SCADA Pro™
Structural Analysis & Design

Example 9

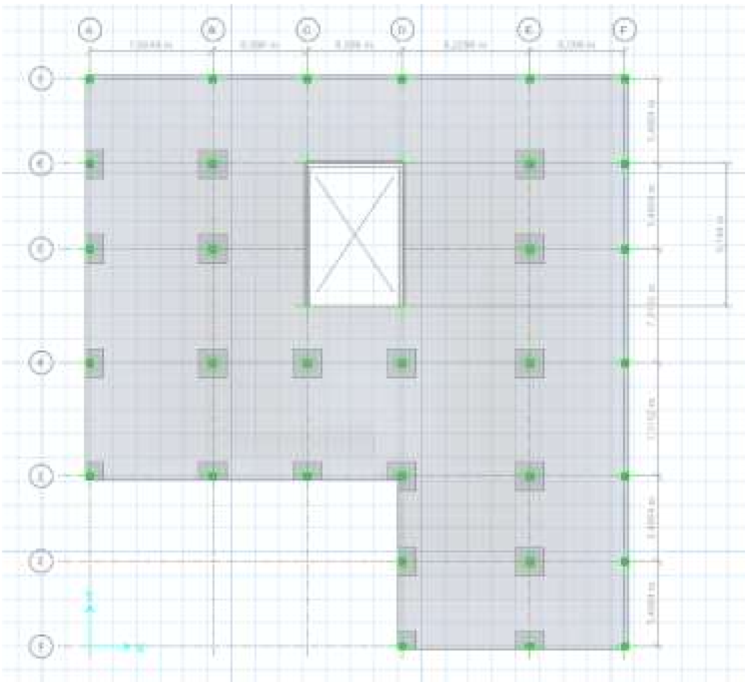
Integrated example of Flat Plates

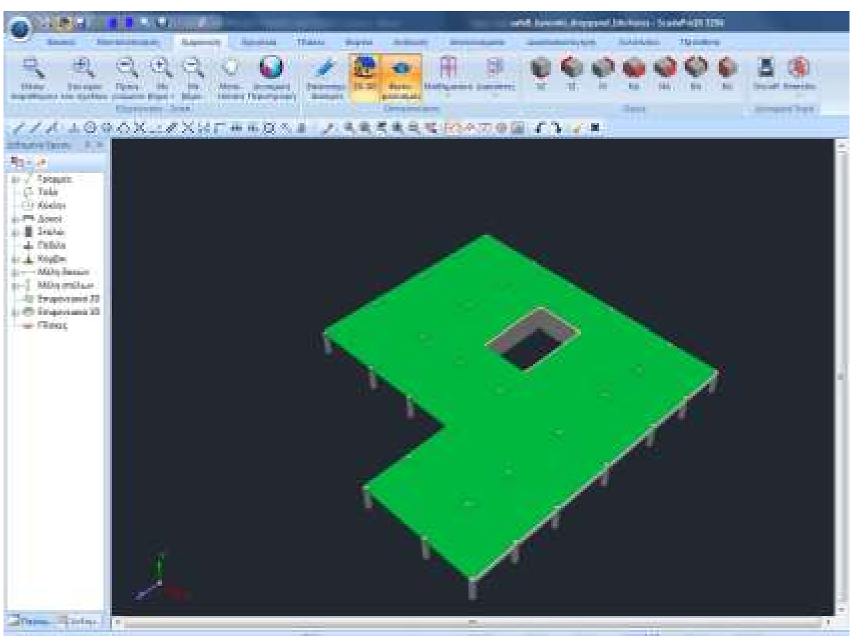
ACE HELLAS
INTEGRATED SOLUTIONS

CONTENTS

FLAT PLATES - EXAMPLE

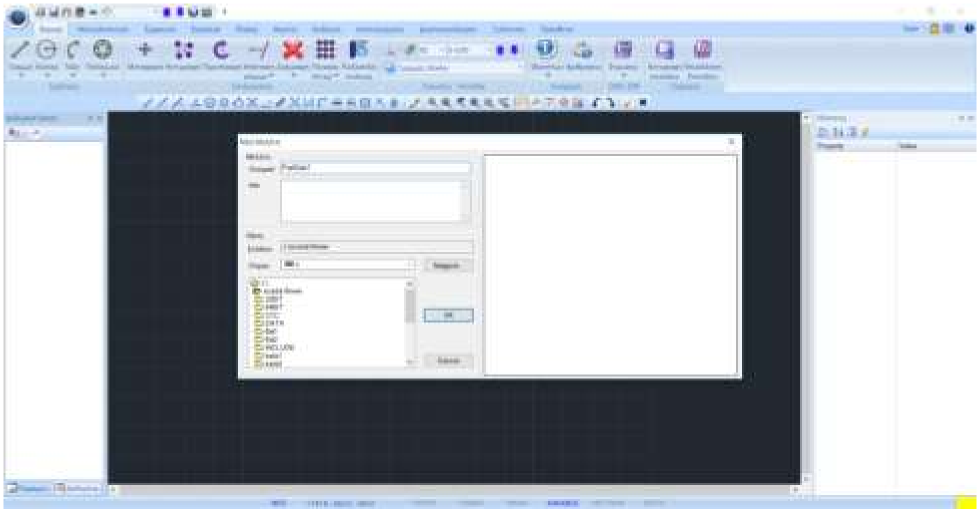
The following example analyses the following operator. It is the same vector that is analyzed in the CSI Safe 2014 tutorial, and the reason for this choice is to draw useful conclusions from the comparison of the results.



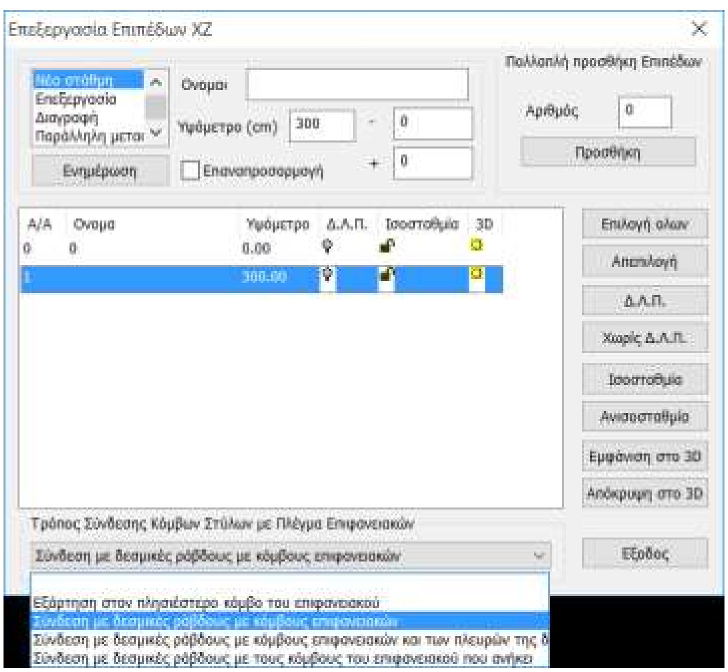


1. Simulation process

1. The process starts by creating a New Project and naming the file.

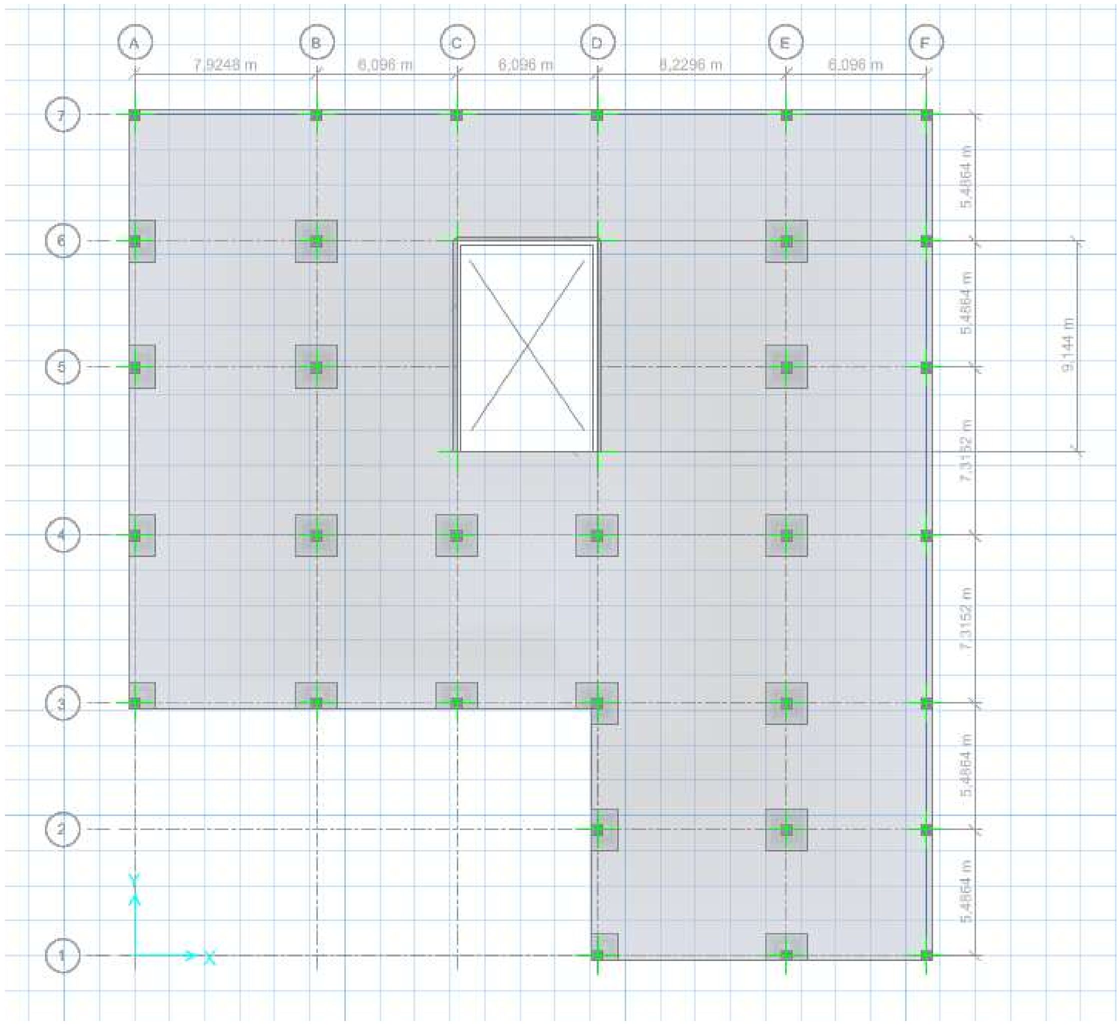


2. Then we set the levels. At the level where the Flat Plate will be defined, we turn off the diaphragm mode and select how to connect the nodes of the columns to the surface grid.

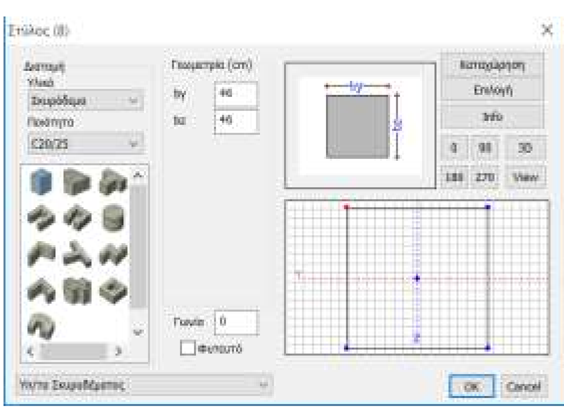


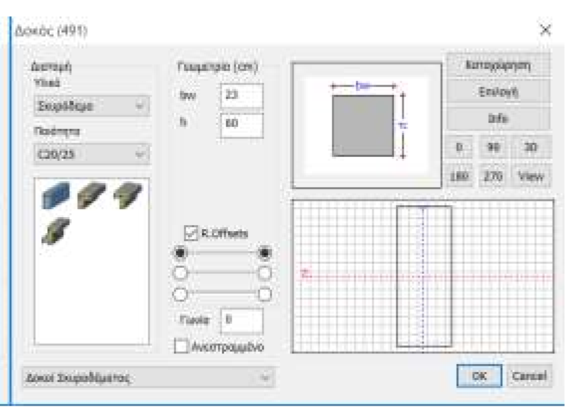
At the bottom of the window there is a choice of the way of connecting the nodes of the columns with the surface grid, for the selected level, we choose the connection with tie rods and with the nodes of the surface grid. At the end we press Update.

3. The floor plan of the model we will simulate is described in the following image

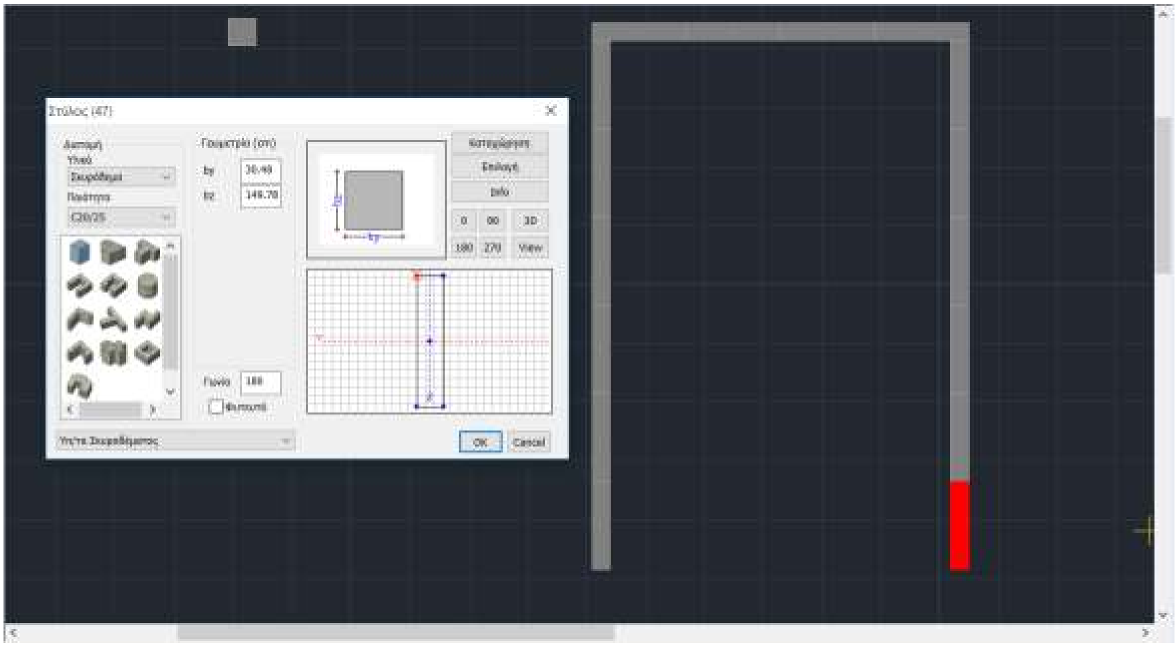


4. We activate Level 1 and insert the columns and beams using the modeling commands and with dimensions as shown in the following pictures:

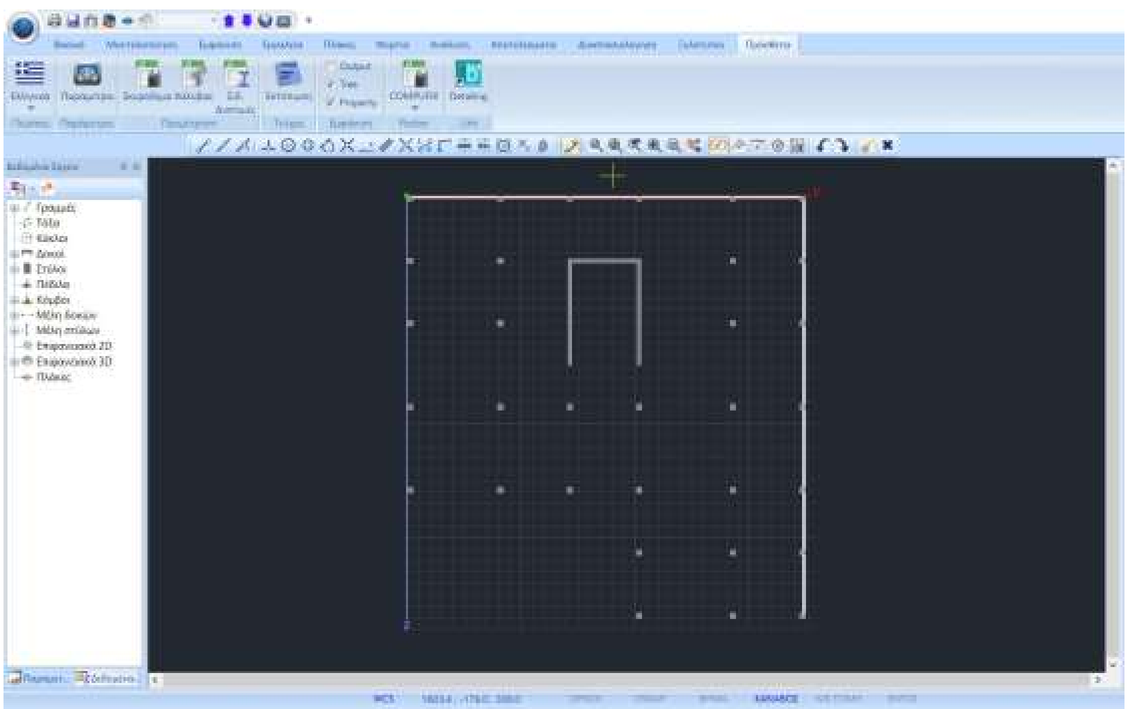




⚠ For the core we choose the composite cross-section simulation because of its large dimensions. We use cross-sections of rectangular poles, which we will then join with rigid rods to give the rigidity of the element.

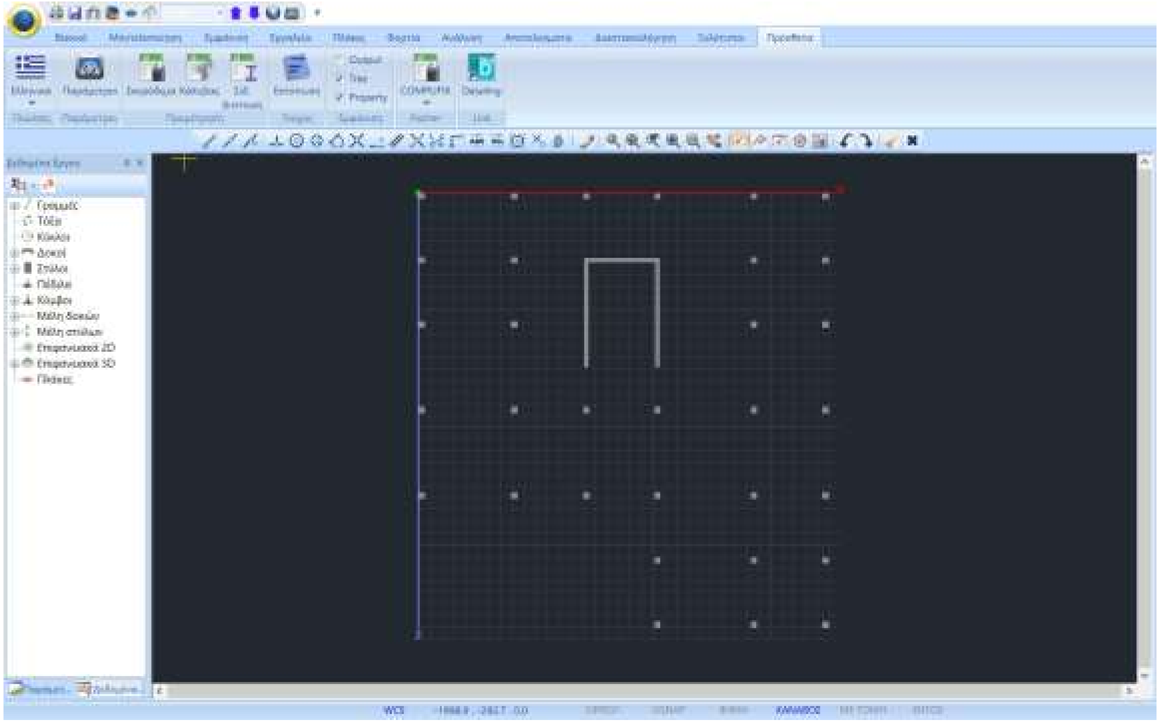


Level 1

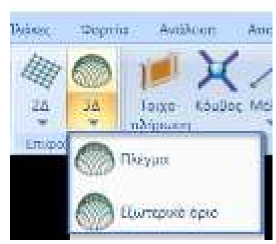


5. With Copy-Paste Level we copy to Level 0 and delete the beams.

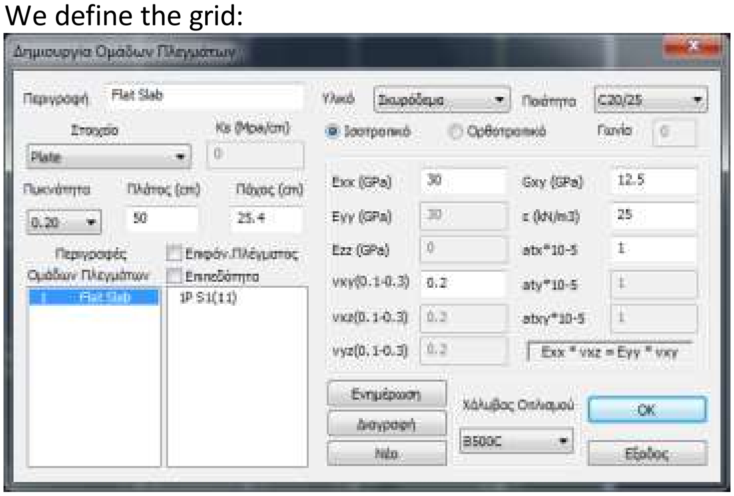
Level 0



6. The next step involves defining and creating the surface mesh that defines the flat plate.



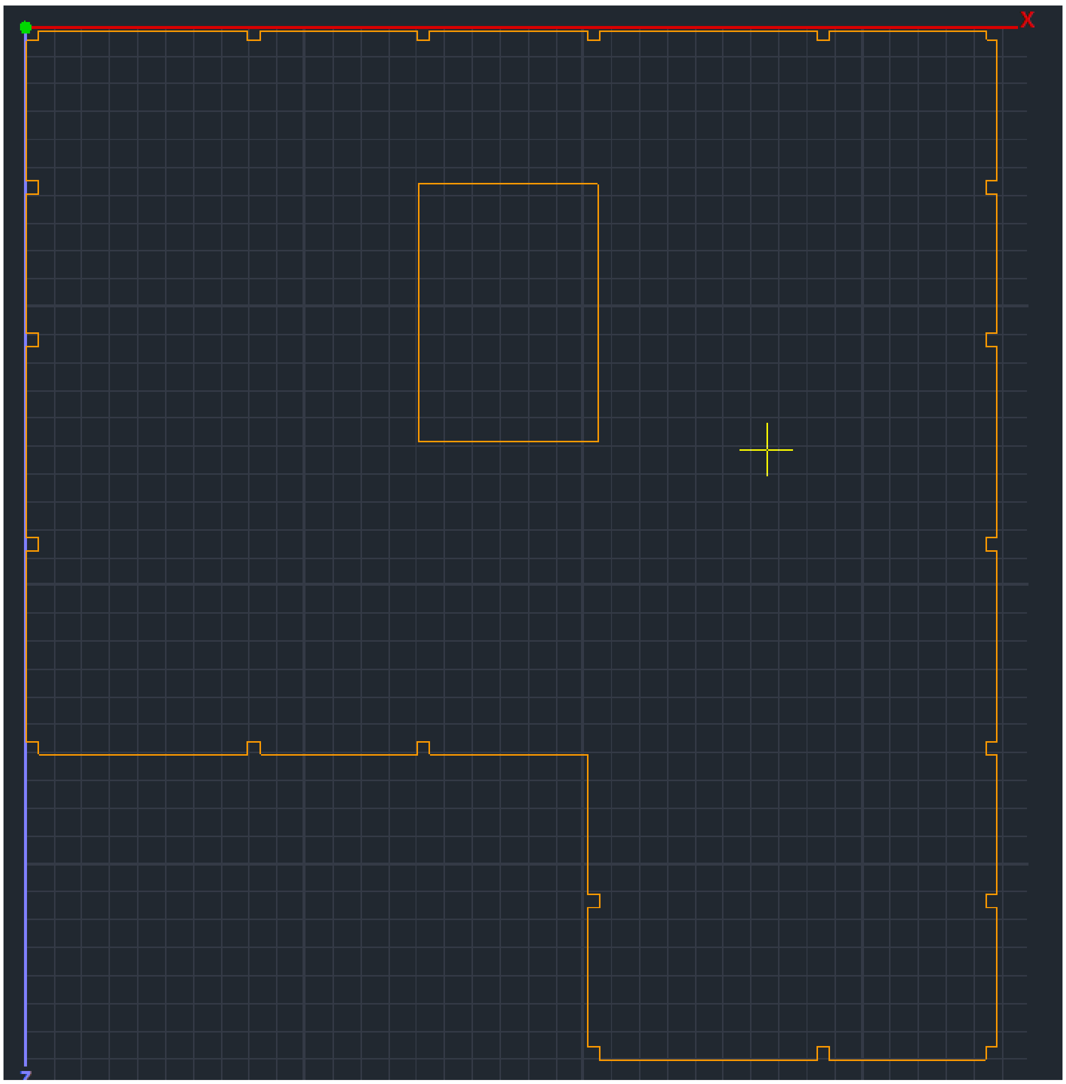
We define the grid:



and with the command Outer Boundary we define the outline of the grid. The definition of the outline can be set automatically, simply by selecting one of the lines that define it and right-clicking.
Prerequisites:

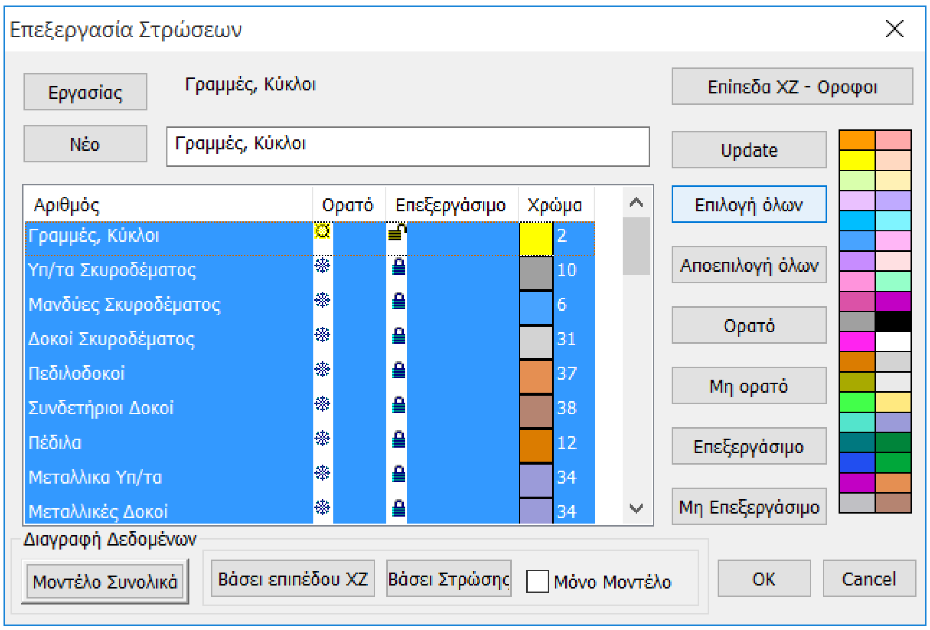
- the contour shall be closed and free of ramifications; and
- the external columns are excluded from this.

We should therefore define an outer boundary like the one depicted in the figure with an orange solid line.
The outer boundary of the hole in the centre will be defined later as the Hole.

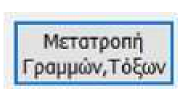


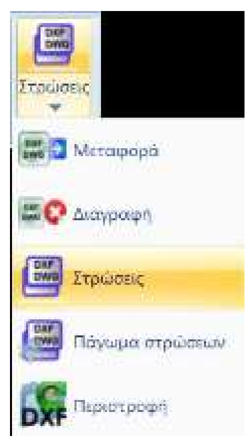
NOTES!!!!

- To draw the outer boundary we can make use of Scada's draw and drag commands and the Edit
  Layers that allows us to manage Layers by making them Invisible and Uneditable for ease of design.



- Another way is to import an auxiliary file with the drawing of the outer boundary and use the Layers command to
  the conversion of its lines to Scada lines.



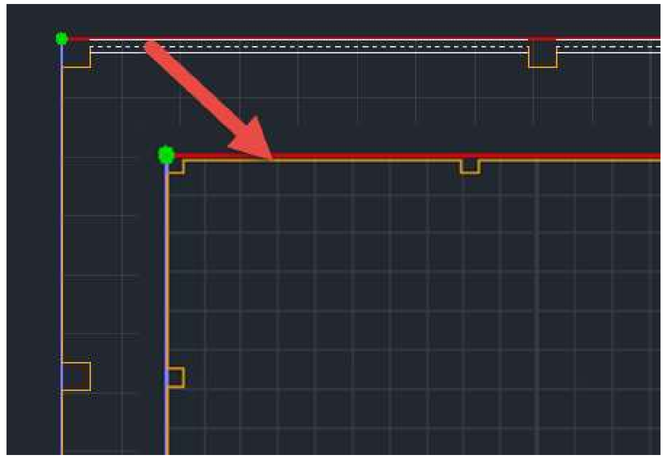


ATTENTION!!!!

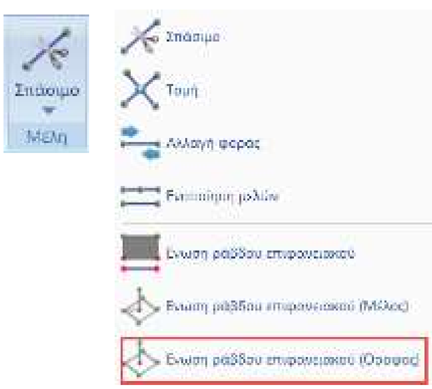
NOTE: *In cases where there are beams at the boundary of the slab, we must ensure that the surface elements of the slab are connected to the members of the perimeter beams.*

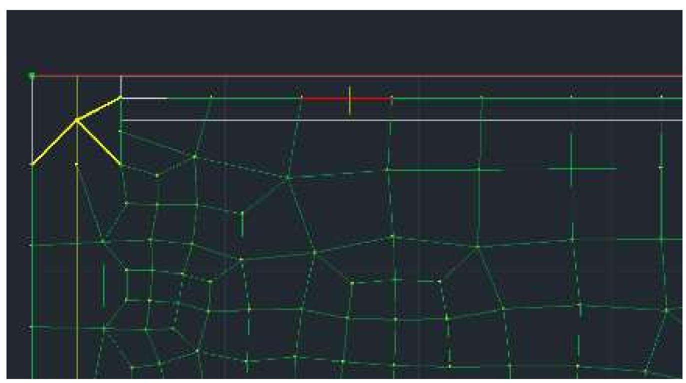
Therefore:

- *the outer limit of the plate shall <u>coincide</u> with the axis of the beam,*

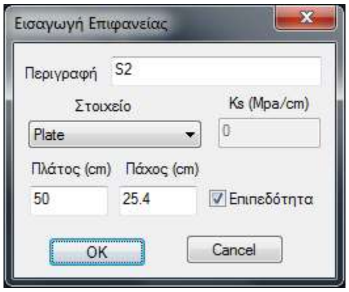


- *after creating the mesh and the mathematical model, the command that breaks the members of the beams and connects them to the elements that grid.*

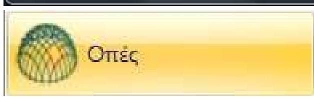




Select the command and left-click on one of the contour lines. Right click and the dialog box for defining the subgrid appears.

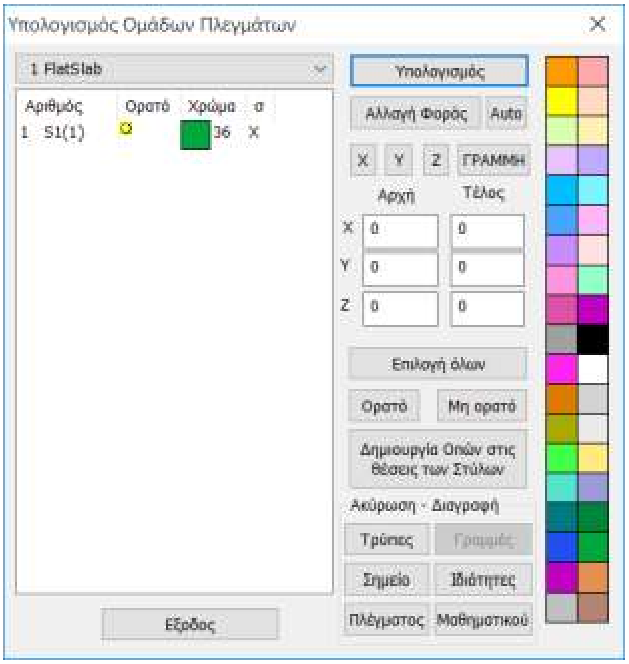


In case the perimeter at any point not closed, an **X** will appear on the screen at that point.

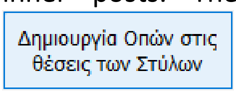


We select the Holes command and show the outline of the hole in a manner similar to the outer boundary, left click on a line and right click to complete.

Having completed the definition of the shape and properties of the mesh, the next step is to calculate it. We select the command and the list of subgrids appears in the dialog box that opens. In this particular example there is a subgrid S1. The number inside the brackets (1) indicates the number of holes defined for this grid.

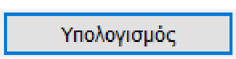


However, in addition to the central hole, there should also be holes in the position of the inner posts. These holes are automatically created by selecting the command



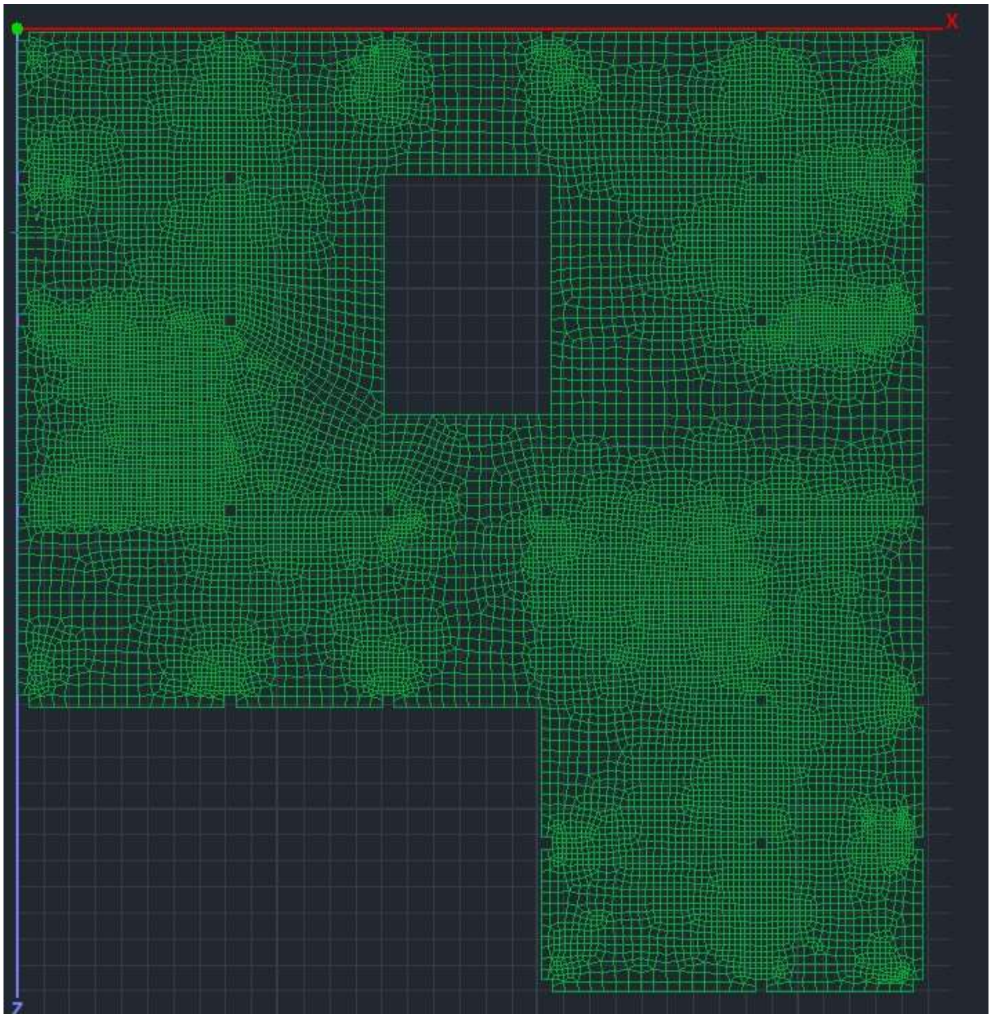
and their number is added to the value in brackets.

The

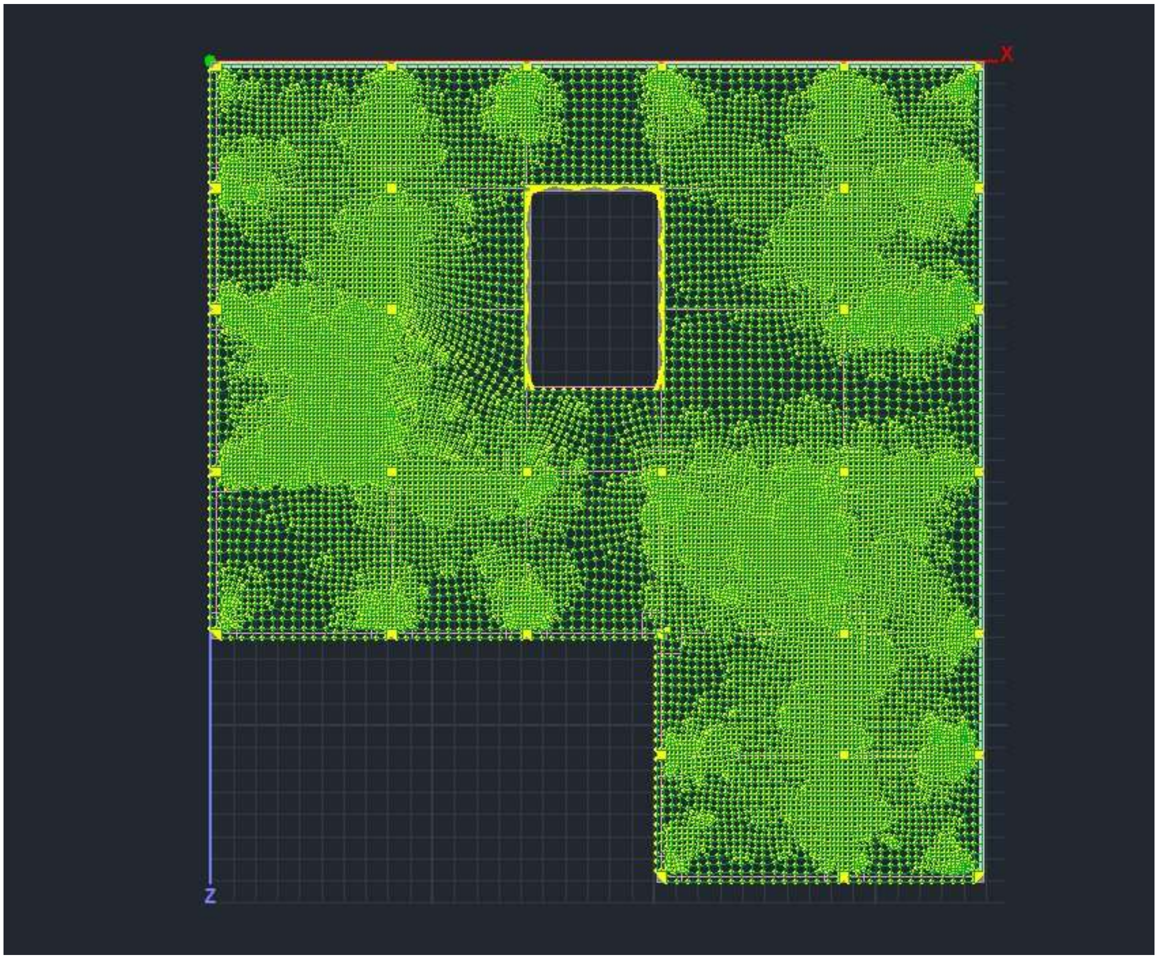


command is used to calculate the grid.

EXAMPLE 9 - FLAT PLATES

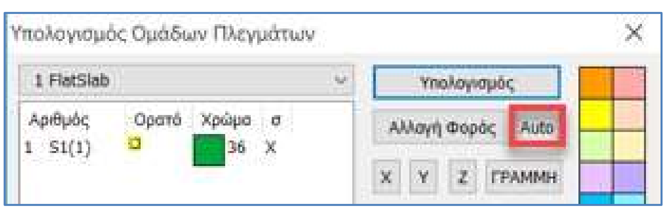


The modelling is completed with the creation of the Mathematical 



NOTE:

⚠ Immediately after creating the surface mathematical model, always remember to open the "Grid Group Calculation" window and press "Auto".

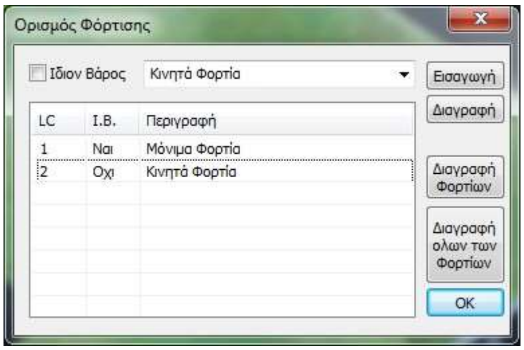


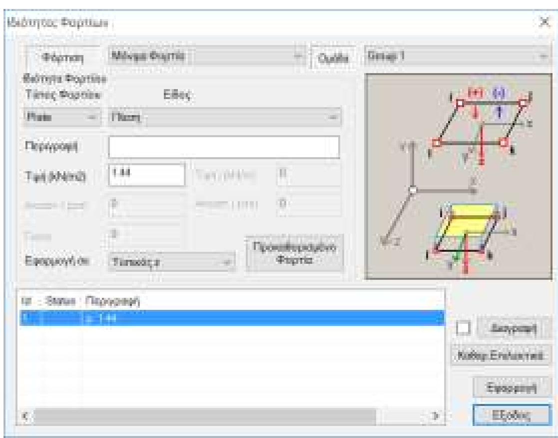
- After the **Modeling**, the **Load Import**, the **Analysis** and the creation of the **Combinations** follow as usual.

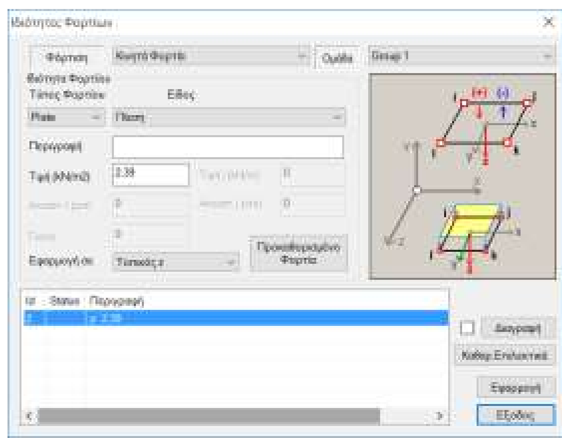
2. Loads

We load the plate with Permanent (1.44KN/m2) and Mobile (2.39KN/m2) loads. The value of the permanent that we define by entering the loads does not include the same weight.

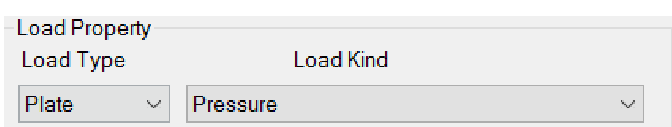
This is why we choose the Same Weight on the Permanent in the Load Determination.





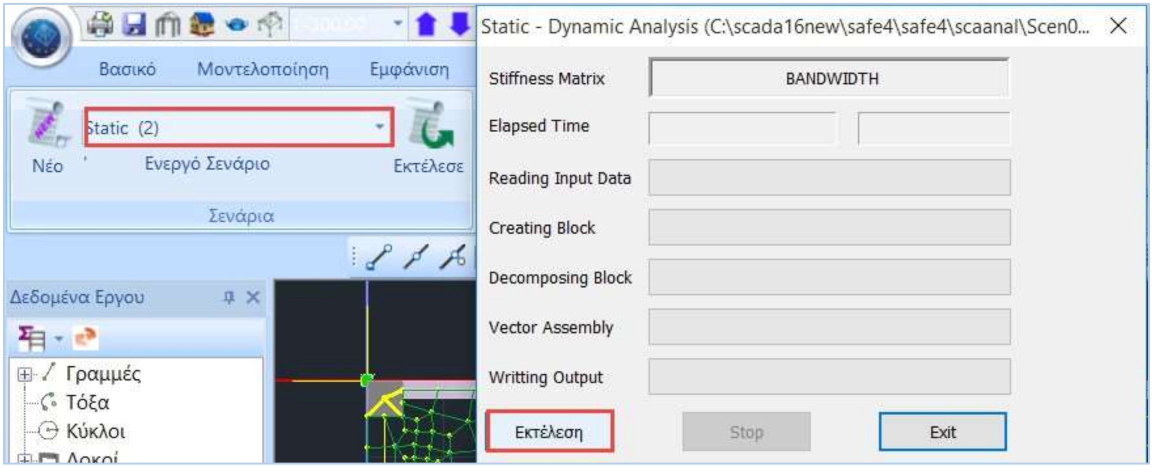


We select the command and with a window across the floor plan. We enter Permanent (1.44KN/m2) and Mobile (2.39KN/m2) as stresses on the Plates.

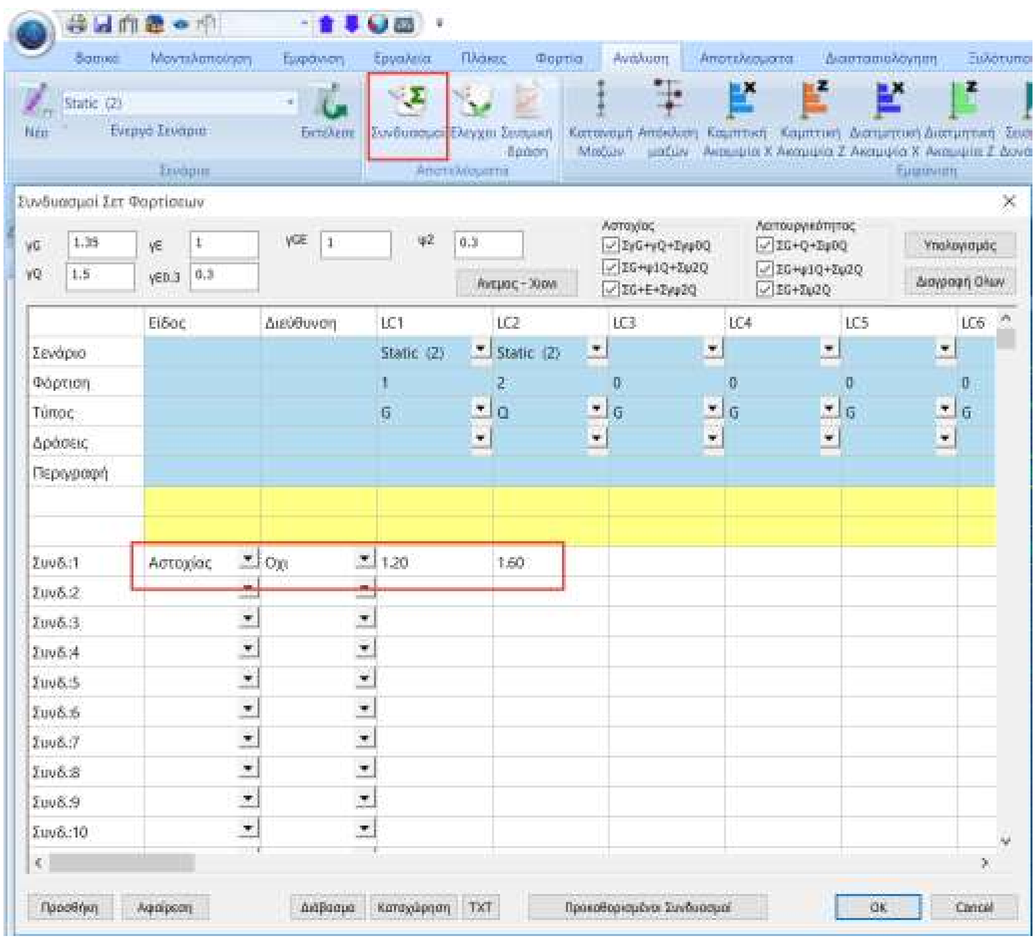


3. Analysis

We create a Static Analysis script and run a simple static analysis.

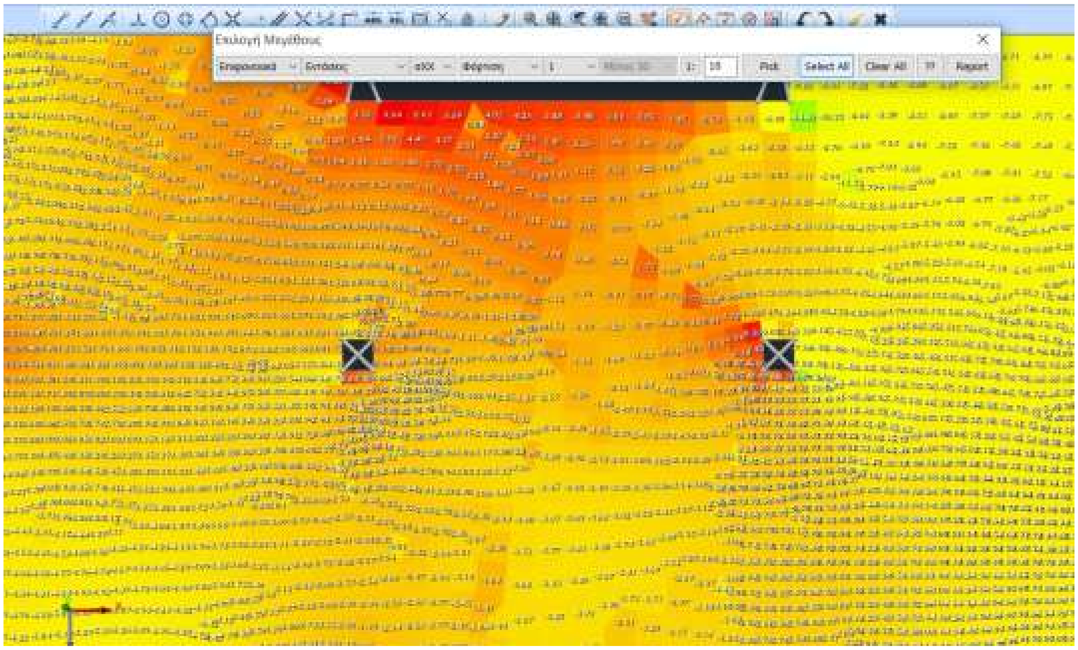


Then, we create the combination 1,20G+1,60Q in the combination field and enter it.

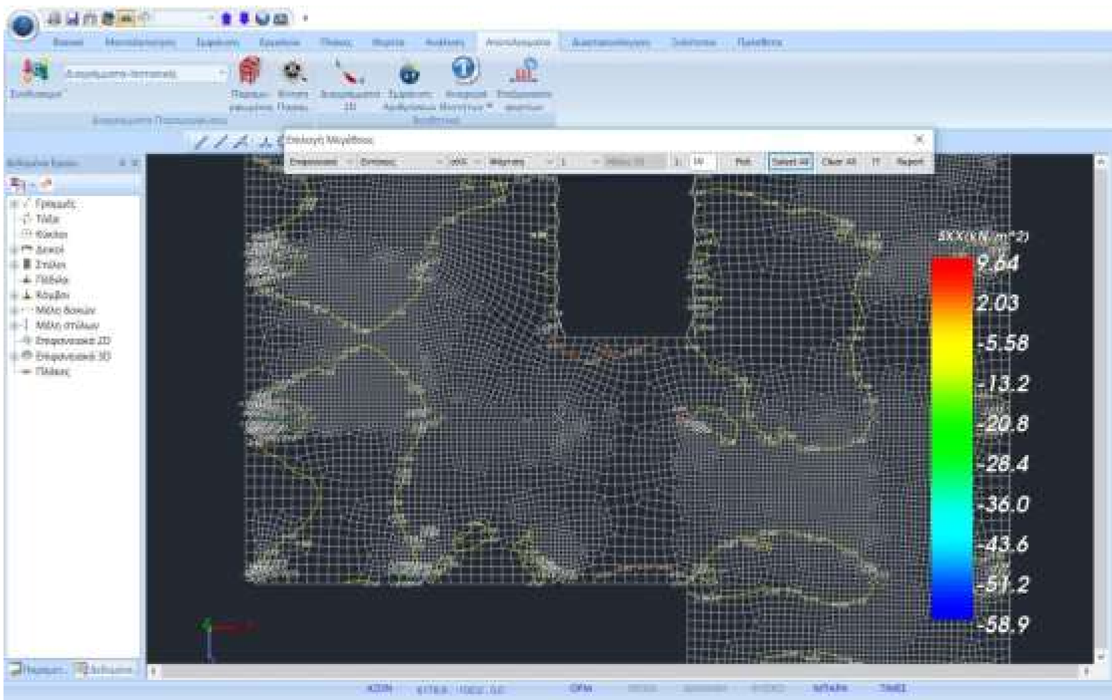


4. Results

In the **Results** field we can read the values of the different sizes either by means of the colour display or by reading the values of the selected size within the surface of the surface element, by activating the Values in the lower horizontal bar.

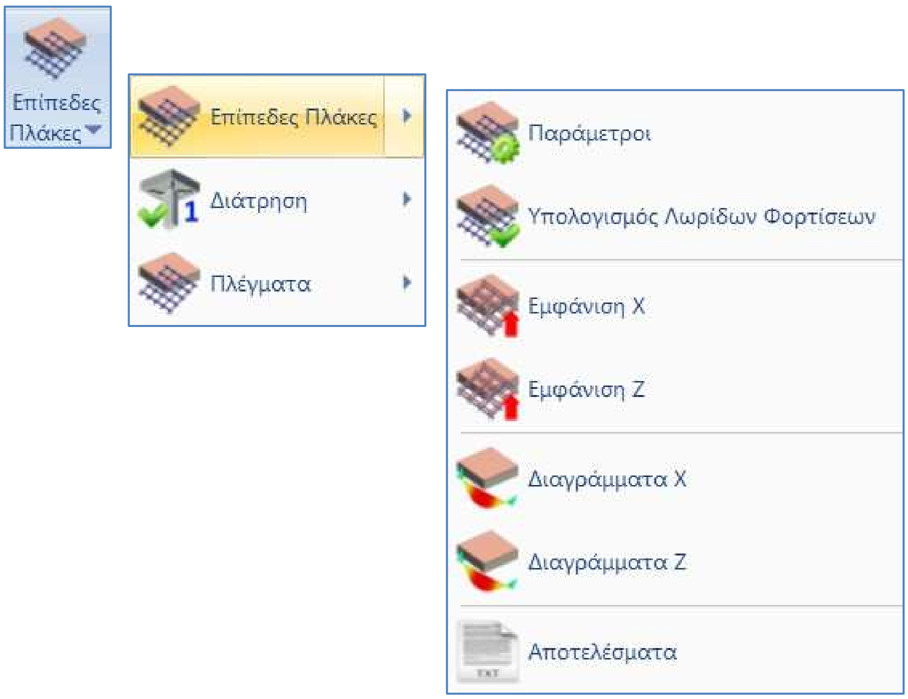


As well as the value of the isovalue on them

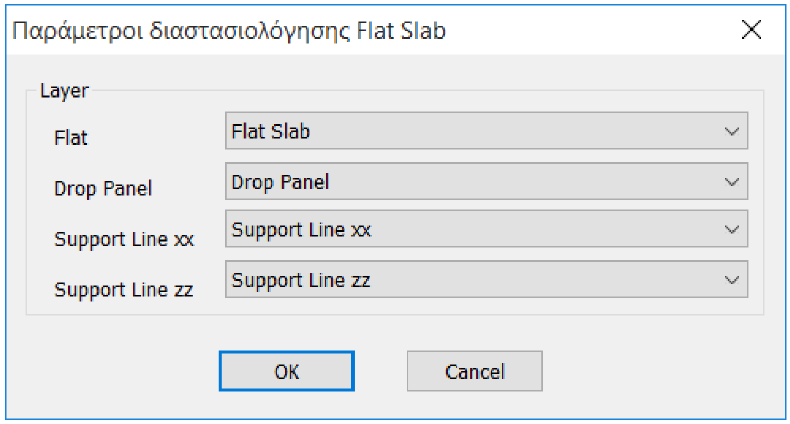


5. Sizing

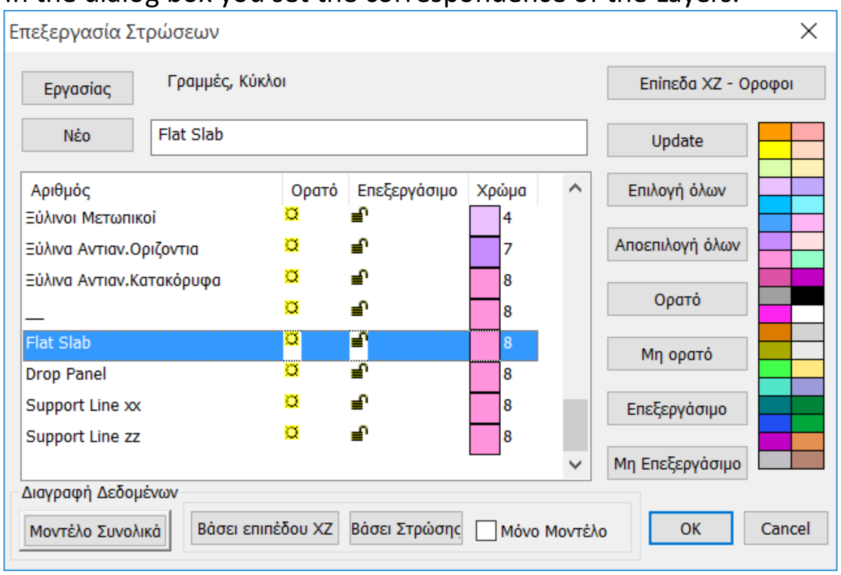
In the Dimensioning field is the Flat Plates command and the necessary subcommands to solve them.
So after calculating the combinations, we select the command and follow the procedure below:



5.1 Parameters



In the dialog box you set the correspondence of the Layers.

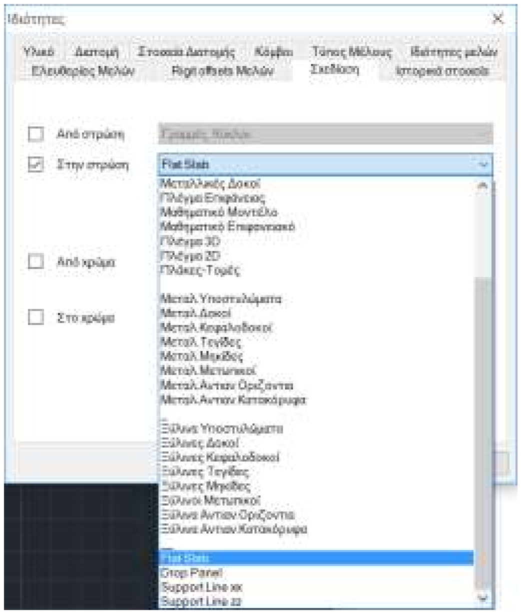


Scada's default list of Layers includes the layers related to the Flat Plates.

- In the "Flat Slab" layer we transfer the outline of the floor plan (including the external columns) and assign it to the "Flat" layer.

Draw the outline of the floor plan with lines.
To transfer the contour lines from the "Lines-Circles" layer to the "Flat Slab" layer,

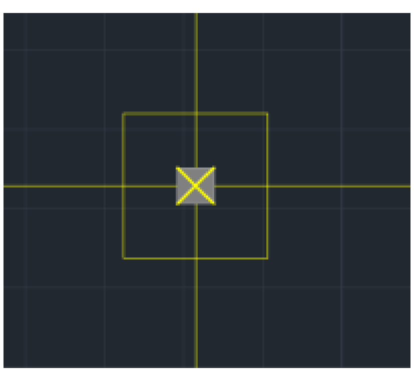
- Freeze all Layers, except "Lines-Circles"
- Select the Multiple Options command
- Left-click to select all the lines of the floor plan contour
- Right click to complete
- In the dialog box, in the Design, we change the Layer to "Flat Slab"

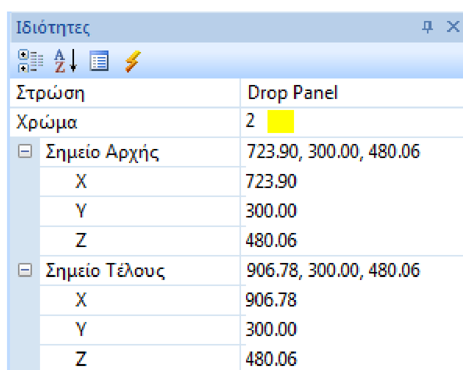


⚠ *For more convenience we can select the "Flat Slab" layer from the beginning, immediately after selecting the Line or Polyline command, so that the outline belongs to the correct layer without having to be moved.*

- Similarly, in the "Drop Panel" layer drag the Lines that define area around the poles, where you will increase the thickness of the slab locally.

"Drop Panels" are optionally inserted around the pillars of the slab relieving it of shear stress.



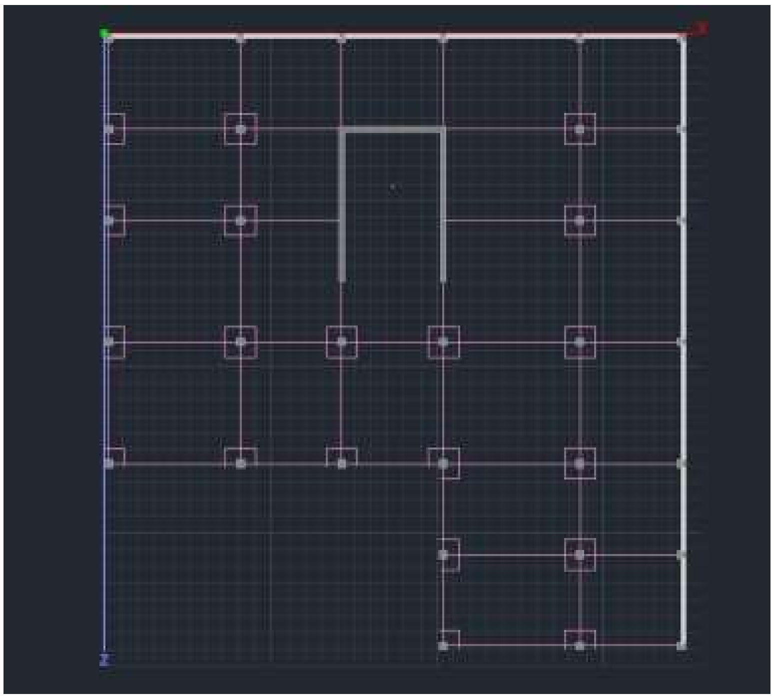


- In the same way, in the Layers "Support Lines xx" and "Support Lines zz" you transfer the Lines that define the Support Lines.

These are lines that enter in both X and Z directions between successive points on the plate. They usually connect pillar nodes and end at the contour of the slab.

§ Instructions for the introduction of support lines on flat slabs

1. The support lines should start from a support column and end in a support (or free end). In all cases they must include at least one support.
2. The support line should only reach the contour of the plate when it is free edge. Otherwise it may stop at the contour or at the node of the column.
3. When the boundary conditions (i.e. what is to the right and left of the support line) change along the line, the line must break at these points.



Drop Panels and Support Lines

Based on the Support Lines you define, the corresponding Loading Lanes will be created (design strips).

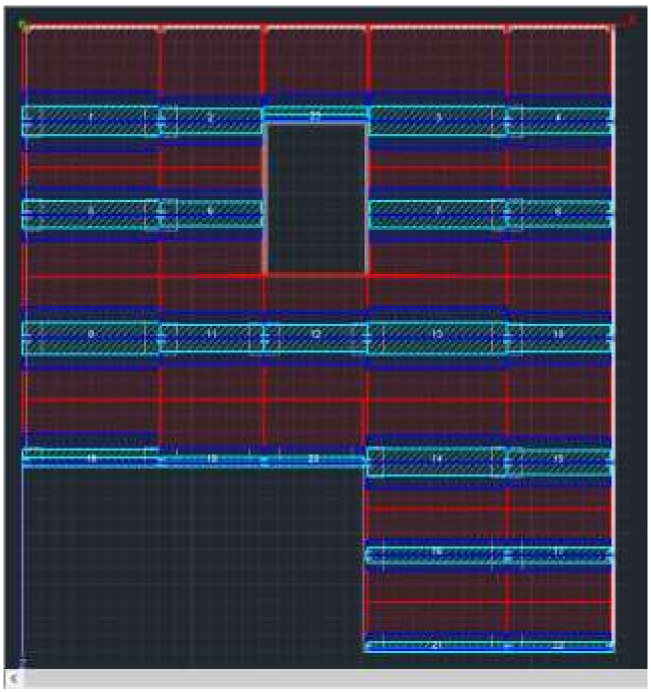
5.2 Calculation of Loading Lanes

According to Annex I of EC2 the flat plate is divided into Loading Lanes. These are areas automatically created by the program on either side of the Support Lines , according to Figure I.1 of EC2.

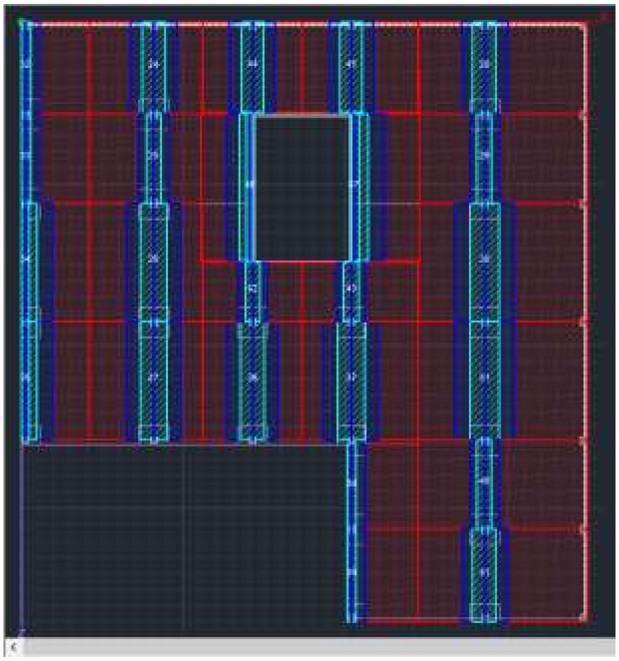
You select the Calculate Load Strips command and the program automatically creates them. Each Loading Strip is divided into sections along its length perpendicular to the Support Line. In each section Scada integrates the internal forces of the finite surface elements of the intersecting sections. From this integration the bending moment about the axis of the section is obtained. This intensive quantity is used to calculate the reinforcement in each individual section.

5.3 Display X, Z

You choose to display the Charge Strips in both directions to display them.



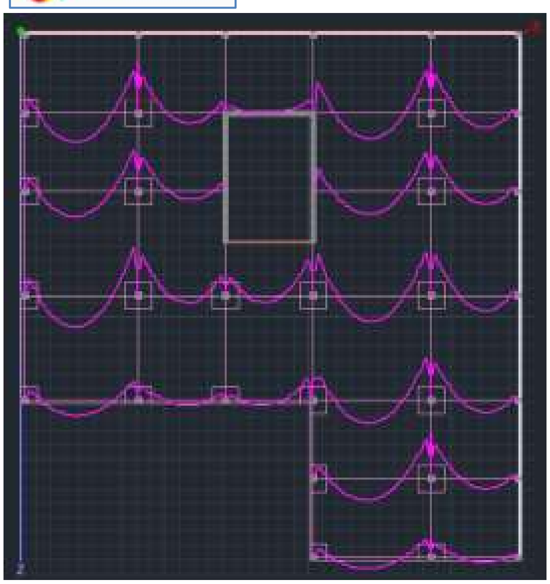
Loading strips along the X-axis

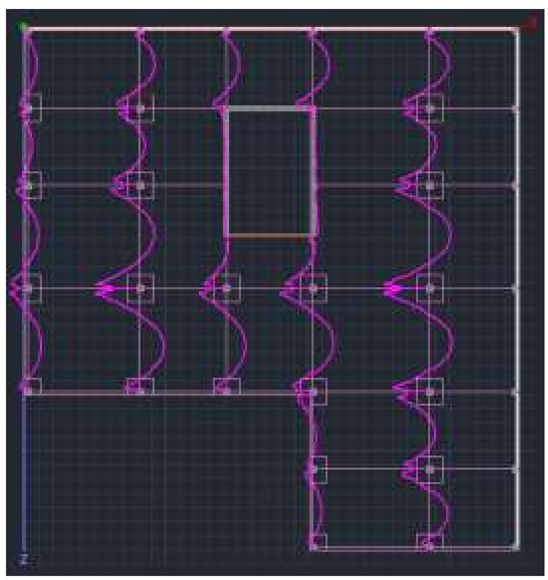


Loading strips along the Z axis

5.4 Diagrams X, Z

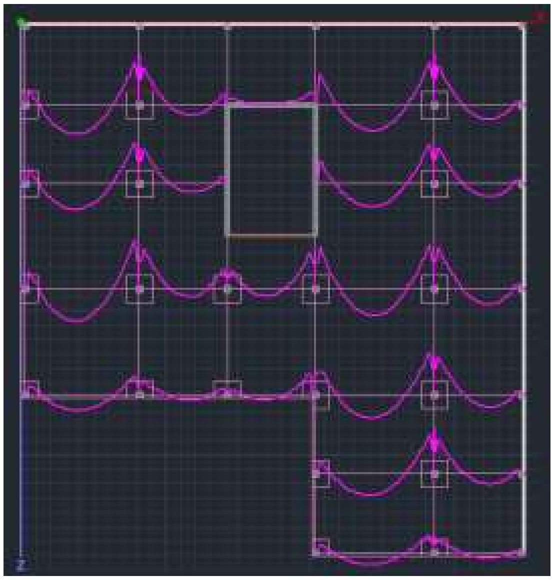
You choose to display the Charts in both directions for their display.

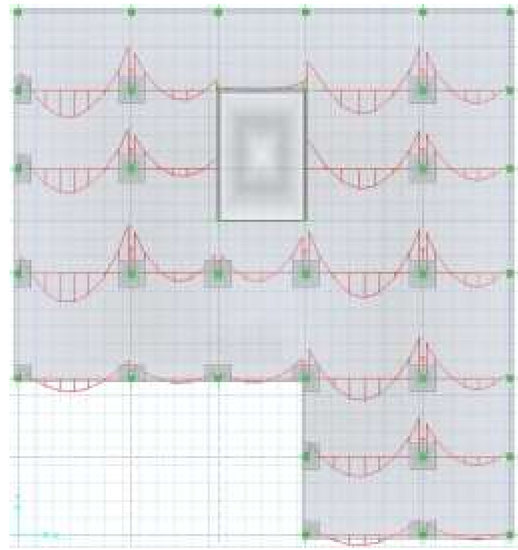




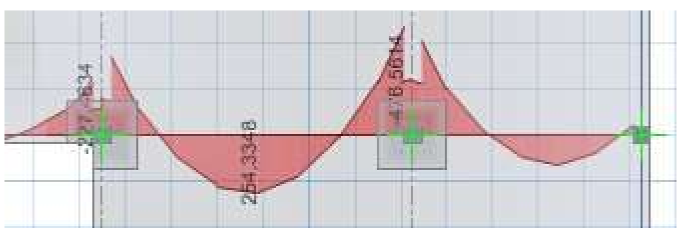
§ Comparison with the results of CSI Safe 2014

By creating the same loading strips in the corresponding Safe vector (Design Strip Objects - where only Column Strips must be defined to match the definition adopted in Scada) the following moment diagrams are obtained. The relevance between the two programs is evident.



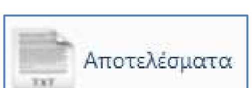


Looking in more detail at the loading strips 14-15 along the X-axis (the numbering is shown in the previous figure), we see that Safe's diagram gives a maximum value at facet 14 equal to 254.3348 kNm.



The corresponding value calculated by Scada Pro is equal to 245.990 kNm, i.e. the difference between the values is in the order of 3% (value found from the scades_FlatSlab folder of the study, file L_14.txt).

5.5 Results



The Results command opens the results file from within the Report.

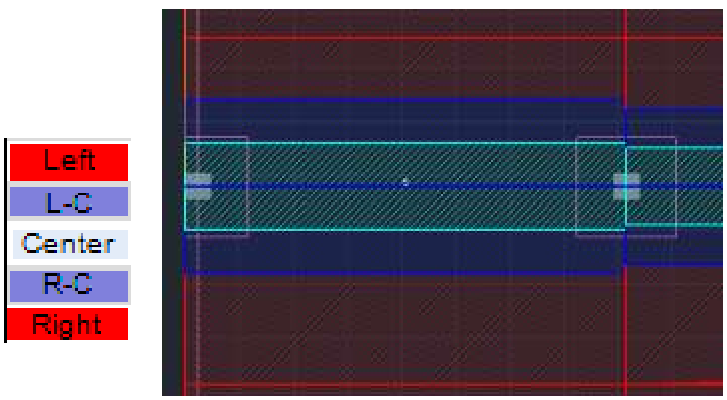
Each page is for one Charging Lane.

First, the characteristics of the Strip are described.

							Page : 1
Strip Calculations							
Description	**Value**	**Units**	**Code**	**Description**	**Value**	**Units**	**Code**
Floor	1			Starting point	corner column		9.4.1&2
# of strip	1			Drop panel	Yes		
Orientation	x-x			*Thickness*	182.88	(cm)	
Length	815.48	(cm)		*Width*		(cm)	
Concrete	C20/25			Finishing point	internal column		9.4.1&2
f_{ck}	20	(MPa)	Table 3.1	Drop panel	Yes		
f_{ctm}	2.20	(MPa)	Table 3.1	*Thickness*	182.88	(cm)	
Steel	S400s			*Width*		(cm)	
f_{yk}	400	(MPa)		Minimum reinforcement			
Cover	20	(mm)		*Tension reinf.*	0.00143	(cm^2/m)	9.2.1.1(1)
Slab thickness	0.25	(cm)		*Compression reinf. (% of span reinf.)*	25	%	9.3.1.2

Then the results of the upper and lower arming are shown in detail for each zone, dividing them into sub-zones.

- Left-Right -> red zone
- L-C R-C-> blue belt
- Center-> blue zone



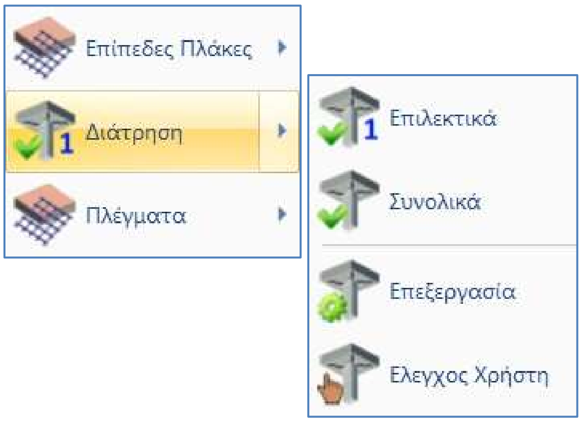
Analysis Results and Reinforcement										Top
	203.87 cm (L_{start})					407.74 cm (L_{centre})				
Zone	M (kNm)	Width (cm)	$A_{s,rqd}$ (cm^2/m)	$A_{s,prvd}$ (cm^2/m)	Φ/s	M (kNm)	Width (cm)	$A_{s,rqd}$ (cm^2/m)	$A_{s,prvd}$ (cm^2/m)	Φ/s
Left		400.0		3.246	8/15		401.1		0.812	8/20
L-C		400.0		3.246	8/15		85.3		1.763	8/20
Center	-80.283	46.0	27.271	27.271	14/5		170.5		6.818	8/7
R-C							85.3		2.043	8/20
Right							103.8		1.471	8/20

	203.87 cm (L_{end})				
Zone	M (kNm)	Width (cm)	$A_{s,rqd}$ (cm^2/m)	$A_{s,prvd}$ (cm^2/m)	Φ/s
Left	-88.070	401.1	2.873	3.246	8/15
L-C	-44.824	85.3	7.054	7.054	8/7
Center	-152.524	170.5	12.422	12.422	10/6
R-C	-51.588	85.3	8.172	8.172	8/6
Right	-45.848	103.8	5.886	5.886	8/8

Analysis Results and Reinforcement										Bottom
	203.87 cm (L_{start})					407.74 cm (L_{centre})				
Zone	M (kNm)	Width (cm)	$A_{s,rqd}$ (cm^2/m)	$A_{s,prvd}$ (cm^2/m)	Φ/s	M (kNm)	Width (cm)	$A_{s,rqd}$ (cm^2/m)	$A_{s,prvd}$ (cm^2/m)	Φ/s
Left	9.207	400.0	0.294	0.812	8/20	70.543	401.1	2.293	3.246	8/15
L-C	9.207	400.0	0.294	0.844	8/20	21.929	85.3	3.377	3.377	8/14
Center	80.591	46.0	27.408	27.408	14/5	43.857	170.5	3.377	3.377	8/14
R-C						21.929	85.3	3.377	3.377	8/14
Right						25.982	103.8	3.284	3.284	8/15

	203.87 cm (L_{end})				
Zone	M (kNm)	Width (cm)	$A_{s,rqd}$ (cm^2/m)	$A_{s,prvd}$ (cm^2/m)	Φ/s
Left	17.335	401.1	0.555	0.812	8/20
L-C	6.505	85.3	0.984	0.984	8/20
Center	23.135	170.5	1.762	1.762	8/20
R-C	3.583	85.3	0.539	0.844	8/20
Right	3.311	103.8	0.409	0.821	8/20

6. Perforation

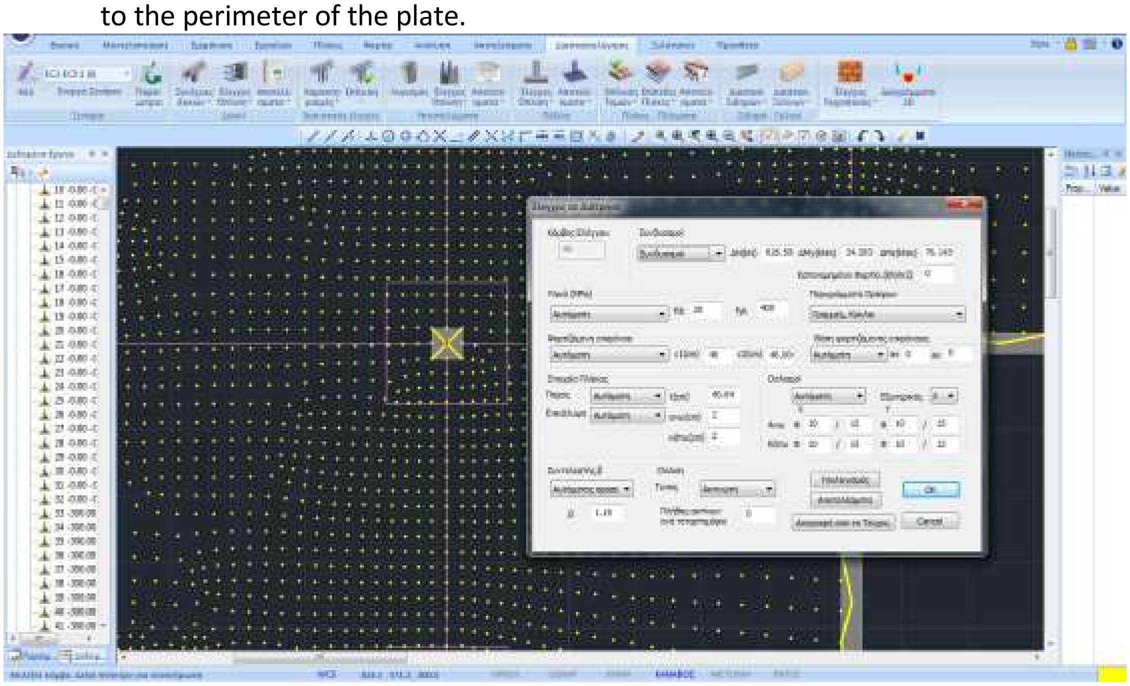


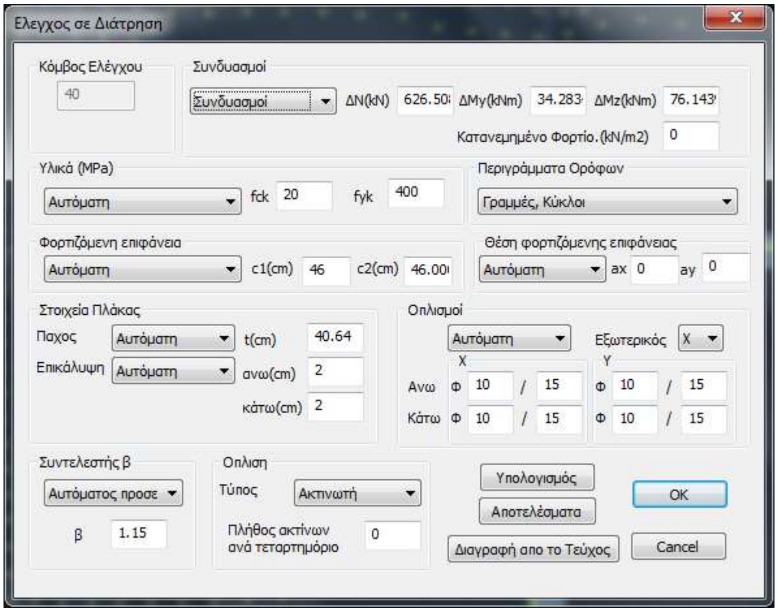
The perforation test can be performed selectively for each pole or overall on all poles in the plan view.

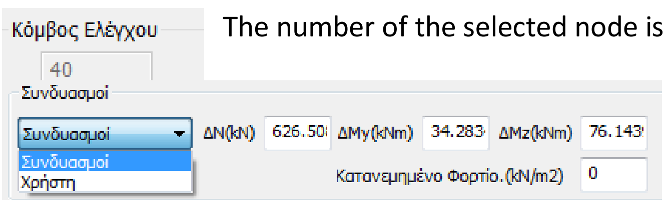
6.1 Selectively

Select the command Selectively, left-click to point to the node of a pole and right-click to open the dialog box where you will set all the necessary parameters.

- In this example, we select the node of an Inner Pillar, node 40.
- The following clarifications are given for the other positions of the poles in relation to the perimeter of the plate.



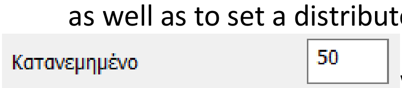




The number of the selected node is automatically filled in and is not editable.

In the Combinations field:

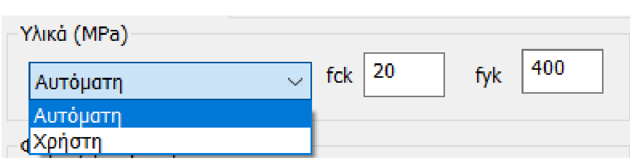
- The Combinations option, makes the program automatically find the combination that results in the worst Axial Dn, and displays its value along with the corresponding moments.
- The User option, allows to set user values for axial and moments in the respective fields, as well as to set a distributed load



which works by "relieving" the plate at that point, resulting in a reduced calculation cutting force compared to the original one.

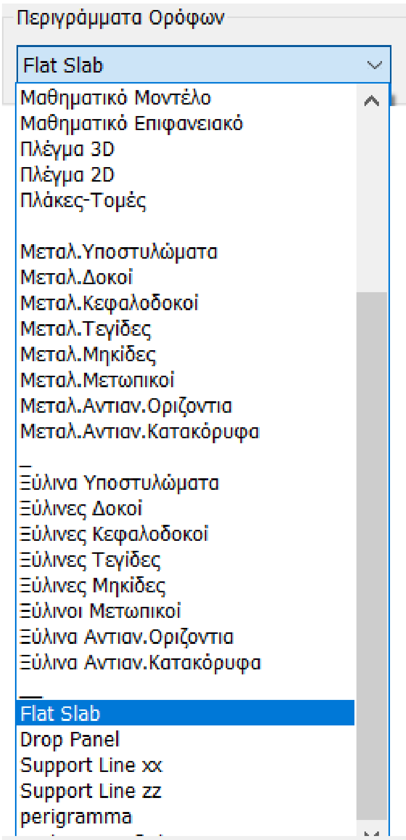
Αρχική τέμνουσα ($V_{Ed,αρχ.}$)	626.5	(kN)
Κατανεμημένο φορτίο (p)	50.0	(kN/m^2)
Απομειωμένη τέμνουσα ($V_{Ed,τελ.}$)	478.8	(kN)

⚠ In this example we have considered only one combination 1,20G+1,60Q and therefore the values of the intensities are derived from it.

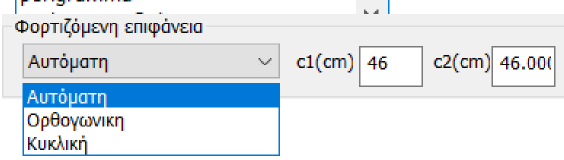


In the Material field the coefficients fck and fyk are filled in automatically with the Automatic option or defined by the user with the User option.

EXAMPLE 9 - FLAT PLATES



In Floor Contours you select the Layer that contains the outline of the slab including the columns that are in the outline.
So we select the Flat Slab layer which contains exactly the lines that define the overall outline of the slab.

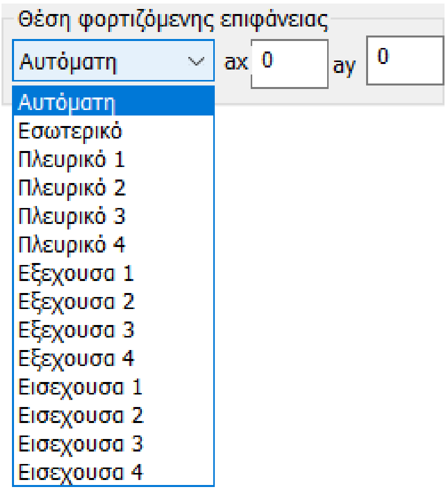


The Loadable Area is defined as the equivalent surface area of the selected pole.

Select:

- Automatic so that the program can calculate the surface area of any type of column by reducing it to an equivalent rectangular one and calculating the corresponding dimensions c1 and c2.
- Rectangular so that the user can define his own dimensions c1 and c2 to calculate the loaded rectangular surface
- Circular in order to calculate a circular loading area of diameter equal to the value c1 to be specified by the user

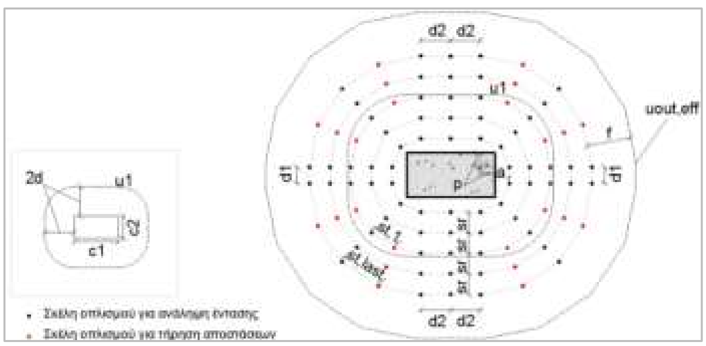
EXAMPLE 9 - FLAT PLATES



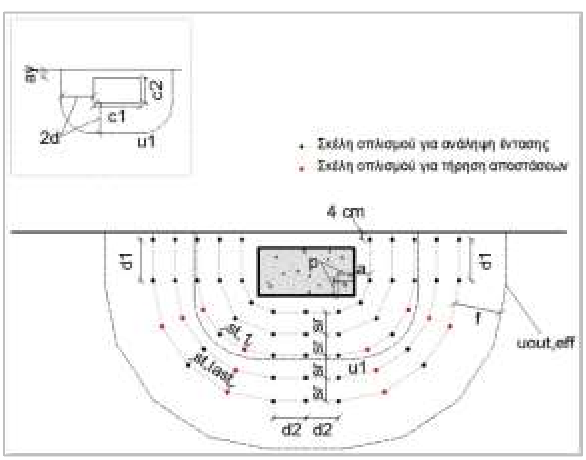
The Load Surface Position can be set either automatically or selectively. It depends on the contour of the plate and the position of the selected post on it. The proposed positions are:

- Internal
- Lateral in 4 directions
- Prominent in the 4 directions
- Incoming in 4 directions

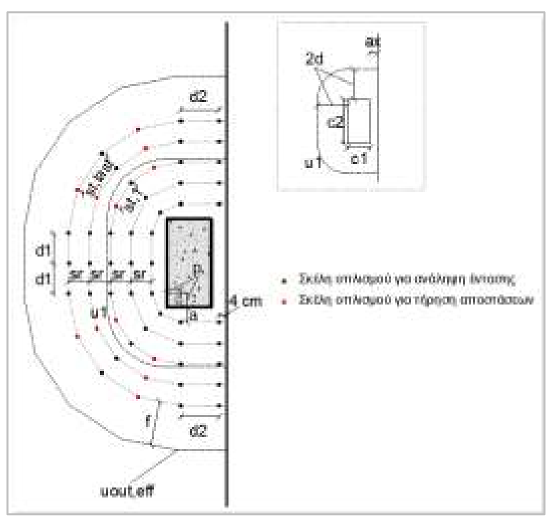
Select the position of the selected pole and set the distances from the perimeter ax and ay (except the inner) according to the following figures:



INTERNAL

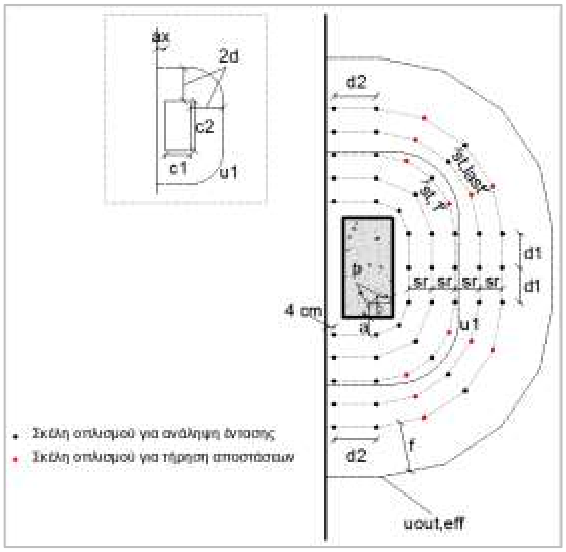


PLEYRIC 1

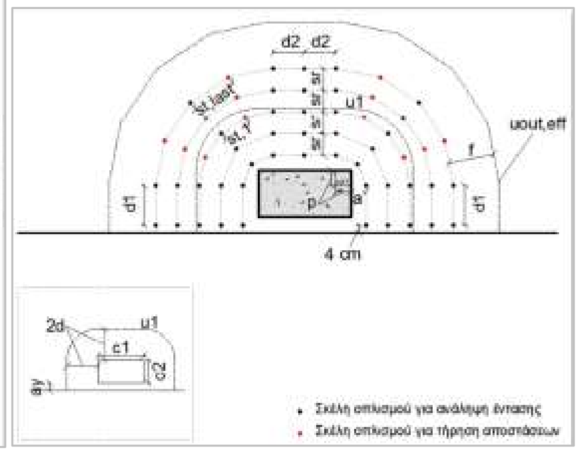


PLEYRICO 2

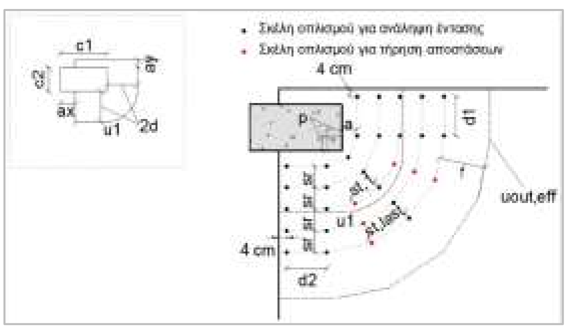
EXAMPLE 9 - FLAT PLATES



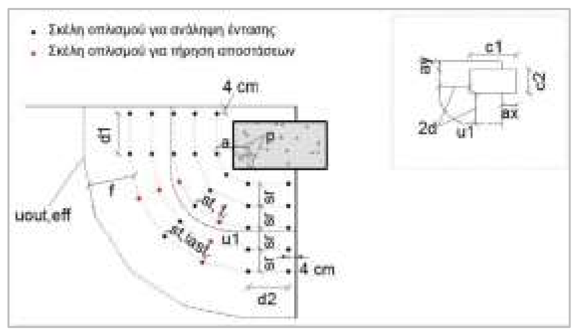
PLEYRICO 4



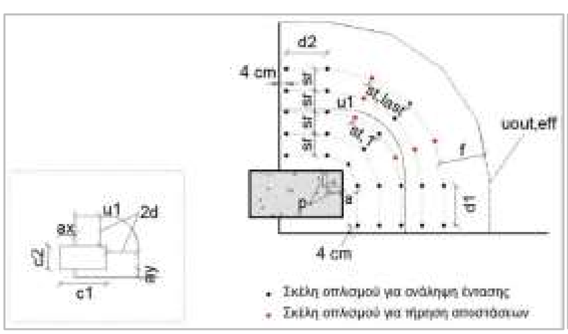
PLEYRICO 3



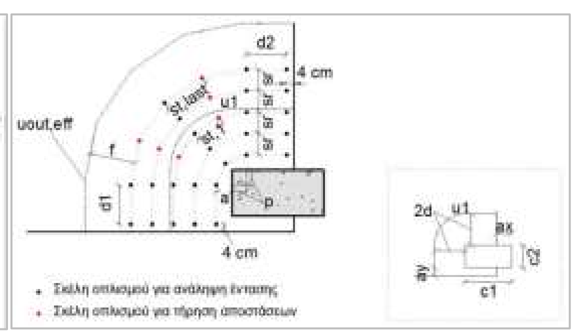
EXECUTIVE 1



EXPERIENCE 2

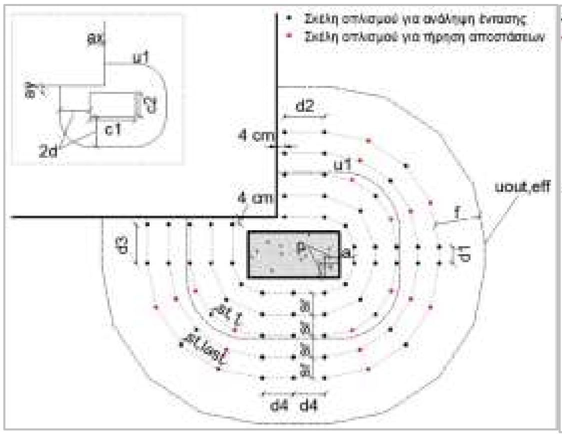


EXECUTIVE 4

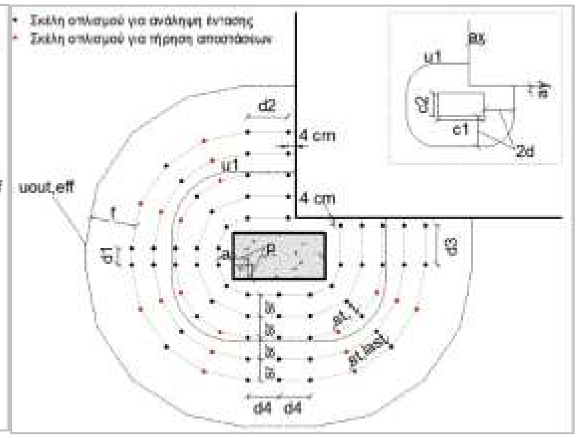


EXPERIENCE 3

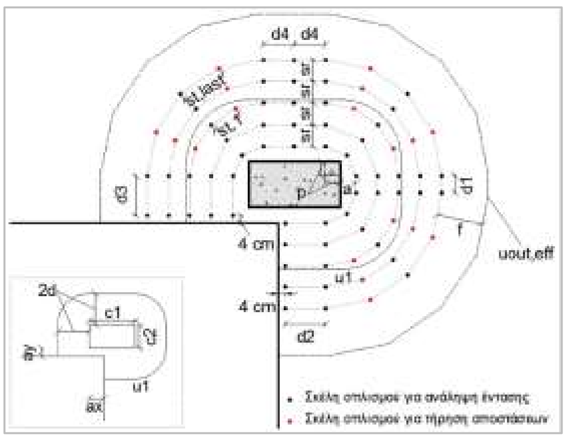
EXAMPLE 9 - FLAT PLATES



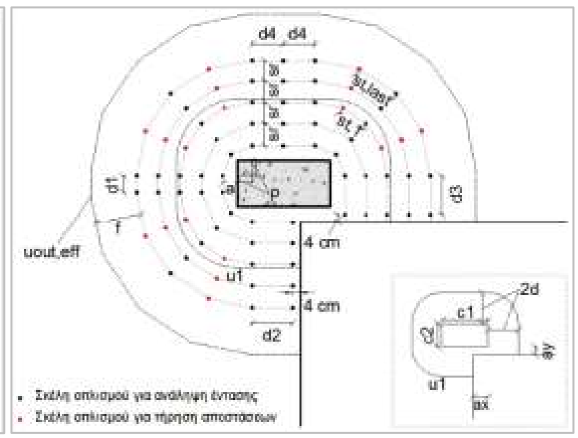
INCOMING 1



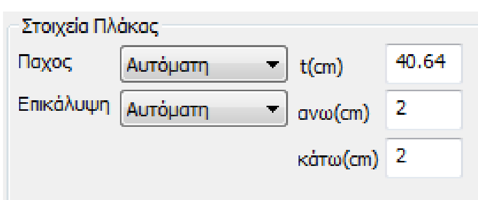
REGISTRANT 2



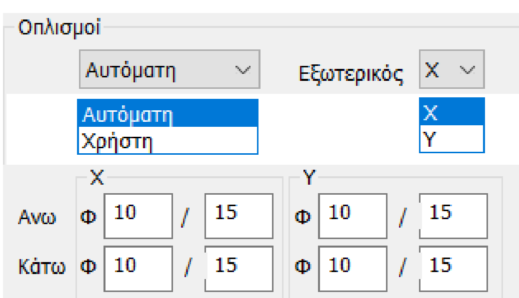
INCOMING 4



REGISTERED 3



The Thickness and Coating of the panel are either taken into account automatically or modified by the User by selecting the corresponding option and defining the corresponding values for the thickness and coating of the upper and lower panel (here the thickness of the drop panel is taken).

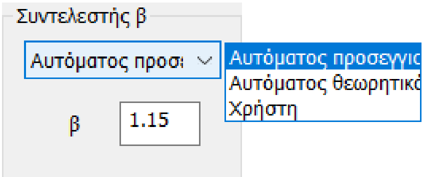


In the Reinforcements field, the longitudinal reinforcement resulting from the calculation of the Flat Plates in the area of the selected column is specified.

With the Automatic selection the longitudinal reinforcement is taken into account:

- Upper for positive (+DN) (e.g. top floor slab)
- Down for DN negative (-DN) (e.g. foundation)

The External X or Y option determines the direction of the external reinforcement in the longitudinal reinforcement grid the slab (either upper or lower grid).

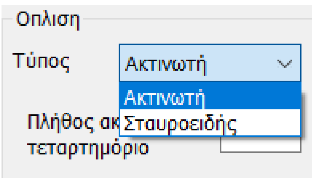


The Coefficient b for the calculation of Perforation can be calculated automatically in two ways:

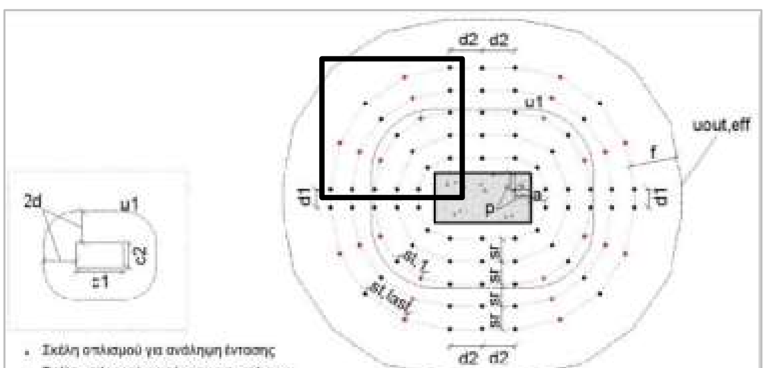
- Automatic approximate or
- Automatic theorist.

⚠ The Approximate mode is a function of the position of the loaded surface and ax, ay.
⚠ The Theoretical mode is a function of Torques My, Mz.

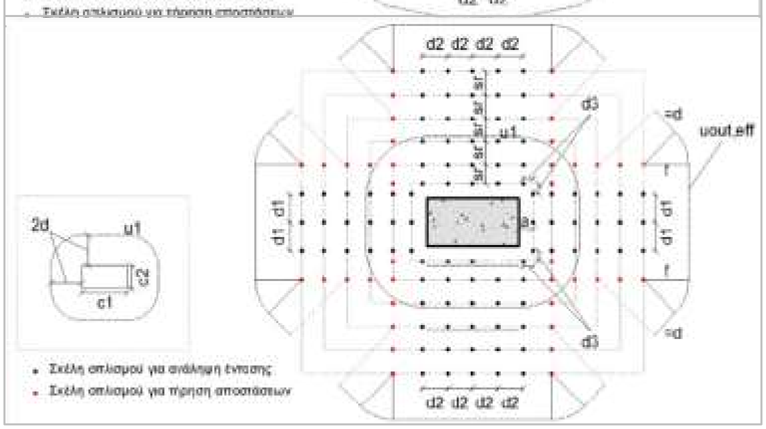
The User option allows you to enter any value for Coefficient b.



Finally, in the Arborization field you define the type of arrangement of the perforation reinforcement by choosing between Radial and Cruciform.
For the Radial array you also set the Number of rays per quadrant. The figure below shows a quadrant of the radial array in the black box. The initial perimeter has 3 reinforcement spans, while the third perimeter is thickened to 5 spans due to constraints on the spacing between reinforcement strands. ScadaPro automatically checks whether the spacing constraints are met on the first perimeter and increases the number of reinforcement spars where required (even on the first perimeter if the number of spars selected by the user is not sufficient).



Radial Armature Arrangement



Cross Armature Arrangement

Υπολογισμός The Calculate command performs all the necessary checks on perforation, taking into account all the above parameters.

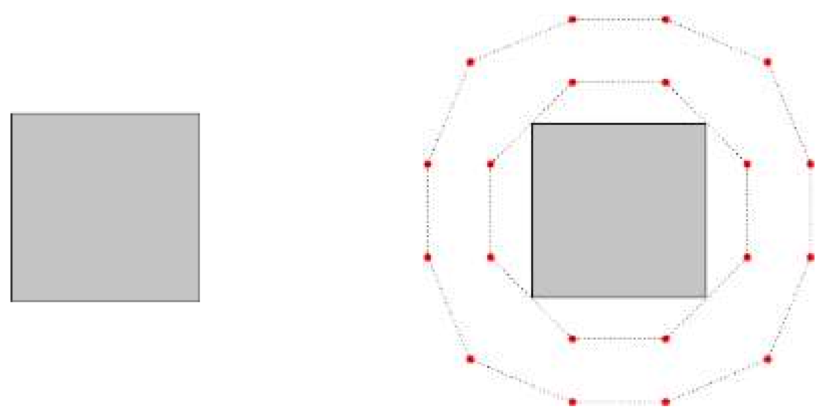
Αποτελέσματα The Results command displays the results file:

Data: list of all data specified in the previous window and required for the perforation test.

					Page : 1
Δεδομένα					
Περιγραφή	Τιμή	Μονάδες	Περιγραφή	Τιμή	Μονάδες
Όροφος	1		Συντελεστής (β) (EC2-6.4.3)	1.150	
# του κόμβου	40		Πάχος πλάκας	40.6	(cm)
Συνδυασμός	1		Επικάλυψη οπλισμού	2.0	(cm)
Αρχική τέμνουσα ($V_{Ed,red}$)	626.5	(kN)	Διάμετρος εξωτερικού διατμητικού οπλισμού	10	(mm)
Κατανεμημένο φορτίο (p)	0.0	(kN/m²)			
Απομειωμένη τέμνουσα ($V_{Ed,red}$)	626.5	(kN)	Απόσταση εξωτ. διατμητ. οπλ.	15.0	(cm)
Καμπτική Ροπή (M_x)	34.3	(kNm)	Διάμετρος εσωτερικού διατμητικού οπλισμού	10	(mm)
Καμπτική Ροπή (M_y)	76.1	(kNm)			
Σχήμα φορτιζόμενης περιοχής	Ορθογωνική		Απόσταση εσωτερικού διατμητικού οπλισμού	15.0	(cm)
Μήκος c_1 (κατά τον άξονα x)	46.0	(cm)			
Μήκος c_2 (κατά τον άξονα y)	46.0	(cm)	Σκυρόδεμα (f_{ck})	20.0	(MPa)
Διάμετρος c		(cm)	Χάλυβας (f_{yk})	400.0	(MPa)
Θέση φορτιζόμενης περιοχής	Εσωτερικό		Διάταξη οπλισμού	Ακτινωτή	
Απόσταση πλάκας κατά x (a_x)		(cm)	Αριθμ. γραμμών οπλισμού ανά τεταρτημόριο	2	
Απόσταση πλάκας κατά y (a_y)		(cm)			

Schematic arrangement of perforation reinforcement: according to the predefined parameters and if a requirement for perforation reinforcement arises.

⚠ In this example there is no reinforcement requirement in perforation and as a result no schematic reinforcement layout is shown (the figure below includes a random radial layout with two reinforcement perimeters).



The **results of** the **audits** include two audits.

If the 1th check shows *Adequacy*, then the 2th check determines the requirement or not of the perforation reinforcement.

							Page : 2
			Αποτελέσματα ελέγχων				
Περιγραφή	Τιμή	Μονάδες	EC2	Περιγραφή	Τιμή	Μονάδες	EC2
Ενεργό πάχος πλάκας (d)	37.6	(cm)	(eq6.32)	Βασική περίμετρος ελέγχου (u_1)	657.0	(cm)	(fig6.15)
Περίμετρος φορτιζόμενης περιοχής (u_0)	184.0	(cm)	(eq6.53)	Διατμητική τάση στην περίμετρο u_1 ($v_{Ed,1}$)	0.291	(MPa)	(eq6.38)
Διατμητική τάση στην περίμετρο u_0 ($v_{Ed,0}$)	1.040	(MPa)	(eq6.38)	Διατμητική αντοχή άοπλου σκυροδέματος ($v_{Rd,c}$)	0.356	(MPa)	(eq6.47)
Μέγιστη διατμητική αντοχή ($v_{Rd,max}$)	3.680	(MPa)	(eq6.53)				

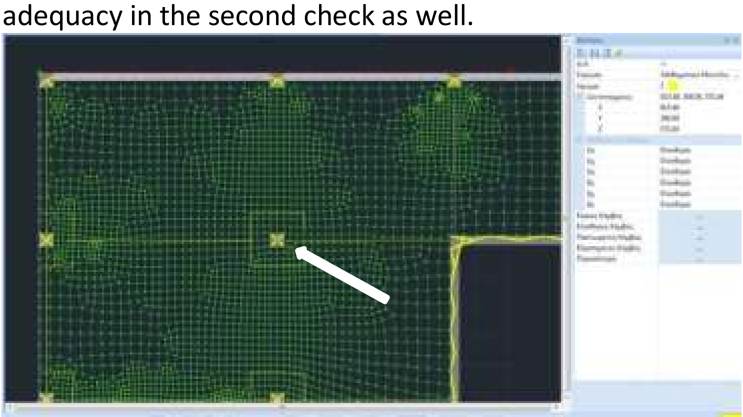
							Page : 2
			Αποτελέσματα ελέγχων				
Περιγραφή	Τιμή	Μονάδες	EC2	Περιγραφή	Τιμή	Μονάδες	EC2
Ενεργό πάχος πλάκας (d)	37.6	(cm)	(eq6.32)	Βασική περίμετρος ελέγχου (u_1)	657.0	(cm)	(fig6.15)
Περίμετρος φορτιζόμενης περιοχής (u_0)	184.0	(cm)	(eq6.53)	Διατμητική τάση στην περίμετρο u_1 ($v_{Ed,1}$)	0.372	(MPa)	(eq6.38)
Διατμητική τάση στην περίμετρο u_0 ($v_{Ed,0}$)	1.328	(MPa)	(eq6.38)	Διατμητική αντοχή άοπλου σκυροδέματος ($v_{Rd,c}$)	0.356	(MPa)	(eq6.47)
Μέγιστη διατμητική αντοχή ($v_{Rd,max}$)	3.680	(MPa)	(eq6.53)	Σταθερά (v_{min})	0.356	(MPa)	(eq6.3)
1ος έλεγχος $v_{Ed,0} \leq v_{Rd,max}$	Επάρκεια			2ος έλεγχος $v_{Ed,1} \leq v_{Rd,c}$	Απαιτείται οπλισμός - προσθήκη οπλισμού διάτρησης - αύξηση διαμήκη οπλισμού πλάκας		

If the 1st (1st) check shows *Non-adequacy*, then the 2nd (2nd) check is not performed and

							Page : 2
			Αποτελέσματα ελέγχων				
Περιγραφή	Τιμή	Μονάδες	EC2	Περιγραφή	Τιμή	Μονάδες	EC2
Ενεργό πάχος πλάκας (d)	37.6	(cm)	(eq6.32)	Βασική περίμετρος ελέγχου (u_1)	657.0	(cm)	(fig6.15)
Περίμετρος φορτιζόμενης περιοχής (u_0)	184.0	(cm)	(eq6.53)	Διατμητική τάση στην περίμετρο u_1 ($v_{Ed,1}$)	1.395	(MPa)	(eq6.38)
Διατμητική τάση στην περίμετρο u_0 ($v_{Ed,0}$)	4.961	(MPa)	(eq6.38)	Διατμητική αντοχή άοπλου σκυροδέματος ($v_{Rd,c}$)	0.356	(MPa)	(eq6.47)
Μέγιστη διατμητική αντοχή ($v_{Rd,max}$)	3.680	(MPa)	(eq6.53)	Σταθερά (v_{min})	0.356	(MPa)	(eq6.3)
1ος έλεγχος $v_{Ed,0} \leq v_{Rd,max}$	Μη επάρκεια - αύξηση διαστάσεων φορτιζόμενης περιοχής - αύξηση πάχους πλάκας - χρήση ανώτερης ποιότητας σκυροδέματος			2ος έλεγχος $v_{Ed,1} \leq v_{Rd,c}$			

some interventions are suggested for the plaque.

As mentioned, in the particular example (node 40 shown in the figure below) being solved, the loading level is not such that shear hardening is required. In other words, there is adequacy in the second check as well.

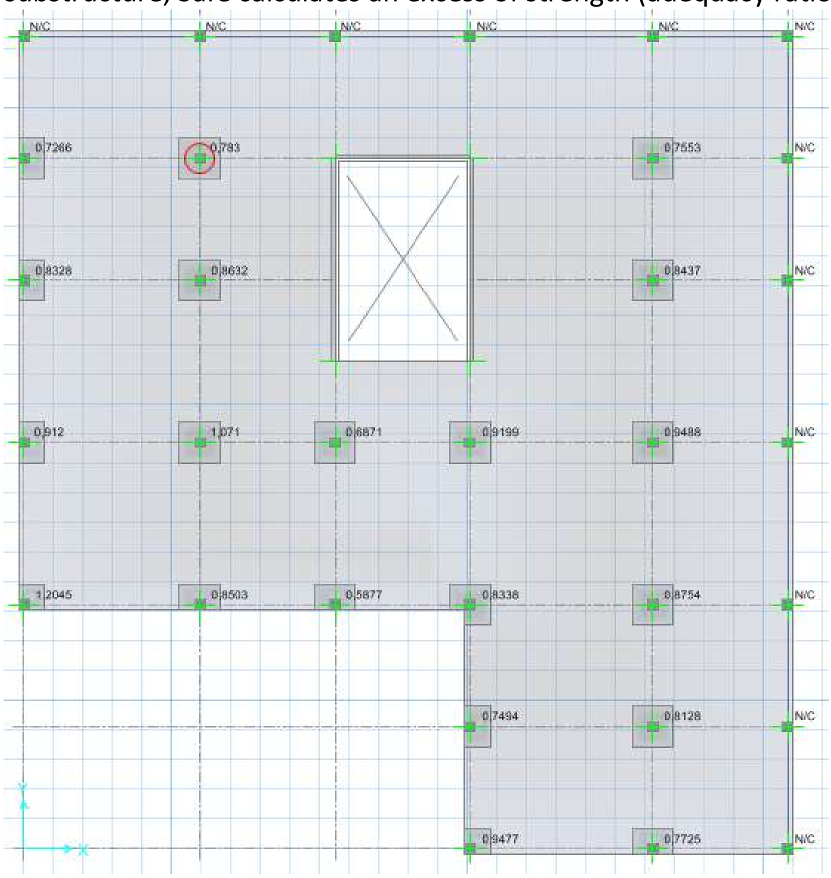


The shear test for this particular column gives a strength-to-strength ratio of 0.291/0.356 = 0.81.

§ Comparison with the results of CSI Safe 2014

The perforation test in Safe 2014 gives the corresponding ratio in the columns (figure below). An adequacy ratio of 0.78 is calculated for the column under consideration. The difference between the two programs is in the order of 4%.

We consider the substructure located two positions below by Z (node 38). For this substructure, Safe calculates an excess of strength (adequacy ratio 1.07) (figure below).

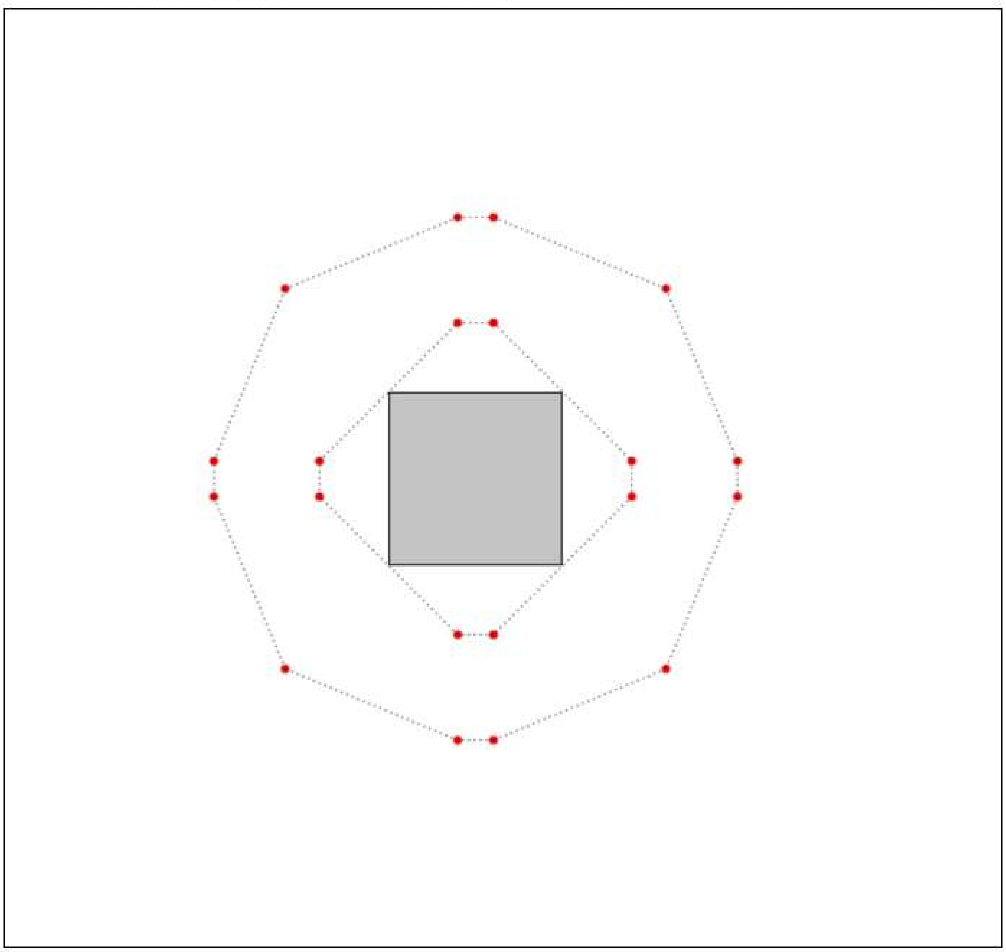


Scada also finds that there is a need for reinforcement for this particular substructure (adequacy ratio 0.394/0.356 = 1.11) and calculates the reinforcement. In detail, the results are as follows:

The first page of the results shows the input data and the arrangement of the reinforcement according to the user's choice. Here a radial arrangement with two reinforcement beams per quadrant was selected.

EXAMPLE 9 - FLAT PLATES

					Page : 1
Δεδομένα					
Περιγραφή	**Τιμή**	**Μονάδες**	**Περιγραφή**	**Τιμή**	**Μονάδες**
Όροφος	1		Συντελεστής (β) (EC2-6.4.3)	1.150	
# του κόμβου	38		Πάχος πλάκας	40.6	(cm)
Συνδυασμός	1		Επικάλυψη οπλισμού	2.0	(cm)
Αρχική τέμνουσα ($V_{Ed,αρχ.}$)	846.7	(kN)	Διάμετρος εξωτερικού διαμήκη οπλισμού	10	(mm)
Κατανεμημένο φορτίο (p)	0.0	(kN/m^2)			
Απομειωμένη τέμνουσα ($V_{Ed,τελ.}$)	846.7	(kN)	Απόσταση εξωτ. διαμήκη οπλ.	15.0	(cm)
Καμπτική Ροπή (M_x)	-32.7	(kNm)	Διάμετρος εσωτερικού διαμήκη οπλισμού	10	(mm)
Καμπτική Ροπή (M_y)	104.4	(kNm)			
Σχήμα φορτιζόμενης περιοχής	Ορθογωνικη		Απόσταση εσωτερικού διαμήκη οπλισμού	15.0	(cm)
Μήκος c_1 (κατά τον άξονα x)	46.0	(cm)			
Μήκος c_2 (κατά τον άξονα y)	46.0	(cm)	Σκυρόδεμα (f_{ck})	20.0	(MPa)
Διάμετρος c		(cm)	Χάλυβας (f_{yk})	400.0	(MPa)
Θέση φορτιζόμενης περιοχής	Εσωτερικό		Διάταξη οπλισμού	Ακτινωτή	
Απόσταση πλάκας κατά x (a_x)		(cm)	Αριθμ. γραμμών οπλισμού ανά τεταρτημόριο	2	
Απόσταση πλάκας κατά y (a_y)		(cm)			



The second page presents the results of the tests and the details of the arming device.

Reinforcement of diameter Φ14 is calculated and the last table shows the reinforcement in groups of reinforcement lines with a specific number of strands in each line (useful presentation in case prefabrication is chosen).
stud-rail punching shear reinforcement system).
Here 8 lines with two strands each and 4 lines with one strand each are used. In the 8 lines the 2 strands are spaced at a distance equal to the distance $_{sr}$ of the table (28 cm).

Page : 2

Αποτελέσματα ελέγχων

Περιγραφή	Τιμή	Μονάδες	EC2	Περιγραφή	Τιμή	Μονάδες	EC2
Ενεργό πάχος πλάκας (d)	37.6	(cm)	(eq6.32)	Βασική περίμετρος ελέγχου (u_1)	657.0	(cm)	(fig6.15)
Περίμετρος φορτιζόμενης περιοχής (u_0)	184.0	(cm)	(eq6.53)	Διατμητική τάση στην περίμετρο u_1 ($v_{Ed,1}$)	0.394	(MPa)	(eq6.38)
Διατμητική τάση στην περίμετρο u_0 ($v_{Ed,0}$)	1.406	(MPa)	(eq6.38)	Διατμητική αντοχή άοπλου σκυροδέματος ($v_{Rd,c}$)	0.356	(MPa)	(eq6.47)
Μέγιστη διατμητική αντοχή ($v_{Rd,max}$)	3.680	(MPa)	(eq6.53)	Σταθερά (v_{min})	0.356	(MPa)	(eq6.3)
1^{ος} έλεγχος: $v_{Ed,0} \leq v_{Rd,max}$	Επάρκεια			2^{ος} έλεγχος: $v_{Ed,1} \leq v_{Rd,c}$	Απαιτείται οπλισμός: - προσθήκη οπλισμού διάτρησης - αύξηση διαμήκη οπλισμού πλάκας		

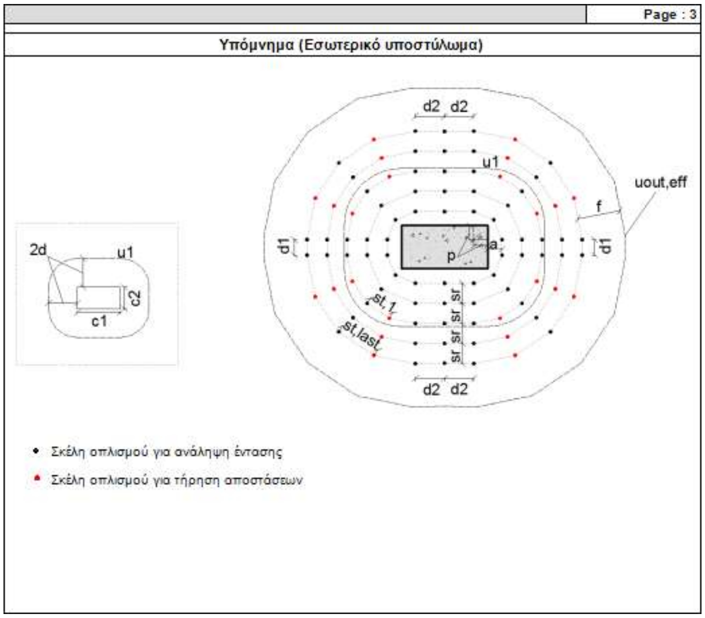
Αποτελέσματα οπλισμού διάτρησης

Περιγραφή	Τιμή	Μονάδες	EC2	Περιγραφή	Τιμή	Μονάδες	EC2
Περίμετρος $u_{out,ef}$	727.0	(cm)	(eq6.54)	Απόσταση (d_3)		(cm)	
Απόσταση 1^{ης} περιμέτρου οπλισμού από φορτιζόμενη επιφάνεια (a)	18.8	(cm)		Απόσταση (d_4)		(cm)	
Οριακή απόσταση: $0.3 \cdot d \leq a \leq 0.5 \cdot d$	11.3<=a<=18.8		(9.4.3)	Γωνία (φ)	90.0	°	
Απόσταση τελευταίας περιμέτρου οπλισμού από την περίμετρο $u_{out,ef}$ (f)	56.6	(cm)		Εφαπτομενική απόσταση των σκελών οπλ. στην τελευταία περίμετρο όπλισης ($s_{t,last}$)	91.8	(cm)	
Οριακή απόσταση: $k \cdot d = 1.5 \cdot d$	56.5	(cm)	(6.4.5)	Οριακή απόσταση: $2.0 \cdot d$	75.3	(cm)	
Ακτινική απόσταση των περιμέτρων οπλισμού (s_r)	28.0	(cm)		Δρώσα τιμή σχεδιασμού αντοχής οπλ. διάτρησης ($f_{ywd,ef}$)	344.1	(MPa)	(eq6.52)
Οριακή απόσταση: $0.75 \cdot d$	28.2	(cm)	(9.4.3)	Απαιτούμενη διατομή σκέλους οπλισμού διάτρησης ($A_{sw,1}$)	1.532	(cm^2)	
Εφαπτομενική απόσταση των σκελών οπλισμού στην περίμετρο u_1 ($s_{t,1}$)	91.8	(cm)		Ελάχιστη διατομή σκέλους ($A_{sw,min}$)	1.532	(cm^2)	(eq9.11)
Οριακή απόσταση: $1.5 \cdot d$	56.5	(cm)	(9.4.3)	Διάμετρος σκέλους που χρησιμοποιείται	14	(mm)	
Μήκος (p)	18.1	(cm)		Διατομή σκέλους που χρησιμοποιείται	1.539	(cm^2)	
Απόσταση (d_1)	9.9	(cm)					
Απόσταση (d_2)	9.9	(cm)					

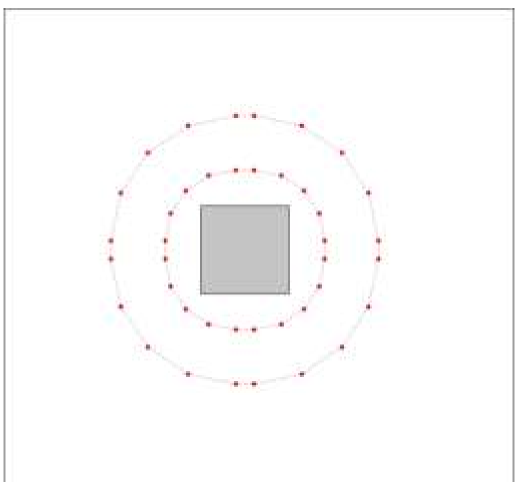
Διάταξη οπλισμού διάτρησης

Ομάδα	Αριθμός γραμμών	Φ (mm)	Αριθμός σκελών ανά γραμμή	Ύψος σκέλους (cm)	Περίμετρος όπου βρίσκεται το 1^{ο} σκέλος της γραμμής	Απόσταση 1^{ου} σκέλους από φορτιζόμ. επιφάνεια
1	8	14	2	36.6	1	18.82
2	4	14	1	36.6	2	46.82

EXAMPLE 9 - FLAT PLATES

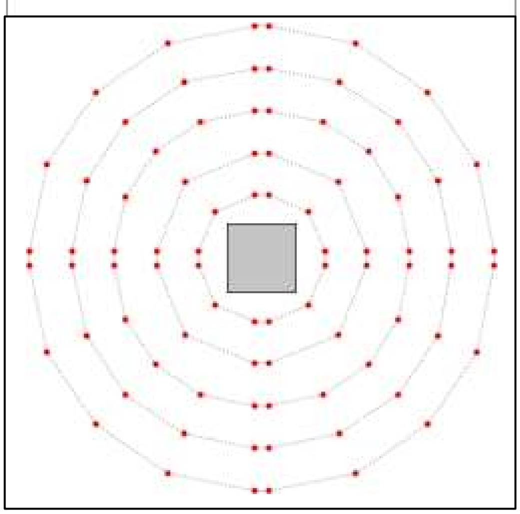


The details of the arrangement referring to the drilling reinforcement results are explained in the Memo on the third page below.



The diameter of the reinforcement strands can be reduced if more reinforcement beams per quadrant are selected. For example, if 5 reinforcement spans per quadrant are selected then the following arrangement is proposed, and the table of reinforcement arrangement is as follows, i.e. a group of reinforcement lines with two F8 strands in each line, spaced 28 cm apart.

Διάταξη οπλισμού διάτρησης						
Ομάδα	Αριθμός γραμμών	Φ (mm)	Αριθμός σκελών ανά γραμμή	Ύψος σκέλους (cm)	Περίμετρος όπου βρίσκεται το 1ο σκέλος της γραμμής	Απόσταση 1ου σκέλους από φορτιζόμ. επιφάνεια
1	20	8	2	36.6	1	18.82

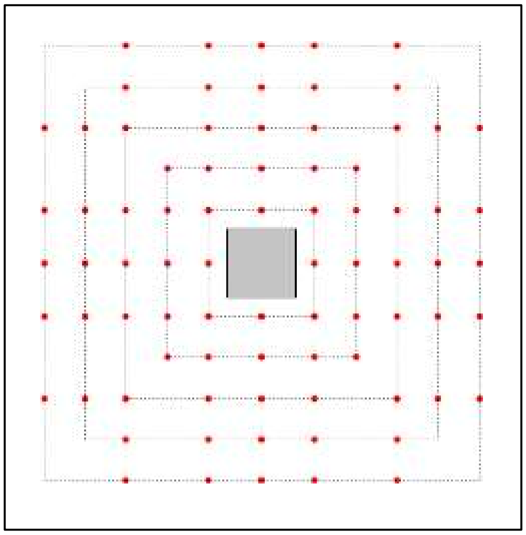


In the same substructure if the user attempts to increase the level of loading and selects a value for the axial load of 1400 kN (user value)

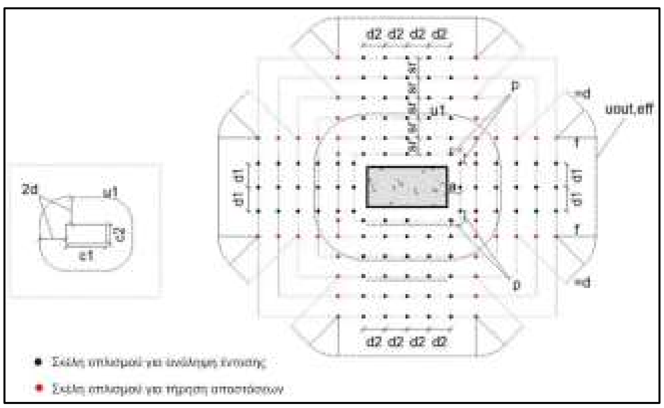
Διάταξη οπλισμού διάτρησης						
Ομάδα	Αριθμός γραμμών	Φ (mm)	Αριθμός σκελών ανά γραμμή	Ύψος σκέλους (cm)	Περίμετρος όπου βρίσκεται το 1ο σκέλος της γραμμής	Απόσταση 1ου σκέλους από φορτιζόμ. επιφάνεια
1	12	16	5	36.6	1	18.82
2	8	16	3	36.6	3	74.82

then radial armouring with 3 reinforcement beams per quadrant gives the following results with F16 reinforcement strands (84 reinforcement strands).

EXAMPLE 9 - FLAT PLATES



Choosing a cruciform arrangement we have arming with Φ16 strands also (80 strands of reinforcement).



The corresponding memo for a cross-shaped arrangement is as follows: