkage" in the setting phase when the concrete is already cured and throughout the life of the structure, although most occurs during the first months after the casting.

Stresses that arise in the phase of "plastic shrinkage", even small magnitudes, it hardly affects the strength of concrete.
Regarding the "hygrometric shrinkage" should be to implement protection for a long time and theoretically for all the life of the structure.
Can not eliminate cracks, we seek to limit the consequences, that is to say, their excessive and uncontrolled openings.

5.5.1 Contraction joints

Are sections of preferential weakening in which they may concentrate the stress of contraction. For the realization of such joints is proposed the use of embedded joint; the dimensional characteristics are indicatively suggested in Figure 20.

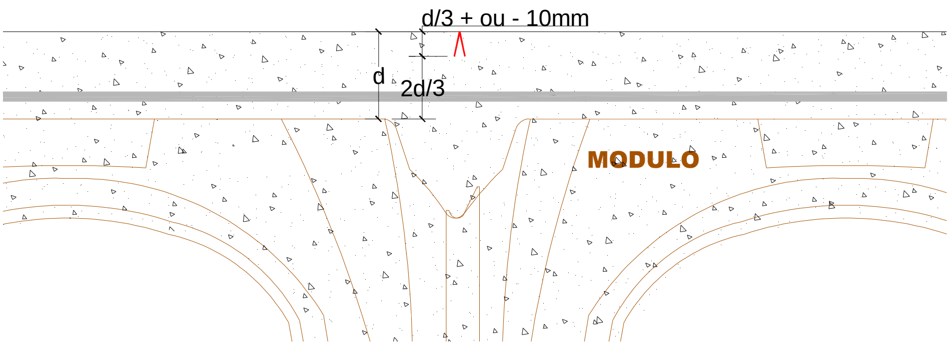


Figure 17

Geoplast will indicate in plan view the correct positioning of contraction joints, in each case the maximum distance between the joints must not exceed 5m for a total area of 25m^2.

5.5.2 Expansion Joints

Expansion joints allow the concrete to expand or retract and to adapt to possible displacements.
The cutting should be made through the entire thickness by interrupting the reinforcement, in some cases it may coincide with the construction joint.
Regarding the performance of the joint for modulo, the rules are similar to a traditional concrete slab.

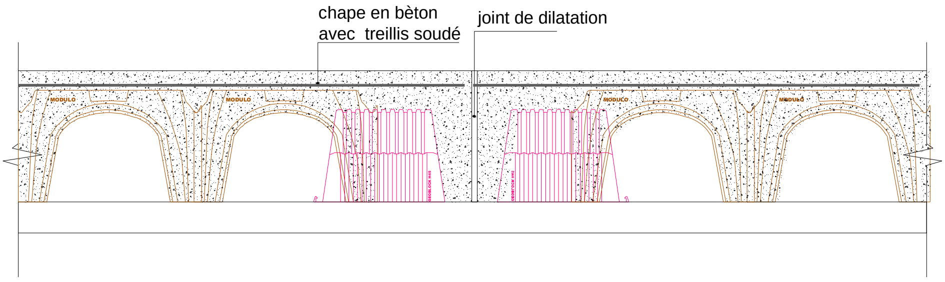


Figure 18

6 *Overall system verification*

Generally the Modulo system lay on a deformable support, characterized by parameters that are defined by geotechnical tests.
The deformability of the soil affects the system causing differential deformations and tensile stresses on the Modulo system.

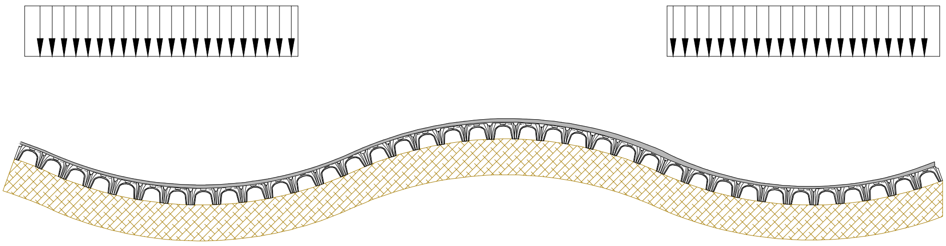


Figure 19

Inside the DTU, chapter C.1.4.6, is defined the formula used to calculate the stress under a distributed load over a strip of flooring in the case of a homogeneous support:

$$M = 0.134 \cdot q \cdot H^2 \cdot \left(\frac{E_b}{E_s}\right)^{2/3}$$ **Equation 19**

Therefore:

q represents the distributed load
H represents the thickness of the system
E_b modulus of deformation of the concrete
E_s modulus of deformation of ground

It is possible to connect the Westergaard modulus measured to the plate of diameter Ø (meter) to the Elastic modulus of a layer, by the expression Es = 0.54Ø Kw wherein Es is expressed in MPa, Ø m and Kw MPa / m.

$$E_s = 0.54 \cdot \pi \cdot K_w = 0.405 \cdot K_w = 0.405 \cdot 50 = 20.25 MPa$$ **Equation 20**

The stresses calculated must be compared with the resistance of the foundation.

EXAMPLE:

given a load of 10,000 N/m2 and a 20cm slab made of concrete C25/30, is necessary to determine whether the chosen section has an adequate thickness and calculate the reinforcement.

$$M = 0.134 \cdot q \cdot H^2 \cdot \left(\frac{E_b}{E_s}\right)^{2/3} = 0.134 \cdot 10000 \cdot 0.20^2 \cdot \left(\frac{31476}{20.25}\right)^{2/3} = 7192\text{daNm} \quad \textbf{Equation 21}$$

The section thickness of 20cm, which verifies this stress is as follows:

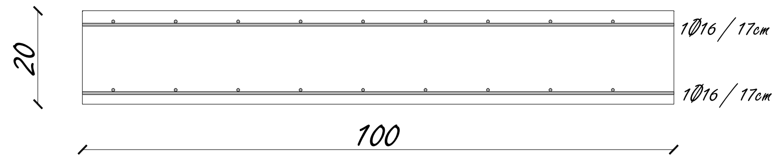
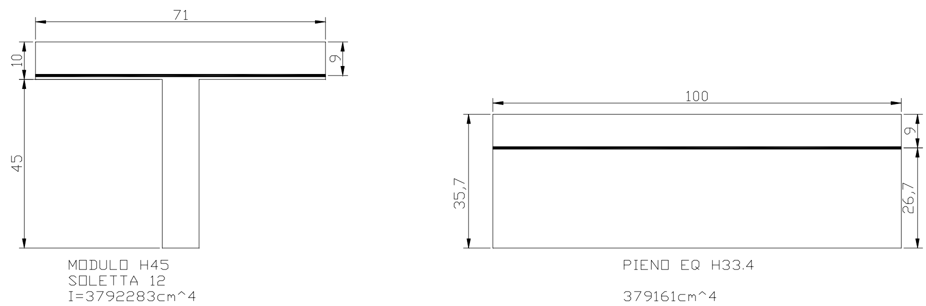


Figure 20

$$M_{res} = 7224\text{daNm} \quad \textbf{Equation 22}$$

To adapt the Modulo system to this calculation has been identified the full slab characterized by a value of inertia equal to that of the Modulo



For example for a Modulo H45 and slab 10cm the full slab equivalent is equal to 36.7cm, applying also in this case a load of 10000daN/m^2 is obtained:

$$M = 0.134 \cdot q \cdot H^2 \cdot \left(\frac{E_b}{E_s}\right)^{2/3} = 0.134 \cdot 10000 \cdot 0.357^2 \cdot \left(\frac{31476}{20.25}\right)^{2/3} = 22916\text{daNm} \quad \textbf{Equation 23}$$

The section that verifies this stress are as follows:

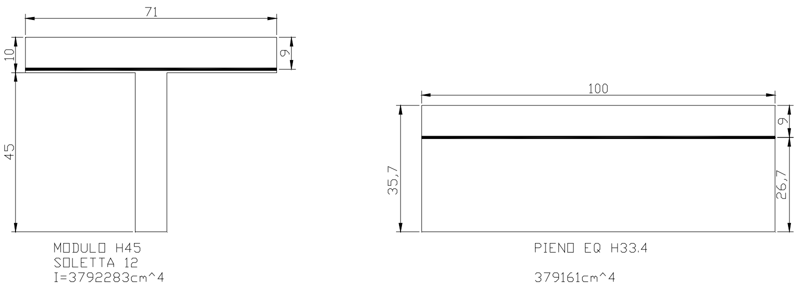


Figure 21

$$M_{res} = 7224 daNm$$ **Equation 24**

This chapter attempts to identify the combination of loads and span more unfavorable to the Modulo system.

To conduct this type of testing we make use of a calculation software that provides the values of rupture and maximum moment acting on the slab.
In order to obtain results in favor of safety is considered as resistant element only the upper slab, not taking into account the effect that the numerous stiffening feet play.
With reference to the load tables shown in the following chapters we have chosen the following combinations to get the most burdensome configuration for the slab.

Slab thickness	***load***	***Figure n.***
cm	daN/m^2	
5	5718	22
20	29835	22

table 20

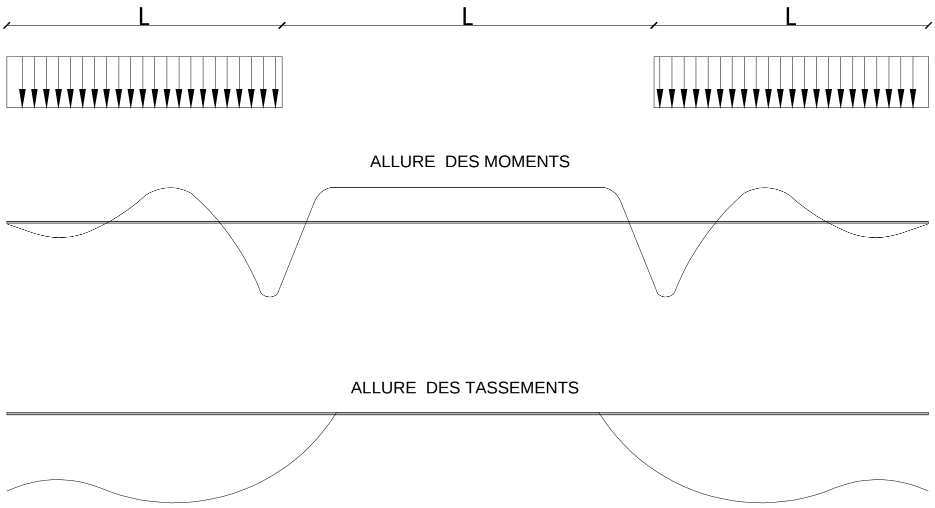


Figure 22

The major stress and subsidence occur in the condition in which the loaded areas have the same extension of the area not loaded.
In this paper we have chosen to identify as amplitude of loaded areas, that represented by the maximum distance between two consecutive contraction joints, or 500cm, other parameter required for parameterization of the soil is the elastic constant of the land imposed to be 1 kg/cm^3.
In the light of these indications we provide the highest stress values and the acting moments

Slab thickness	*load*	*Figure n.*	*Settlement*	*compression moment*	*tensile moment*
cm	daN/m^2		cm	kNm	kNm
5	5718	22	0.013	0.044	-0.026
20	29835	22	0.064	1.128	-1.558

table 21

The respective sections 5x100cm and 20x100cm are surely verified for the positive moments, with regard to the negative moments must verify the tensile resistant section provides a moment value greater than those given in Table 22.

$$M_{Rd} = A_s \cdot f_{yd} \cdot d \cdot \left(1 - \frac{A_s \cdot f_{yd}}{2 \cdot i \cdot d \cdot f_{ctk}}\right) \qquad \textbf{Equation 25}$$

therefore:
f_{ctk} 1.5 MPa for C25/30
d effective height that in the case of tensile strength corresponds to 10mm

$$M_{Rd} = 257 \cdot 391 \cdot 10 \cdot \left(1 - \frac{257 \cdot 391}{2 \cdot 1000 \cdot 10 \cdot 1.5}\right) = -2361010\text{Nmm} = -2.361\text{kNm} \qquad \textbf{Equation 26}$$

In this calculation of global bending, have not been taken into account the Modulo elements H3, H6, H9, as for heights so reduced the stiffening effect of the feet is important and allows to obtain better results.

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TABLE PROVIDING THE THICKNESS OF THE TABLE AS A FUNCTION OF LOAD SERVICE, CONCENTRATED OR DISTRIBUTED

Table prepared for a concrete C25/30 and for a soil Westergaard Modulus of 50 MPa / m.

The attached tables have been calculated on the basis of what exposed through calculation programs considering:

- The reinforcement mesh of reference is as identified by imposing ST 25 C.
- The values of loads and pressures on the ground can vary depending on the reinforcements and must be calculated case by case;
- In case the coverage is exceeded more than the minimum specified in the tables (4 cm) should set up a separate calculation;
- For coverage lower than the minimum provided in the tables (1cm) should set up a separate calculation;
- The installation or the thickness of the slab that is not listed in the table will be subject of a complementary calculation.

NB.

The values reported in the following tables provide slightly different values than those calculated in the examples in section 5.2.2.1 as the tables have been calculated on square load imprint and non-circular, for which the critical perimeter of the punching occurs in a slightly different way.

EXAMPLE OF CALCULATION FOR MODULO H60

Load of 2300 daN ON 8x8cm imprint

<u>1 step</u>

Perform a pre-dimensioning of the system by looking for in the table the imprint load immediately below the one given (8x8), the loading value immediately greater than that given (2300 daN)

In our case imprint 5x5cm load 2703 daN, this combination corresponds to a slab thickness 8cm reinforced with ST 25 C mesh.

<u>2 step</u>

Since this configuration is certainly verified is necessary to check the solution with the thickness of the slab immediately below, or 7cm.

In function of the simplifications described in chapter 5.2.2.1 the resistant section is obtained by the following formula:

$$M_{Rd} = A_s \cdot f_{yd} \cdot d\left(1 - \frac{A_s \cdot f_{yd}}{2 \cdot i \cdot d \cdot f_{cd}}\right) \qquad \textbf{Equation 27}$$

therefore:

A_s	257 mm^2 (ST 25 C);
f_{yd}	391 Mpa ;
d	60 mm;
i	1000 mm;
f_{cd}	11.33 MPa.
b	80 mm

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$$M_{Rd} = 257 \cdot 391 \cdot 60 \cdot \left(1 - \frac{257 \cdot 391}{2 \cdot 1000 \cdot 60 \cdot 11.33}\right) = 5583605\text{Nmm} = 5.584\text{kNm}$$ **Equation 28**

3 step

The value of the maximum load that can be applied to the section to match the bending moment is obtained from the inverse formula:

$$Q_{max} = \frac{8 \cdot M_{res}}{(2 \cdot i - b) \cdot b} = \frac{8 \cdot 5.584}{(2 \cdot 1 - 0.08) \cdot 0.08} = 291\text{kN/m}$$ **Equation 29**

$$F = Q_{max} \cdot b = 291 \cdot 0.08 = 23.28\text{kN} = 2328\text{daN}$$ **Equation 30**

With bending verification is obtained that the value of maximum load that can be applied on a 8x8cm imprint to a slab of 7cm with ST 25 C mesh is equal to 2328 daN, greater than that required, therefore the slab can be of 7 cm.

4 step

For comparison it carries out the calculation of the maximum load to be applied according to the punching test.

The design value of the punching strength of a slab without punching reinforcements along the control section:

$$v_{Rd,c} = C_{Rd,c} \cdot k \cdot (100 \cdot \rho_l \cdot f_{ck})^{1/3}$$ **Equation 31**

$C_{Rd,c} = 0.18 / \gamma_c$;

γ_c 1.50 ;

ρ_l percentages of tensile reinforcement;

f_{ck} Characteristic compressive strength;

d 60 mm ;

a 80 mm ;

$$v_{Rd,c} = 0.12 \cdot 2.00 \cdot (100 \cdot 0.0064 \cdot 25)^{1/3} = 0.605\text{N/mm}^2 = 60500\text{daN/m}^2$$

The maximum load is equal to:

$$v_{Rd,c} \cdot u_l \cdot d = V_{Ed}$$ **Equation 32**

u_l 1040 mm ;

$$60500 \cdot 1.04 \cdot 0.06 = 3775.2\text{daN}$$

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MULTIMODULO H13-H40 (71x71cm)

a	charge pression	EPAISSEUR DALLE 5 min	5 max	6 min	6 max	7 min	7 max	8 min	8 max	9 min	9 max	10 min	10 max	12 min	12 max	15 min	15 max	20 min	20 max
5	P	150	1505	150	1928	150	2351	150	2774	150	3197	150	3620	150	4467	150	5736	150	7851
	s0	0,28	2,77	0,28	3,54	0,28	4,32	0,28	5,10	0,28	5,88	0,28	6,65	0,28	8,21	0,28	10,54	0,28	14,43
	s5	0,09	0,89	0,09	1,14	0,09	1,40	0,09	1,65	0,09	1,90	0,09	2,15	0,09	2,65	0,09	3,40	0,09	4,66
	s10	0,04	0,44	0,04	0,56	0,04	0,68	0,04	0,80	0,04	0,93	0,04	1,05	0,04	1,29	0,04	1,66	0,04	2,27
	s15	0,03	0,26	0,03	0,33	0,03	0,40	0,03	0,47	0,03	0,55	0,03	0,62	0,03	0,76	0,03	0,98	0,03	1,34
	s20	0,02	0,17	0,02	0,22	0,02	0,26	0,02	0,31	0,02	0,36	0,02	0,41	0,02	0,50	0,02	0,65	0,02	0,88
10	P	150	1588	150	2035	150	2482	150	2928	150	3375	150	3821	150	4715	150	6054	150	8288
	s0	0,28	2,92	0,28	3,74	0,28	4,56	0,28	5,38	0,28	6,20	0,28	7,02	0,28	8,67	0,28	11,13	0,28	15,23
	s5	0,09	0,94	0,09	1,21	0,09	1,47	0,09	1,74	0,09	2,00	0,09	2,27	0,09	2,80	0,09	3,59	0,09	4,92
	s10	0,04	0,46	0,04	0,59	0,04	0,72	0,04	0,85	0,04	0,98	0,04	1,11	0,04	1,36	0,04	1,75	0,04	2,40
	s15	0,03	0,27	0,03	0,35	0,03	0,42	0,03	0,50	0,03	0,58	0,03	0,65	0,03	0,81	0,03	1,03	0,03	1,42
	s20	0,02	0,18	0,02	0,23	0,02	0,28	0,02	0,33	0,02	0,38	0,02	0,43	0,02	0,53	0,02	0,68	0,02	0,93
15	P	150	1682	150	2155	150	2628	150	3100	150	3573	150	4046	150	4992	150	6411	150	8775
	s0	0,28	3,09	0,28	3,96	0,28	4,83	0,28	5,70	0,28	6,57	0,28	7,44	0,28	9,18	0,28	11,78	0,28	16,13
	s5	0,09	1,00	0,09	1,28	0,09	1,56	0,09	1,84	0,09	2,12	0,09	2,40	0,09	2,96	0,09	3,80	0,09	5,21
	s10	0,04	0,49	0,04	0,62	0,04	0,76	0,04	0,90	0,04	1,03	0,04	1,17	0,04	1,45	0,04	1,86	0,04	2,54
	s15	0,03	0,29	0,03	0,37	0,03	0,45	0,03	0,53	0,03	0,61	0,03	0,69	0,03	0,85	0,03	1,10	0,03	1,50
	s20	0,02	0,19	0,02	0,24	0,02	0,30	0,02	0,35	0,02	0,40	0,02	0,46	0,02	0,56	0,02	0,72	0,02	0,99
20	P	150	1787	150	2289	150	2792	150	3294	150	3797	150	4299	150	5304	150	6811	150	9323
	s0	0,28	3,28	0,28	4,21	0,28	5,13	0,28	6,06	0,28	6,98	0,28	7,90	0,28	9,75	0,28	12,52	0,28	17,14
	s5	0,09	1,06	0,09	1,36	0,09	1,66	0,09	1,96	0,09	2,25	0,09	2,55	0,09	3,15	0,09	4,04	0,09	5,53
	s10	0,04	0,52	0,04	0,66	0,04	0,81	0,04	0,95	0,04	1,10	0,04	1,24	0,04	1,54	0,04	1,97	0,04	2,70
	s15	0,03	0,31	0,03	0,39	0,03	0,48	0,03	0,56	0,03	0,65	0,03	0,73	0,03	0,91	0,03	1,16	0,03	1,59
	s20	0,02	0,20	0,02	0,26	0,02	0,31	0,02	0,37	0,02	0,43	0,02	0,48	0,02	0,60	0,02	0,77	0,02	1,05
25	P	150	1906	150	2442	150	2978	150	3514	150	4050	150	4586	150	5658	150	7265	150	9945
	s0	0,28	3,50	0,28	4,49	0,28	5,47	0,28	6,46	0,28	7,44	0,28	8,43	0,28	10,40	0,28	13,36	0,28	18,28
	s5	0,09	1,13	0,09	1,45	0,09	1,77	0,09	2,09	0,09	2,40	0,09	2,72	0,09	3,36	0,09	4,31	0,09	5,90
	s10	0,04	0,55	0,04	0,71	0,04	0,86	0,04	1,02	0,04	1,17	0,04	1,33	0,04	1,64	0,04	2,10	0,04	2,88
	s15	0,03	0,33	0,03	0,42	0,03	0,51	0,03	0,60	0,03	0,69	0,03	0,78	0,03	0,97	0,03	1,24	0,03	1,70
	s20	0,02	0,21	0,02	0,28	0,02	0,34	0,02	0,40	0,02	0,46	0,02	0,52	0,02	0,64	0,02	0,82	0,02	1,12
30	P	150	2042	150	2616	150	3191	150	3765	150	4339	150	4913	150	6062	150	7784	150	10655
	s0	0,28	3,75	0,28	4,81	0,28	5,87	0,28	6,92	0,28	7,98	0,28	9,03	0,28	11,14	0,28	14,31	0,28	19,59
	s5	0,09	1,21	0,09	1,55	0,09	1,89	0,09	2,23	0,09	2,58	0,09	2,92	0,09	3,60	0,09	4,62	0,09	6,32
	s10	0,04	0,59	0,04	0,76	0,04	0,92	0,04	1,09	0,04	1,26	0,04	1,42	0,04	1,75	0,04	2,25	0,04	3,08
	s15	0,03	0,35	0,03	0,45	0,03	0,55	0,03	0,64	0,03	0,74	0,03	0,84	0,03	1,04	0,03	1,33	0,03	1,82
	s20	0,02	0,23	0,02	0,29	0,02	0,36	0,02	0,42	0,02	0,49	0,02	0,55	0,02	0,68	0,02	0,88	0,02	1,20
distrib	P	150	5718	150	7326	150	8934	150	10542	150	12149	150	13757	150	16973	150	21796	150	29835
	s0	0,56	10,51	0,56	13,47	0,56	16,42	0,56	19,38	0,56	22,33	0,56	25,29	0,56	31,20	0,56	40,07	0,56	54,84
	s5	0,18	3,39	0,18	4,35	0,18	5,30	0,18	6,26	0,18	7,21	0,18	8,16	0,18	10,07	0,18	12,94	0,18	17,71
	s10	0,09	1,66	0,09	2,12	0,09	2,59	0,09	3,05	0,09	3,52	0,09	3,98	0,09	4,91	0,09	6,31	0,09	8,64
	s15	0,05	0,98	0,05	1,25	0,05	1,53	0,05	1,80	0,05	2,08	0,05	2,35	0,05	2,90	0,05	3,72	0,05	5,10
	s20	0,03	0,64	0,03	0,83	0,03	1,01	0,03	1,19	0,03	1,37	0,03	1,55	0,03	1,91	0,03	2,46	0,03	3,36

table 22

a load imprint	[cm]	σ_0	pressure on the ground in the absence of lean concrete	[daN/m^2]
s slab thickness	[cm]	σ_5	pressure on the ground with 5 cm of lean concrete	[daN/m^2]
P concentrated load	[daN]	σ_{10}	pressure on the ground with 10 cm of lean concrete	[daN/m^2]
q distributed load	[daN/m^2]	σ_{15}	pressure on the ground with 15 cm of lean concrete	[daN/m^2]
		σ_{25}	pressure on the ground with 20 cm of lean concrete	[daN/m^2]

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MODULO H13-H40 (50x50cm)

a	charge pression	EPAISSEUR DALLE																	
		5		6		7		8		9		10		12		15		20	
		min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
5	**P**	**150**	**1484**	**150**	**1901**	**150**	**2319**	**150**	**2736**	**150**	**3154**	**150**	**3571**	**150**	**4406**	**150**	**5658**	**150**	**7745**
	s0	0,19	1,89	0,19	2,43	0,19	2,96	0,19	3,49	0,19	4,02	0,19	4,55	0,19	5,62	0,19	7,22	0,19	9,88
	s5	0,07	0,71	0,07	0,91	0,07	1,11	0,07	1,31	0,07	1,51	0,07	1,71	0,07	2,11	0,07	2,71	0,07	3,70
	s10	0,04	0,37	0,04	0,47	0,04	0,58	0,04	0,68	0,04	0,78	0,04	0,89	0,04	1,09	0,04	1,41	0,04	1,92
	s15	0,02	0,23	0,02	0,29	0,02	0,35	0,02	0,42	0,02	0,48	0,02	0,54	0,02	0,67	0,02	0,86	0,02	1,18
	s20	0,02	0,15	0,02	0,19	0,02	0,24	0,02	0,28	0,02	0,32	0,02	0,37	0,02	0,45	0,02	0,58	0,02	0,79
10	**P**	**150**	**1541**	**150**	**1974**	**150**	**2407**	**150**	**2840**	**150**	**3274**	**150**	**3707**	**150**	**4573**	**150**	**5873**	**150**	**8039**
	s0	0,19	1,97	0,19	2,52	0,19	3,07	0,19	3,62	0,19	4,18	0,19	4,73	0,19	5,83	0,19	7,49	0,19	10,25
	s5	0,07	0,74	0,07	0,94	0,07	1,15	0,07	1,36	0,07	1,57	0,07	1,77	0,07	2,19	0,07	2,81	0,07	3,85
	s10	0,04	0,38	0,04	0,49	0,04	0,60	0,04	0,71	0,04	0,81	0,04	0,92	0,04	1,14	0,04	1,46	0,04	2,00
	s15	0,02	0,23	0,02	0,30	0,02	0,37	0,02	0,43	0,02	0,50	0,02	0,56	0,02	0,69	0,02	0,89	0,02	1,22
	s20	0,02	0,16	0,02	0,20	0,02	0,25	0,02	0,29	0,02	0,33	0,02	0,38	0,02	0,47	0,02	0,60	0,02	0,82
15	**P**	**150**	**1602**	**150**	**2052**	**150**	**2502**	**150**	**2953**	**150**	**3403**	**150**	**3853**	**150**	**4754**	**150**	**6105**	**150**	**8357**
	s0	0,19	2,04	0,19	2,62	0,19	3,19	0,19	3,77	0,19	4,34	0,19	4,92	0,19	6,06	0,19	7,79	0,19	10,66
	s5	0,07	0,77	0,07	0,98	0,07	1,20	0,07	1,41	0,07	1,63	0,07	1,84	0,07	2,27	0,07	2,92	0,07	4,00
	s10	0,04	0,40	0,04	0,51	0,04	0,62	0,04	0,73	0,04	0,85	0,04	0,96	0,04	1,18	0,04	1,52	0,04	2,08
	s15	0,02	0,24	0,02	0,31	0,02	0,38	0,02	0,45	0,02	0,52	0,02	0,58	0,02	0,72	0,02	0,93	0,02	1,27
	s20	0,02	0,16	0,02	0,21	0,02	0,26	0,02	0,30	0,02	0,35	0,02	0,39	0,02	0,49	0,02	0,62	0,02	0,85
20	**P**	**150**	**1667**	**150**	**2136**	**150**	**2605**	**150**	**3074**	**150**	**3543**	**150**	**4012**	**150**	**4950**	**150**	**6357**	**150**	**8702**
	s0	0,19	2,13	0,19	2,73	0,19	3,32	0,19	3,92	0,19	4,52	0,19	5,12	0,19	6,31	0,19	8,11	0,19	11,10
	s5	0,07	0,80	0,07	1,02	0,07	1,25	0,07	1,47	0,07	1,69	0,07	1,92	0,07	2,37	0,07	3,04	0,07	4,16
	s10	0,04	0,41	0,04	0,53	0,04	0,65	0,04	0,76	0,04	0,88	0,04	1,00	0,04	1,23	0,04	1,58	0,04	2,16
	s15	0,02	0,25	0,02	0,32	0,02	0,40	0,02	0,47	0,02	0,54	0,02	0,61	0,02	0,75	0,02	0,96	0,02	1,32
	s20	0,02	0,17	0,02	0,22	0,02	0,27	0,02	0,31	0,02	0,36	0,02	0,41	0,02	0,51	0,02	0,65	0,02	0,89
25	**P**	**150**	**1739**	**150**	**2228**	**150**	**2717**	**150**	**3206**	**150**	**3695**	**150**	**4185**	**150**	**5163**	**150**	**6630**	**150**	**9075**
	s0	0,19	2,22	0,19	2,84	0,19	3,47	0,19	4,09	0,19	4,71	0,19	5,34	0,19	6,59	0,19	8,46	0,19	11,58
	s5	0,07	0,83	0,07	1,07	0,07	1,30	0,07	1,53	0,07	1,77	0,07	2,00	0,07	2,47	0,07	3,17	0,07	4,34
	s10	0,04	0,43	0,04	0,55	0,04	0,67	0,04	0,80	0,04	0,92	0,04	1,04	0,04	1,28	0,04	1,65	0,04	2,25
	s15	0,02	0,26	0,02	0,34	0,02	0,41	0,02	0,49	0,02	0,56	0,02	0,64	0,02	0,78	0,02	1,01	0,02	1,38
	s20	0,02	0,18	0,02	0,23	0,02	0,28	0,02	0,33	0,02	0,38	0,02	0,43	0,02	0,53	0,02	0,68	0,02	0,93
30	**P**	**150**	**1817**	**150**	**2328**	**150**	**2839**	**150**	**3350**	**150**	**3861**	**150**	**4372**	**150**	**5394**	**150**	**6928**	**150**	**9483**
	s0	0,19	2,32	0,19	2,97	0,19	3,62	0,19	4,27	0,19	4,93	0,19	5,58	0,19	6,88	0,19	8,84	0,19	12,10
	s5	0,07	0,87	0,07	1,11	0,07	1,36	0,07	1,60	0,07	1,85	0,07	2,09	0,07	2,58	0,07	3,31	0,07	4,54
	s10	0,04	0,45	0,04	0,58	0,04	0,71	0,04	0,83	0,04	0,96	0,04	1,09	0,04	1,34	0,04	1,72	0,04	2,36
	s15	0,02	0,28	0,02	0,35	0,02	0,43	0,02	0,51	0,02	0,59	0,02	0,66	0,02	0,82	0,02	1,05	0,02	1,44
	s20	0,02	0,19	0,02	0,24	0,02	0,29	0,02	0,34	0,02	0,39	0,02	0,45	0,02	0,55	0,02	0,71	0,02	0,97
distrib	**P**	**150**	**4050**	**150**	**5189**	**150**	**6328**	**150**	**7467**	**150**	**8606**	**150**	**9745**	**150**	**12022**	**150**	**15439**	**150**	**21134**
	s0	0,39	5,17	0,39	6,62	0,39	8,07	0,39	9,52	0,39	10,98	0,39	12,43	0,39	15,33	0,39	19,69	0,39	26,96
	s5	0,14	1,94	0,14	2,48	0,14	3,03	0,14	3,57	0,14	4,12	0,14	4,66	0,14	5,75	0,14	7,38	0,14	10,11
	s10	0,08	1,01	0,08	1,29	0,08	1,57	0,08	1,85	0,08	2,14	0,08	2,42	0,08	2,99	0,08	3,84	0,08	5,25
	s15	0,05	0,61	0,05	0,79	0,05	0,96	0,05	1,13	0,05	1,31	0,05	1,48	0,05	1,82	0,05	2,34	0,05	3,21
	s20	0,03	0,41	0,03	0,53	0,03	0,65	0,03	0,76	0,03	0,88	0,03	1,00	0,03	1,23	0,03	1,58	0,03	2,16

table 23

a load imprint [cm]
s slab thickness [cm]
P concentrated load [daN]
q distributed load [daN/m^2]

σ_0 pressure on the ground in the absence of lean concrete [daN/m^2]
σ_5 pressure on the ground with 5 cm of lean concrete [daN/m^2]
σ_{10} pressure on the ground with 10 cm of lean concrete [daN/m^2]
σ_{15} pressure on the ground with 15 cm of lean concrete [daN/m^2]
σ_{25} pressure on the ground with 20 cm of lean concrete [daN/m^2]

MODULO H45-H70 (71x71cm)

a	charge pression	EPAISSEUR DALLE																	
		5		6		7		8		9		10		12		15		20	
		min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
5	P	**150**	**1466**	**150**	**1878**	**150**	**2291**	**150**	**2703**	**150**	**3115**	**150**	**3527**	**150**	**4352**	**150**	**5589**	**150**	**7650**
	s0	0,17	1,63	0,17	2,09	0,17	2,55	0,17	3,00	0,17	3,46	0,17	3,92	0,17	4,84	0,17	6,21	0,17	8,50
	s5	0,07	0,64	0,07	0,82	0,07	1,01	0,07	1,19	0,07	1,37	0,07	1,55	0,07	1,91	0,07	2,45	0,07	3,36
	s10	0,04	0,34	0,04	0,44	0,04	0,53	0,04	0,63	0,04	0,73	0,04	0,82	0,04	1,02	0,04	1,30	0,04	1,79
	s15	0,02	0,21	0,02	0,27	0,02	0,33	0,02	0,39	0,02	0,45	0,02	0,51	0,02	0,63	0,02	0,81	0,02	1,11
	s20	0,01	0,14	0,01	0,18	0,01	0,23	0,01	0,27	0,01	0,31	0,01	0,35	0,01	0,43	0,01	0,55	0,01	0,75
10	P	**150**	**1505**	**150**	**1928**	**150**	**2351**	**150**	**2774**	**150**	**3197**	**150**	**3620**	**150**	**4467**	**150**	**5736**	**150**	**7851**
	s0	0,17	1,67	0,17	2,14	0,17	2,61	0,17	3,08	0,17	3,55	0,17	4,02	0,17	4,96	0,17	6,37	0,17	8,72
	s5	0,07	0,66	0,07	0,85	0,07	1,03	0,07	1,22	0,07	1,40	0,07	1,59	0,07	1,96	0,07	2,52	0,07	3,45
	s10	0,04	0,35	0,04	0,45	0,04	0,55	0,04	0,65	0,04	0,75	0,04	0,85	0,04	1,04	0,04	1,34	0,04	1,83
	s15	0,02	0,22	0,02	0,28	0,02	0,34	0,02	0,40	0,02	0,46	0,02	0,52	0,02	0,65	0,02	0,83	0,02	1,13
	s20	0,01	0,15	0,01	0,19	0,01	0,23	0,01	0,27	0,01	0,31	0,01	0,36	0,01	0,44	0,01	0,56	0,01	0,77
15	P	**150**	**1545**	**150**	**1980**	**150**	**2415**	**150**	**2849**	**150**	**3284**	**150**	**3718**	**150**	**4587**	**150**	**5891**	**150**	**8064**
	s0	0,17	1,72	0,17	2,20	0,17	2,68	0,17	3,17	0,17	3,65	0,17	4,13	0,17	5,10	0,17	6,55	0,17	8,96
	s5	0,07	0,68	0,07	0,87	0,07	1,06	0,07	1,25	0,07	1,44	0,07	1,63	0,07	2,01	0,07	2,59	0,07	3,54
	s10	0,04	0,36	0,04	0,46	0,04	0,56	0,04	0,67	0,04	0,77	0,04	0,87	0,04	1,07	0,04	1,38	0,04	1,88
	s15	0,02	0,22	0,02	0,29	0,02	0,35	0,02	0,41	0,02	0,47	0,02	0,54	0,02	0,66	0,02	0,85	0,02	1,17
	s20	0,01	0,15	0,01	0,19	0,01	0,24	0,01	0,28	0,01	0,32	0,01	0,37	0,01	0,45	0,01	0,58	0,01	0,79
20	P	**150**	**1588**	**150**	**2035**	**150**	**2482**	**150**	**2928**	**150**	**3375**	**150**	**3821**	**150**	**4715**	**150**	**6054**	**150**	**8288**
	s0	0,17	1,76	0,17	2,26	0,17	2,76	0,17	3,25	0,17	3,75	0,17	4,25	0,17	5,24	0,17	6,73	0,17	9,21
	s5	0,07	0,70	0,07	0,89	0,07	1,09	0,07	1,29	0,07	1,48	0,07	1,68	0,07	2,07	0,07	2,66	0,07	3,64
	s10	0,04	0,37	0,04	0,48	0,04	0,58	0,04	0,68	0,04	0,79	0,04	0,89	0,04	1,10	0,04	1,41	0,04	1,93
	s15	0,02	0,23	0,02	0,29	0,02	0,36	0,02	0,42	0,02	0,49	0,02	0,55	0,02	0,68	0,02	0,88	0,02	1,20
	s20	0,01	0,16	0,01	0,20	0,01	0,24	0,01	0,29	0,01	0,33	0,01	0,38	0,01	0,46	0,01	0,59	0,01	0,81
25	P	**150**	**1634**	**150**	**2093**	**150**	**2553**	**150**	**3012**	**150**	**3471**	**150**	**3931**	**150**	**4849**	**150**	**6227**	**150**	**8524**
	s0	0,17	1,82	0,17	2,33	0,17	2,84	0,17	3,35	0,17	3,86	0,17	4,37	0,17	5,39	0,17	6,92	0,17	9,47
	s5	0,07	0,72	0,07	0,92	0,07	1,12	0,07	1,32	0,07	1,52	0,07	1,73	0,07	2,13	0,07	2,73	0,07	3,74
	s10	0,04	0,38	0,04	0,49	0,04	0,60	0,04	0,70	0,04	0,81	0,04	0,92	0,04	1,13	0,04	1,45	0,04	1,99
	s15	0,02	0,24	0,02	0,30	0,02	0,37	0,02	0,44	0,02	0,50	0,02	0,57	0,02	0,70	0,02	0,90	0,02	1,23
	s20	0,01	0,16	0,01	0,21	0,01	0,25	0,01	0,30	0,01	0,34	0,01	0,39	0,01	0,48	0,01	0,61	0,01	0,84
30	P	**150**	**1682**	**150**	**2155**	**150**	**2628**	**150**	**3100**	**150**	**3573**	**150**	**4046**	**150**	**4992**	**150**	**6411**	**150**	**8775**
	s0	0,17	1,87	0,17	2,39	0,17	2,92	0,17	3,44	0,17	3,97	0,17	4,50	0,17	5,55	0,17	7,12	0,17	9,75
	s5	0,07	0,74	0,07	0,95	0,07	1,15	0,07	1,36	0,07	1,57	0,07	1,78	0,07	2,19	0,07	2,81	0,07	3,85
	s10	0,04	0,39	0,04	0,50	0,04	0,61	0,04	0,72	0,04	0,83	0,04	0,94	0,04	1,17	0,04	1,50	0,04	2,05
	s15	0,02	0,24	0,02	0,31	0,02	0,38	0,02	0,45	0,02	0,52	0,02	0,58	0,02	0,72	0,02	0,93	0,02	1,27
	s20	0,01	0,17	0,01	0,21	0,01	0,26	0,01	0,30	0,01	0,35	0,01	0,40	0,01	0,49	0,01	0,63	0,01	0,86
distrib	P	**150**	**2859**	**150**	**3663**	**150**	**4467**	**150**	**5271**	**150**	**6075**	**150**	**6879**	**150**	**8486**	**150**	**10898**	**150**	**14918**
	s0	0,34	6,41	0,34	8,21	0,34	10,01	0,34	11,81	0,34	13,61	0,34	15,41	0,34	19,01	0,34	24,42	0,34	33,42
	s5	0,13	2,53	0,13	3,24	0,13	3,95	0,13	4,67	0,13	5,38	0,13	6,09	0,13	7,51	0,13	9,65	0,13	13,21
	s10	0,07	1,35	0,07	1,72	0,07	2,10	0,07	2,48	0,07	2,86	0,07	3,24	0,07	3,99	0,07	5,13	0,07	7,02
	s15	0,04	0,83	0,04	1,07	0,04	1,30	0,04	1,54	0,04	1,77	0,04	2,00	0,04	2,47	0,04	3,18	0,04	4,35
	s20	0,03	0,57	0,03	0,73	0,03	0,88	0,03	1,04	0,03	1,20	0,03	1,36	0,03	1,68	0,03	2,16	0,03	2,95

table 24

a load imprint	[cm]	σ_0	pressure on the ground in the absence of lean concrete	[daN/m^2]
s slab thickness	[cm]	σ_5	pressure on the ground with 5 cm of lean concrete	[daN/m^2]
P concentrated load	[daN]	σ_{10}	pressure on the ground with 10 cm of lean concrete	[daN/m^2]
q distributed load	[daN/m^2]	σ_{15}	pressure on the ground with 15 cm of lean concrete	[daN/m^2]
		σ_{25}	pressure on the ground with 20 cm of lean concrete	[daN/m^2]

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Example 1:

known concentrated load, calculated minimum slab thickness and pressure on the ground.

2400daN load on 10x10cm imprint load;

A_ individuated in column “a” the imprint load;

B_ scroll horizontally to locate the load immediately above 2400daN;

C_ at this point it identifies the minimum thickness of the slab;

D_ scrolling through the values in the vertical axis you locate the pressure on the ground

a	charge pression	5		6		7		8	
		min	max	min	max	min	max	min	ma
5	P	150	1505	150	1928	150	2351	150	277
	s0	0,28	2,77	0,28	3,54	0,28	4,32	0,28	5,1
	s5	0,09	0,89	0,09	1,14	0,09	1,40	0,09	1,6
	s10	0,04	0,44	0,04	0,56	0,04	0,68	0,04	0,8
	s15	0,03	0,26	0,03	0,33	0,03	0,40	0,03	0,4
	s20	0,02	0,17	0,02	0,22	0,02	0,26	0,02	0,3
10	P	150	1588	150	2035	150	2482	150	292
	s0	0,28	2,92	0,28	3,74	0,28	4,56	0,28	5,3
	s5	0,09	0,94	0,09	1,21	0,09	1,47	0,09	1,7
	s10	0,04	0,46	0,04	0,59	0,04	0,72	0,04	0,8
	s15	0,03	0,27	0,03	0,35	0,03	0,42	0,03	0,5
	s20	0,02	0,18	0,02	0,23	0,02	0,28	0,02	0,3
	P	150	1682	150	2155	150	2628	150	310
	s0	0,28	3,09	0,28	3,96	0,28	4,83	0,28	5,7
	s5	0,09	1,00	0,09	1,28	0,09	1,56	0,09	1,8

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Example 2:

known distributed load, calculate the minimum slab and pressure on the ground.

Load 6000daN/m^2;

A_ individuated in column “a” the distributed load;

B_ scroll horizontally to locate the load immediately above 6000daN;

C_ at this point it identifies the minimum thickness of the slab;

D_ scrolling through the values in the vertical axis you locate the pressure on the ground

a	charge pression	5		6		
		min	max	min	max	min
5	P	150	1505	150	1928	150
	s0	0,28	2,77	0,28	3,54	0,28
	s5	0,09	0,89	0,09	1,14	0,09
	s10	0,04	0,44	0,04	0,56	0,04
	s15	0,03	0,26	0,03	0,33	0,03
	s20	0,02	0,17	0,02	0,22	0,02
10	P	150	1588	150	2035	150
	s0	0,28	2,92	0,28	3,74	0,28
	s5	0,09	0,94	0,09	1,21	0,09
	s10	0,04	0,46	0,04	0,59	0,04
	s15	0,03	0,27	0,03	0,35	0,03
	s20	0,02	0,18	0,02	0,23	0,02
15	P	150	1682	150	2155	150
	s0	0,28	3,09	0,28	3,96	0,28
	s5	0,09	1,00	0,09	1,28	0,09
	s10	0,04	0,49	0,04	0,62	0,04
	s15	0,03	0,29	0,03	0,37	0,03
	s20	0,02	0,19	0,02	0,24	0,02
20	P	150	1787	150	2289	150
	s0	0,28	3,28	0,28	4,21	0,28
	s5	0,09	1,06	0,09	1,36	0,09
	s10	0,04	0,52	0,04	0,66	0,04
	s15	0,03	0,31	0,03	0,39	0,03
	s20	0,02	0,20	0,02	0,26	0,02
25	P	150	1906	150	2442	150
	s0	0,28	3,50	0,28	4,49	0,28
	s5	0,09	1,13	0,09	1,45	0,09
	s10	0,04	0,55	0,04	0,71	0,04
	s15	0,03	0,33	0,03	0,42	0,03
	s20	0,02	0,21	0,02	0,28	0,02
30	P	150	2042	150	2616	150
	s0	0,28	3,75	0,28	4,81	0,28
	s5	0,09	1,21	0,09	1,55	0,09
	s10	0,04	0,59	0,04	0,76	0,04
	s15	0,03	0,35	0,03	0,45	0,03
	s20	0,02	0,23	0,02	0,29	0,02
distrib	P	150	5718	150	7326	150
	s0	0,56	10,51	0,56	13,47	0,56
	s5	0,18	3,39	0,18	4,35	0,18
	s10	0,09	1,66	0,09	2,12	0,09
	s15	0,05	0,98	0,05	1,25	0,05
	s20	0,03	0,64	0,03	0,83	0,03

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Example 3:

Slab thickness and concentreated imprint load known, calculate the maximum load and pressure on the ground

8 cm slab load imprint 15x15cm;

A_ individuate in column “a” the imprint load;

B_inviduate in column “EPAISSEU” the slab thickness;

C_ the intersection between the two straight lines identifies the maximum applicable load;

D_ scrolling through the values in the vertical axis you locate the pressure on the ground.

a	charge pression	EPAISSEU								
		5		6		7		8		
		min	max	min	max	min	max	min	max	min
5	P	150	1546	150	2136	150	2798	150	3529	150
	s0	0,28	2,84	0,28	3,93	0,28	5,14	0,28	6,49	0,28
	s5	0,09	0,92	0,09	1,27	0,09	1,66	0,09	2,09	0,09
	s10	0,04	0,45	0,04	0,62	0,04	0,81	0,04	1,02	0,04
	s15	0,03	0,26	0,03	0,37	0,03	0,48	0,03	0,60	0,03
	s20	0,02	0,17	0,02	0,24	0,02	0,32	0,02	0,40	0,02
10	P	150	1914	150	2563	150	3280	150	4063	150
	s0	0,28	3,52	0,28	4,71	0,28	6,03	0,28	7,47	0,28
	s5	0,09	1,14	0,09	1,52	0,09	1,95	0,09	2,41	0,09
	s10	0,04	0,55	0,04	0,74	0,04	0,95	0,04	1,18	0,04
	s15	0,03	0,33	0,03	0,44	0,03	0,56	0,03	0,69	0,03
	s20	0,02	0,22	0,02	0,29	0,02	0,37	0,02	0,46	0,02
15	P	150	2283	150	2990	150	3763	150	4598	150
	s0	0,28	4,20	0,28	5,50	0,28	6,92	0,28	8,45	0,28
	s5	0,09	1,35	0,09	1,77	0,09	2,23	0,09	2,73	0,09
	s10	0,04	0,66	0,04	0,87	0,04	1,09	0,04	1,33	0,04
	s15	0,03	0,39	0,03	0,51	0,03	0,64	0,03	0,79	0,03
	s20	0,02	0,26	0,02	0,34	0,02	0,42	0,02	0,52	0,02
	P	150	2651	150	3418	150	4245	150	5132	150

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Accessories

GeoBlock elements made of regenerated polypropylene are characterized by a form that allows for pouring concrete between the slab and foundation in one intervention.
The GeoBlock is realized with a series of grooves in the upper and lateral side, allowing the Geoblock to be fixed underneath Modulo's domes. The grooves allow to slide and position the GeoBlock forward or backward according to the specific of the site.
Its arched shape, and the characteristic of being supported on four sides, allows it to withstand the load of the concrete, also the coupling allowed by the grooves allows to block the Geoblock without that the lateral thrust change its position.

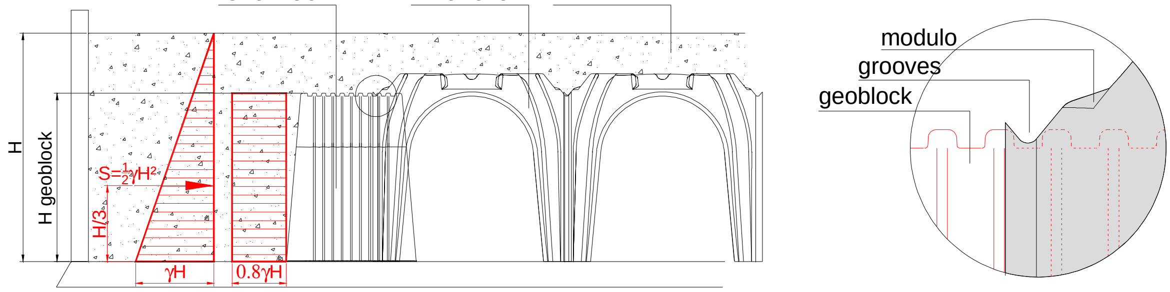

Figure 23

The GeoBlock has a punching strength of 1.5 kN on a certified imprint of 8x8cm.
GeoBlock is 0.8γH x Hgeoblock / b geoblock for various loading situations we notice that the load pressure is less than the resistant pressure.

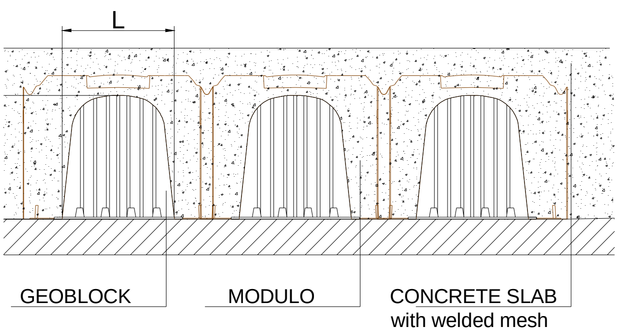

Figure 24

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CHARACTERISTICS OF GEOBLOCK ELEMENTS (MODULO)		
GEOBLOCK	b [cm]	h [cm]
H13	28.0	7.0
H15	26.4	9.5
H17	30.0	11.5
H20	28.0	14.5
H25	31.5	20.5
H27	34.0	21.0
H30	31.7	24.5
H35	35.0	30.0
H40	36.0	34.0
H45	50.0	36.0
H50	51.0	41.0
H55	52.0	46.0
H60	52.0	51.0
H65	53.0	56.0
H70	53.0	61.0

table 25

CHARACTERISTICS OF GEOBLOCK ELEMENTS **(MULTIMODULO)**		
GEOBLOCK	b [cm]	h [cm]
H13	23.5	7.0
H15	22.0	9.0
H17	24.5	11.5
H20	21.0	14.0
H25	26.0	19.5
H27	24.5	21.0
H30	23.5	24.0
H35	26.0	29.0
H40	26.0	34.0

table 26

Example of pressure load on MODULO H70 + Geoblock

$H = 1m$

$H_{geoblock} = 0{,}61m$

$b_{geoblock} = 0{,}53m$

$\gamma = 2500\ daN/m^2$

punching 150 DaN on imprint 0.08x0.08m = 23440 DaN/m^2

pressure on the GeoBlock 0.8 x 2500 x 1.5 x 0.61 / 0.53 = 3450 daN/m^2

B References

The MODULO / MULTIMODULO / MODULO system exceeds 8,000,000 m^2 of installations.
Among the main achievements that may be mentioned for the last few years:

Réalisation	Site	Année	Produit & m^2
FORT & FILS	Montfermeil, France	2011	MODULO H variable, 700 m2
PRIMARY SCHOOL	Villefranche sur mer, Francia	2011	MODULO H variable, 800 m2
DIGITEO LAB site POLITECNIQUE	Parigi, France	2011	MODULO H10, 2.800 m2
COCTEAU MUSEUM	Menton, France	2010	MODULO H17, 1.000 m2
LEON GROSSE	Ivry-sur-seine	2010	MODULO H6, 5.000m2
HIGH VELOCITY TRAIN STATION	Roma, Italie	2010	MULTIMODULO H20, 6.000m2
GOLF PARK	Taormina, Italie	2010	MODULO H70, 8.000 m2
MOROCCO MALL	Casablanca, Maroc	2009	MODULO H45, 45.000 m2
GYMNASE ANGERS	France	2009	MODULO H45, 1.120 m2
IMMEUBLE D'HABITATION	Montreuil	2009	MODULO H13, 2.100 m2
NOUVEAU BUREAU DON GNOCCHI	Firenze, Italie	2009	MODULO H60, 8.600 m2
CIUDAD DE LAS ARTES	Valencia, Spain	2008	MODULO H20-27-35-50, 1.800 m2
COLD ROOM	Trevenzuolo, Italie	2008	MODULO H60, 5.000 m2
CIVIL SUBDIVISION	VillaMaggiore, Italie	2008	MODULO H40, 6.000 m2
CANTIERI NAVALI AZIMUT	Livorno, Italie	2008	MODULO H6, 2.700 m2
COMO HOSPITAL	Como, Italie	2008	MODULO H55, 18.000 m2
GOLF CLUB	Sciacca, Italie	2007	MODULO H65 3.700 m2
PARCO AGRICOLO	Milano, Italie	2007	MODULO H55, 4.500 m2
INDUSTRIAL SUBDIVISION	Mestre, Italie	2007	MODULO H17-H30-H40, 9.750 m2
INDUSTRIAL SUBDIVISION	Livorno, Italie	2007	MULTIMODULO H27, 2.650 m2
HALLE INDUSTRIELLE	Oristano, Italie	2007	MULTIMODULO H30, 2.000 m2
VARESE HOSPITAL	Varese, Italie	2006	MODULO H60, 18.000 m2
LOTISSEMENT CIVIL	Padova, Italie	2006	MODULO H17, 19.000 m2
AIRPORT FONTANAROSSA	Catania, Italie	2005	MODULO H70, 14.500 m2
CARREFOUR MALL	Assago, Italie	2005	MODULO H35-H40 -H60,20.000 m2
IPERCITY MALL	Albignasego, Italie	2005	MULTIMODULO H17-H17, 24.000
MACCHI HOSPITAL	Varese, Italie	2004	MODULO H60, 28.500 m2
MILAN AIRPORT	Malpensa, Italie	2004	MODULO H35 3.600 m2

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Tables and figures of the Technical Dossier

	H3			
	dimension [cm]	h [cm]	L [cm]	Concrete consumption [m^3/ m^2]
	50x50	**2.1**	**5.5**	**0.004**
	H6			
	dimension [cm]	h [cm]	L [cm]	Consommation béton [m^3/ m^2]
	50x50	**4.5**	**5.4**	**0.009**
	H9			
	dimension [cm]	h [cm]	L [cm]	Consommation béton [m^3/ m^2]
	58x58	**7.5**	**20.5**	**0.010**

	H13					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m^3/ m^2]
	50x50	**7**	**28**	**70**	**50**	**0.028**
	H15					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m^3/ m^2]
	50x50	**9.5**	**26.4**	**90**	**70**	**0.030**
	H17					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m^3/ m^2]
	50x50	**11.5**	**30**	**110**	**100**	**0.035**
	H20					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m^3/ m^2]
	50x50	**14.5**	**28**	**140**	**120**	**0.037**
	H25					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m^3/ m^2]
	50x50	**20.5**	**31.5**	**200**	**140**	**0.038**
	H27					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m^3/ m^2]
	50x50	**21**	**34**	**200**	**160**	**0.040**

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	**H30**					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m^3/ m^2]
	50x50	**24.5**	**31.7**	**240**	**140**	**0.045**
	**H35**					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m^3/ m^2]
	50x50	**30**	**35**	**300**	**150**	**0.052**
	**H40**					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m^3/ m^2]
	50x50	**34**	**36**	**290**	**140**	**0.056**
	**H45**					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m^3/ m^2]
	71x71	**36**	**50**	**360**	**220**	**0.064**
	**H50**					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m^3/ m^2]
	71x71	**41**	**51**	**400**	**220**	**0.076**
	**H55**					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m^3/ m^2]
	71x71	**46**	**52**	**400**	**220**	**0.076**
	**H60**					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m^3/ m^2]
	71X71	**51**	**52**	**400**	**220**	**0.079**
	**H65**					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m^3/ m^2]
	71X71	**56**	**53**	**460**	**240**	**0.084**
	**H70**					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m^3/ m^2]
	71X71	**61**	**53**	**460**	**260**	**0.083**

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	H13					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m3/ m2]
	71x71	**7.5**	**23.5**	**70**	**50**	0.020
	H15					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m3/ m2]
	71x71	**9.0**	**22.0**	**90**	**70**	**0.027**
	H17					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m3/ m2]
	71x71	**11.5**	**24.5**	**110**	**100**	**0.028**
	H20					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m3/ m2]
	71x71	**14.0**	**21.0**	**140**	**100**	**0.032**
	H25					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m3/ m2]
	71x71	**19.5**	**26.0**	**170**	**120**	**0.033**
	H27					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m3/ m2]
	71x71	**21.0**	**24.5**	**210**	**100**	**0.035**
	H30					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m3/ m2]
	71x71	**24.0**	**23.5**	**220**	**100**	**0.042**
	H35					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m3/ m2]
	71x71	**29.0**	**26.0**	**250**	**120**	**0.045**
	H40					
	dimension [cm]	h [cm]	L [cm]	Ømax 1 tube [mm]	Ømax 2 tube [mm]	Concrete consumption [m3/ m2]
	71x71	**34.0**	**26.0**	**300**	**120**	**0.050**

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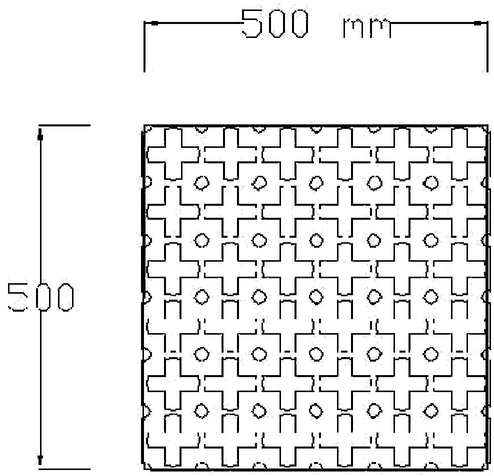
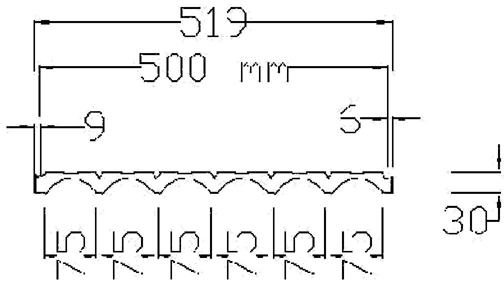
MODULO H 3 cm

En plan



Sur coupe



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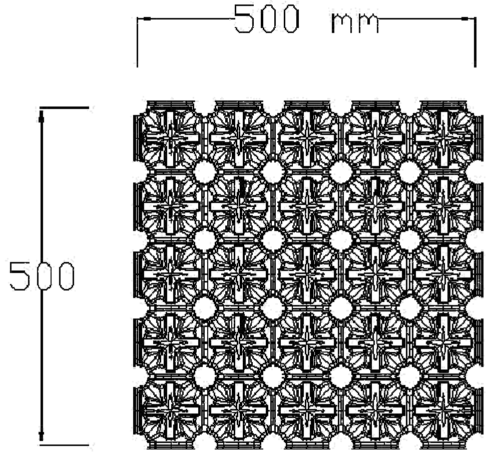
MODULO H 6 cm

En plan



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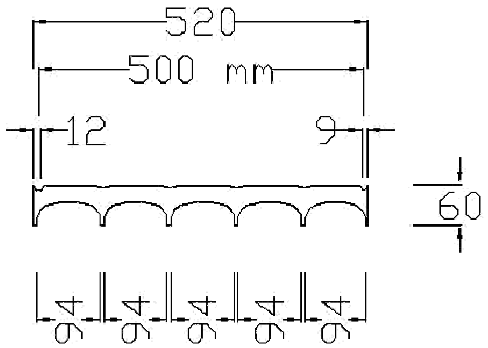

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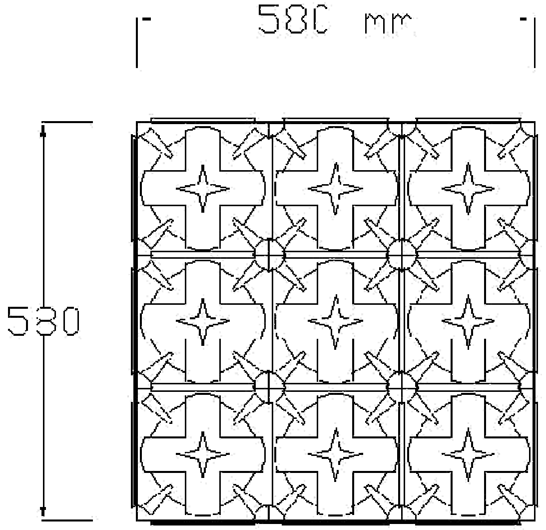
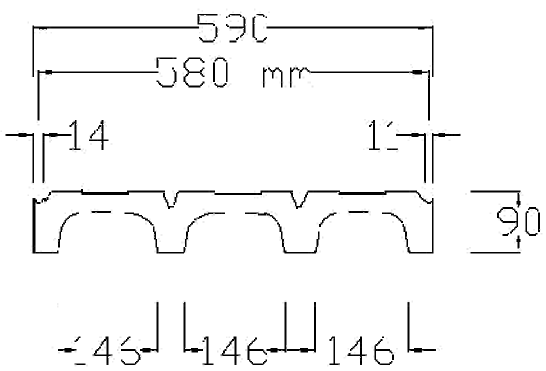
MODULO H 9 cm

En plan



Sur coupe



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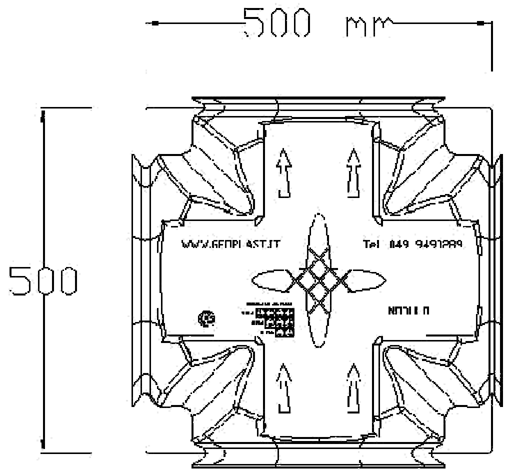
MODULO H 13÷17 cm

En plan



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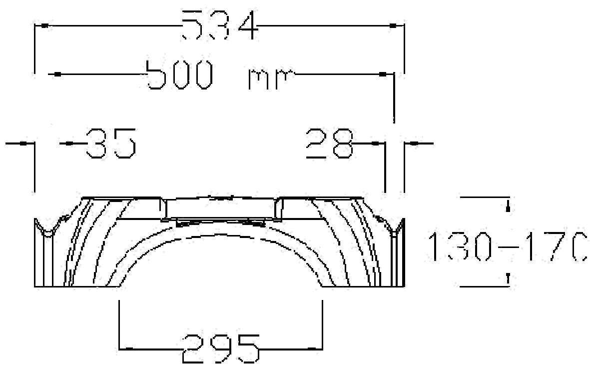

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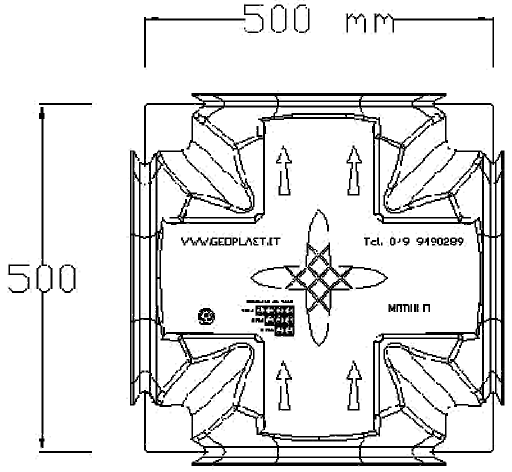
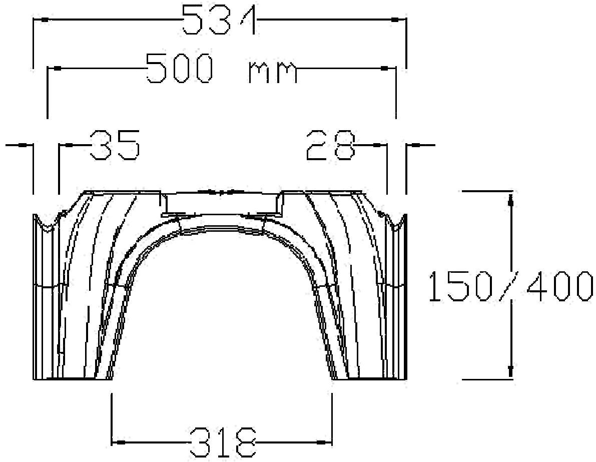
MODULO H 15÷40 cm

En plan



Sur coupe



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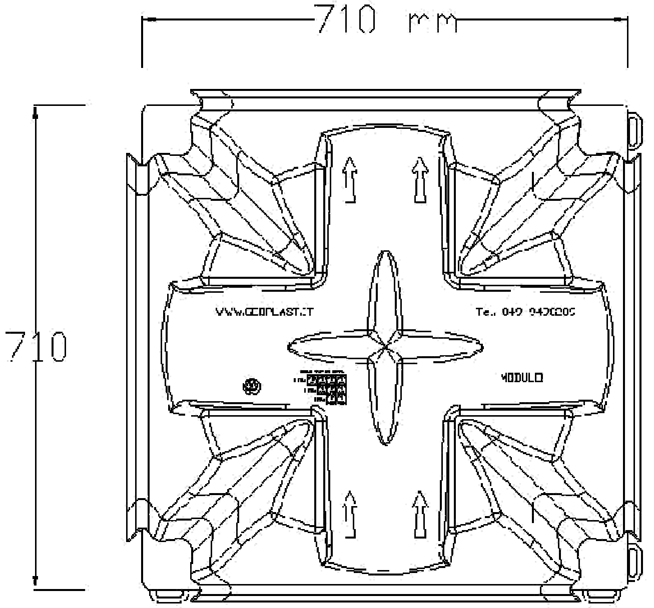
MODULO H 45; 55; 65 cm

En plan



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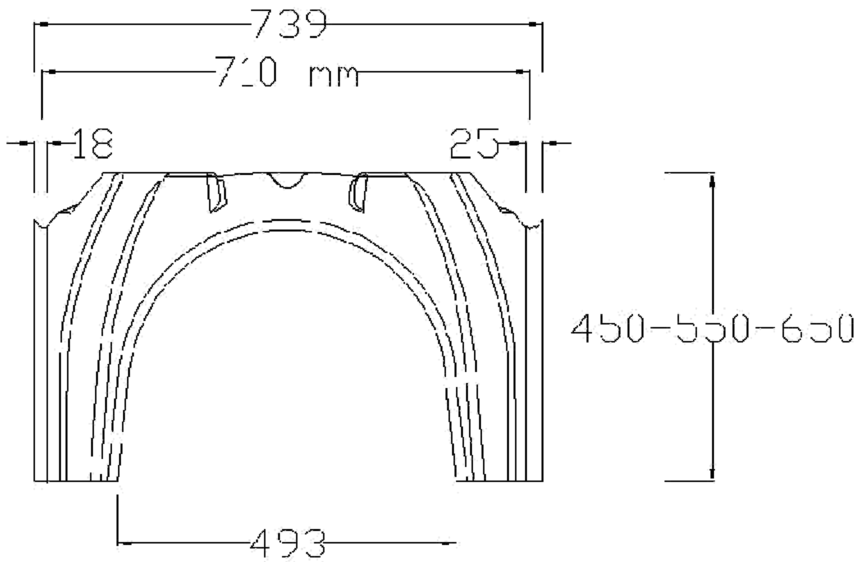

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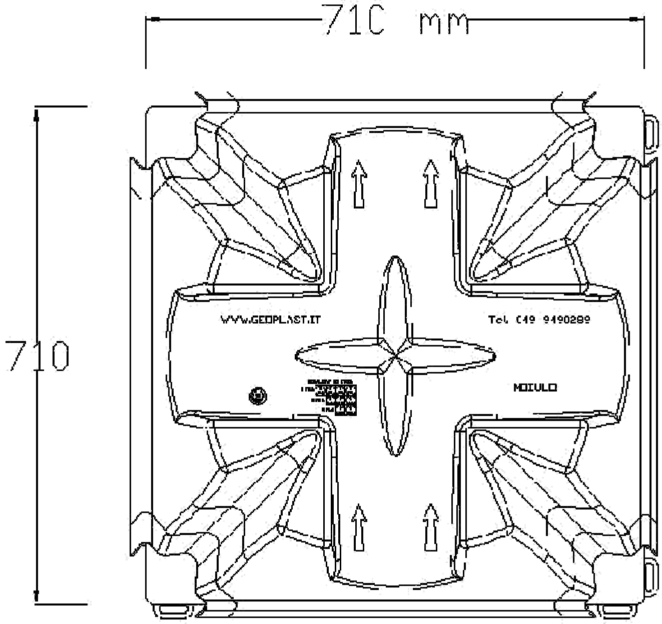
MODULO H 50 cm

En plan



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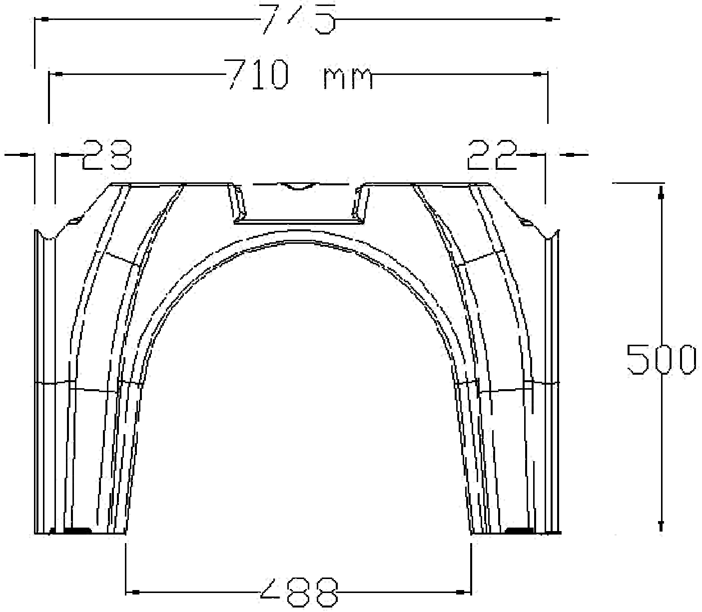

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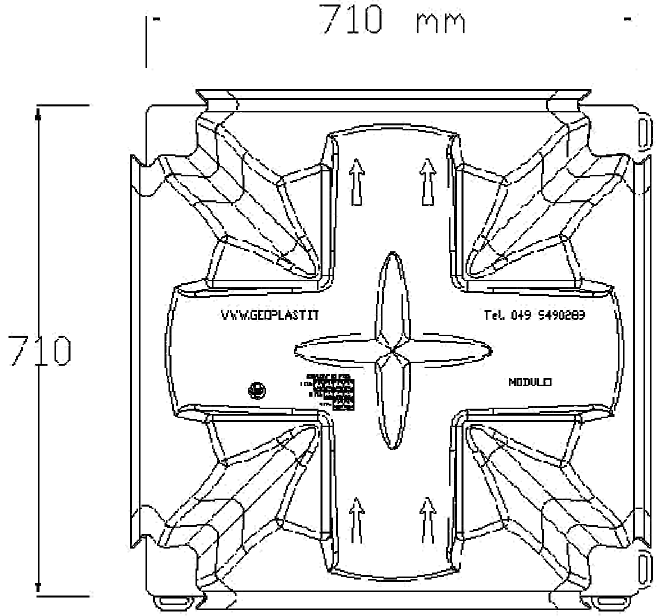
MODULO H 60; 70 cm

En plan



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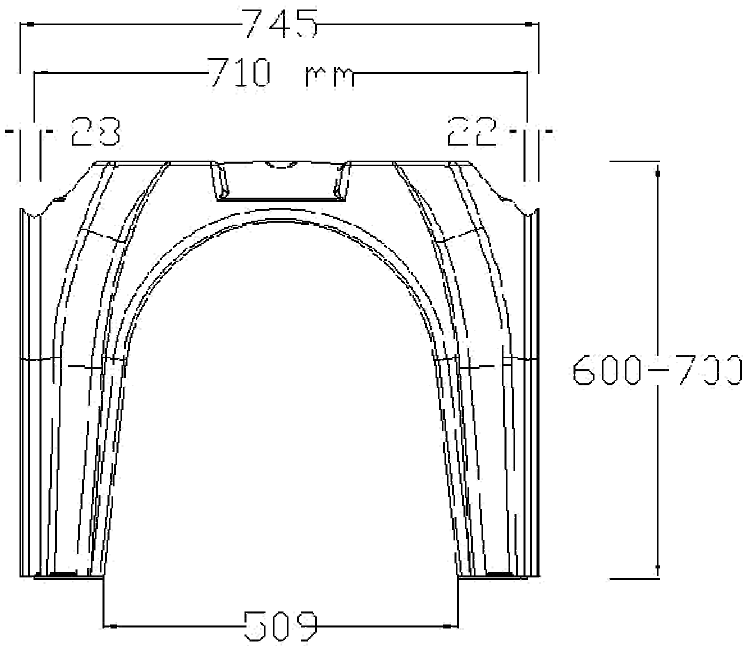

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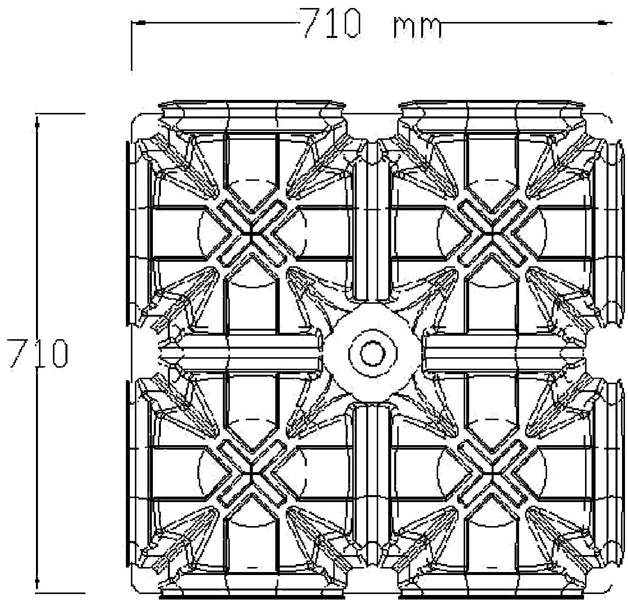
MULTIMODULO H 13 ; 17 ; 25 cm

En plan



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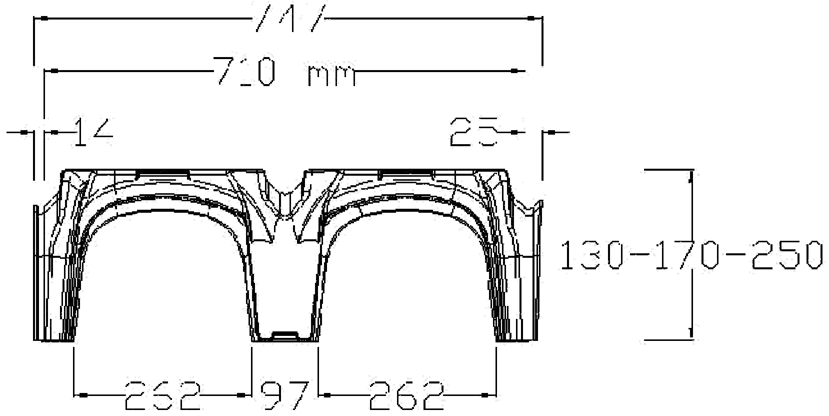

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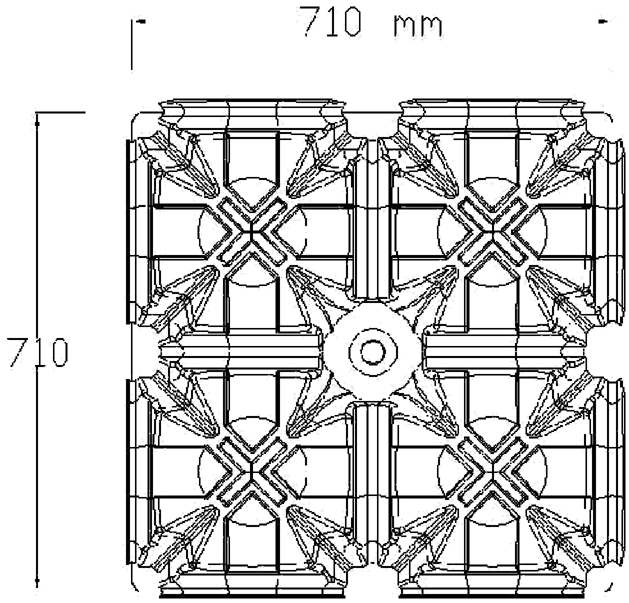
MULTIMODULO H 15 ; 27 ; 35 cm

En plan



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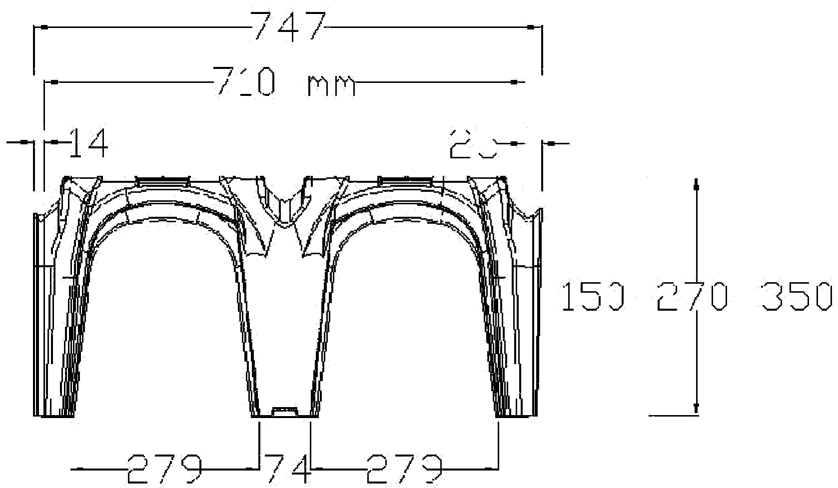
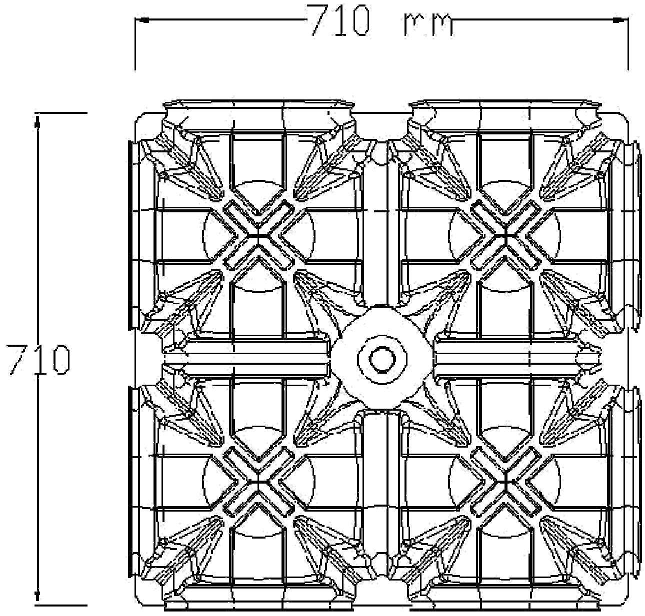


MULTIMODULO H 20 ; 30 ; 40 cm

En plan



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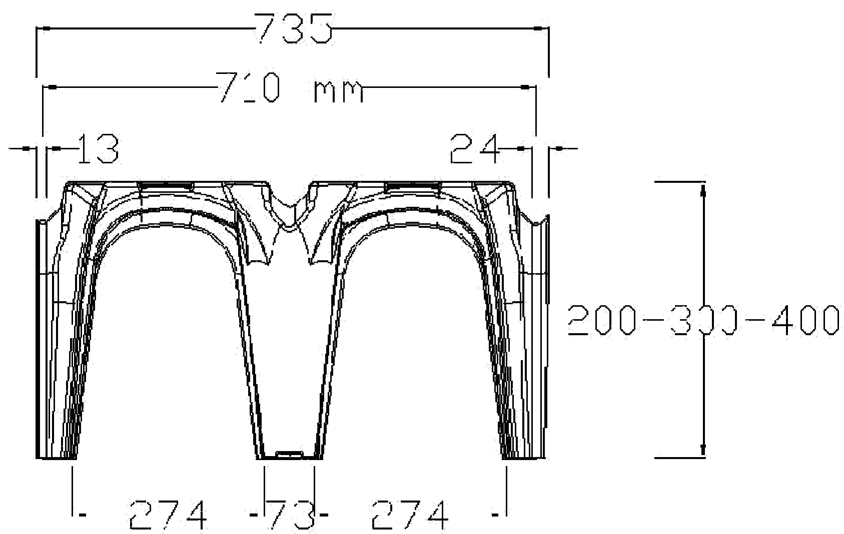

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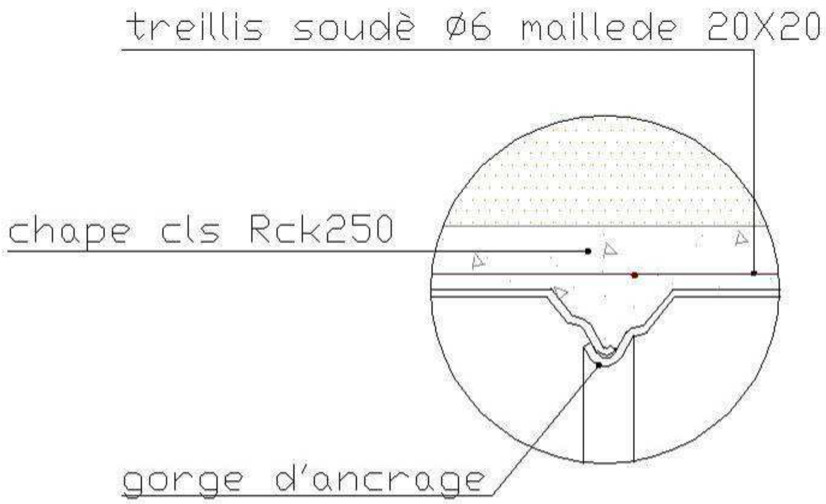
Detail ancrage entre les elements



Detail of foot support for MODULO H55 – H70

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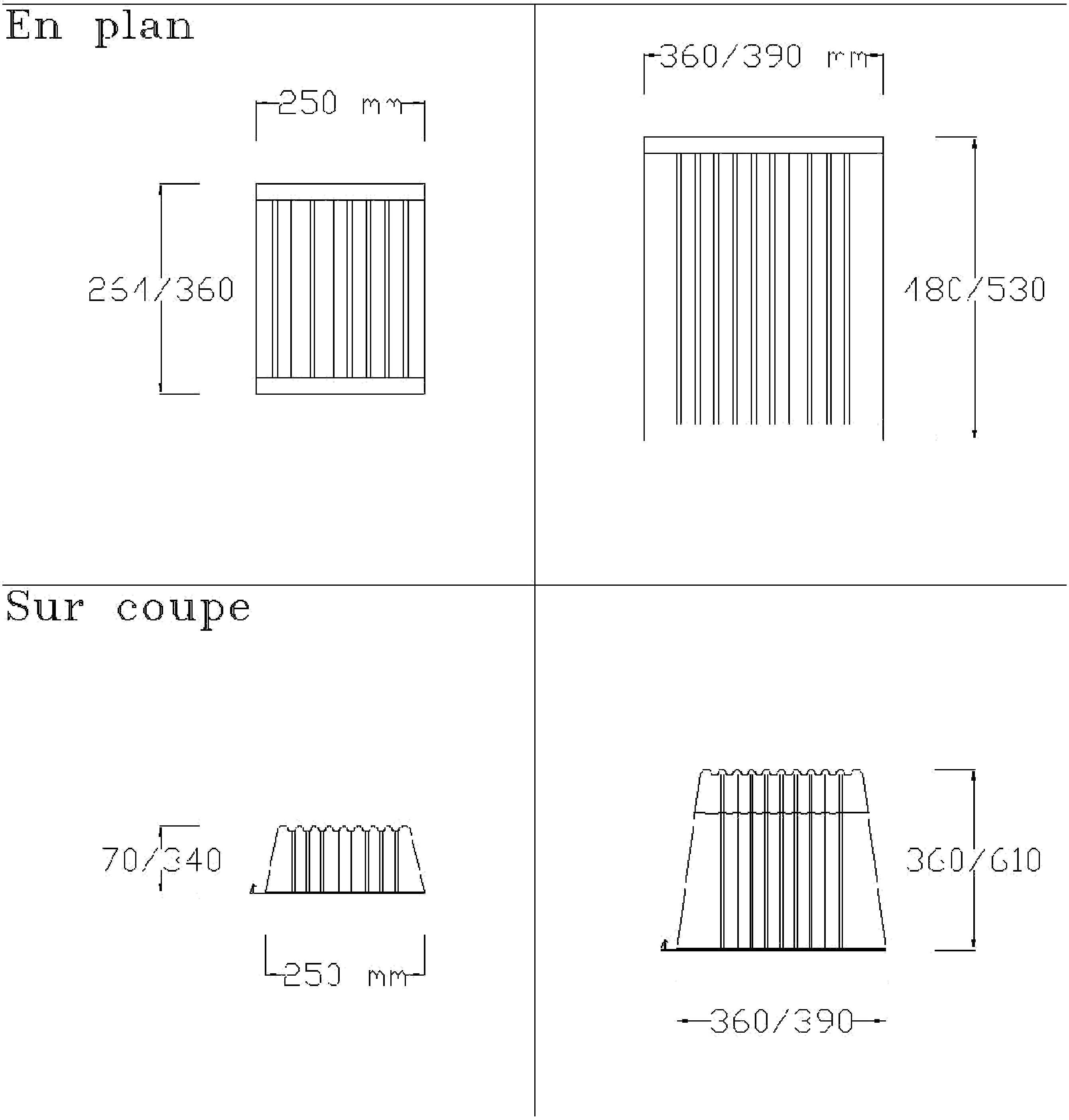
GEBLOCK for MODULO and MULTIMODULO



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