

Example 5 Flat slabs







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I. FLAT SLABS - EXAMPLE

In the following example, the structure below is analyzed. It is the same structure analyzed in the CSI Safe 2014 tutorial. Useful conclusions may be drawn by the comparison of the results from the two software.





1. Simulation Process

1. The process begins by creating a new project and name the file.

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2. Then define the levels. At the level that will define the flat slab, turn off the Rigid Link Constrain function and choose how the Connection Method of Columns nodes with Mesh Surface.

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Name Edit Delete Move Execute Readjustment	Add multiple levels Number 5 Add
n/n Name Height R.L.C. Even H 3D 0 0 0 0.00 ♀	Select All Deselect R.L.C Non R.L.C. Even Height Non Even Height Display in 3D
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At the bottom of the window there is the option for choosing the Connection Method of the Columns nodes with the Mesh Surface, for the selected level. Select "Rigid Links in nodes of the surface" and press Update.





Level 1

4. Activate level 1 and start inserting the columns and the beams using modeling commands according the image's dimensions:



Project ... Reproject ...



About the core, choose simulation with complex cross section, due to the large dimensions. Use rectangular columns profiles, and then join them by using height rigidity beam members to yield the stiffness of the component.



WCS 1077.7 , 3410.0 , 0.0



Level 0 5. Using Copy-Paste Level copy all in level 0 and delete the beams.

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And using External Boundary set the slab outline. The boundary can be defined automatically, simply by selecting one of its lines and then right-click.



Preconditions: The boundary:

- should be closed and without ramifications and
- the external columns should be excluded from this.

So we must define a border like the orange solid line shown in Figure. The outer limit of the hole in the center will be set later as a hole.





Line

To draw the External Boundary you can use the design commands and osnaps. Edit Layers command needs to make Layers Non Visible and Non Editable for easier design.

NOTES!!!

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Convert Lines -Arcs

 Alternatively, insert an auxiliary design file, containing the outer limit and by using the Layers command, convert the design lines in SCADA lines.





ATTENTION!!!

ATTENTION: In cases where in the plate boundary there are beams, we must ensure the connection of the surface elements of the plate with the members of the perimeter beams. That's why:

The external boundary of the slab should <u>coincides</u> with the axis of the beam



after create the mesh and the mathematical model, you should use the command that breaks the beam's members and connects them with the mesh elements.







External Boundary

Select the command and left-click on one of the contour lines. Right click and displays a dialog boxes with the surface setting.

Insert Surface Element	Х		
Description S1			
Element	Ks (MPa/cm)		
Plate ~	0		
Width (cm) Thickness 50 20	Flat Surface		
ОК	Cancel		
Holes			

If there is one or more points where the perimeter is not a closed area, on the screen will appear one or more **X** indicates that point/s.

Select Holes command and show the contour of the hole like you did before for the external boundary, left click on a line and right click to complete the command.



When the form and the properties of the mesh are completed, comes the calculation. Select the command and in the dialog box that opens displays the list of the mesh. In this example there is a mesh S1. The number in brackets (1) shows the number of holes that have been set for the mesh.

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Apart from the central hole should be also present the holes in place of the internal columns. Creating Holes in the Column's location These holes are generated automatically by selecting the command and their number is added to the value in brackets. Calculation to calculate the mesh. Use



The modeling is completed by the creation of the Mathematical Model.







2. Loads

Apply Dead Loads (1,44KN/m2) and Live Loads (2,39KN/m2) to the entire slab. In the value of the Dead Loads The value of the self weight of the slab is not included in the value of Dead Loads (the S.W. is checked in the Dead Load definition.

Load Case Definition	
Self-weight Dead Load	Insert
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to include all th	e plan view. Apply Dead (1,44KN/m2) and Live (2,39KN/m2)
loads as pressure on the Plate.	
Load Property	
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3. Analysis

Create a **Static** Scenario and run the simple static analysis.

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ad Groups Combination ad Groups Combination ad Groups Combination ad Groups Combination ad Groups Combination Combina	ns 1	No V V V V V V V V V V V V V V V V V V V	↓ ψ2 0.3 ↓ ↓2 0.3 ↓ ↓ LC1 Static (2) ↓ 1 G ↓ ↓ 1.20	Vind - Snow LC2 Static (2) 2 Q 1.60	Ultimate > 2yG+yq+2y 2G+ytQ+2 UC3 UC3 UC3 G G G G G G G G G G G G G	AUDO Q W2Q 2Q C C C C C C C C C C C C C	Serviceability ✓ ΣG-Q+Σφ00 ✓ ΣG-Q+Σφ2Q ↓ ✓ ZG+Σψ2Q ↓ ✓	2 122 0 0 G	▼ ▼ ▼	alation LCC6 G	×	
ad Groups Combination ad Groups Combination ad Groups Combination (1.35) yE (2000) (1.5) yE (2000) (20)	ns 1 0.3 0 0.3 .	No V V V V V V V V V V V V V V V V V V V	↓ ψ2 0.3 ↓ ↓2 0.3 ↓ ↓ LC1 Static (2) ↓ 1 G ↓ ↓ 1 1.20	Vind - Snow LC2 Static (2) 2 Q 1.60	Ultimate > 2yG+qv2xy > 2G+qv1Q+2 > 2G+qv1Q+2 LC3	AUDO Q W2Q 2Q C C C C C C C C C C C C C	Serviceability ✓ ΣG-Q+Σφ00 ✓ ΣG-Q+2ψ2Q 1 ✓ ZG+Σψ2Q 4 ✓	2 122 0 0 6 6		alation te All LC6 G	×	



4. Post-Processor

In **Post-Processor** field, you can read the values of the different sizes, either by the color imaging either by reading the values of the selected size in the surface of the mesh element, activating VALUES in the lower horizontal bar.







In Members Design field there is the Flat Slab command and the necessary sub commands for solving them.

First load and calculate the combinations and then select the command and start the following procedure :





Parameters	Flat Slab Design Pa	rameters		
~~~	Layer			
	Flat	Flat Slab		~
	Drop Panel	Drop Panel		~
	Support Line xx	Support Line x	x	~
	Support Line zz	Support Line z	Z	~
the dialog box you	define the correla	tion between	Layers.	
the dialog box you it Layers Current	define the correlat	tion between	Layers.	
the dialog box you it Layers Current New Flat Slab	define the correlat	tion between	Layers. × Levels XZ - Storeys Update	
the dialog box you t Layers Current Lines circle New Flat Slab Number imber Secondary Columns imber Hor.Wind bracings	define the correlat	tion between	Levels XZ - Storeys Update Select All Deselect All	
the dialog box you it Layers Current Lines circle New Flat Slab Number Timber Secondary Columns Timber Hor.Wind bracings	define the correlat	tion between	Layers.	
the dialog box you it Layers Current Lines circle New Flat Slab Number imber Secondary Columns imber Hor.Wind bracings imber Vert.Wind bracings – lat Slab	define the correlat	tion between	Layers.	
the dialog box you it Layers Current Lines circle New Flat Slab Number Timber Secondary Columns Timber Hor.Wind bracings Timber Vert.Wind bracings	define the correlat	tion between	Layers.	
the dialog box you it Layers Current New Flat Slab Number imber Secondary Columns imber Hor.Wind bracings imber Vert.Wind bracings 	define the correlation s Visible Editable Col Q el Q el Q el Q el Q el Q el Q el Q e	tion between	Layers.	

 In "Flat Slab" layer transfer the outline of the slab (including external columns) and correspond it to the Layer "Flat".

Outline the slab using lines.

To transfer the contour lines of the layer "Lines circles" into the layer "Flat Slab",

- Frizz all Layers (Not Visible-Not Editable), except " Lines circles "
- Select the command Multiselect Edit (Basic)
- By Left-click select all contour lines
- Right click to complete.
- In the dialog box, in Draw, change layer to Layer "Flat Slab"



Member Properties	Element				Month	Joi Type
	Element	Releases	Element Rig	id Offsets	Draw	Histor
<ul> <li>From Layer</li> <li>To Layer</li> <li>From Color</li> <li>To Color</li> </ul>	Mathe Mathe Surfac Mesh Slabs Steel Steel Main I Purlin Girde Seco Hor.W VertV Timbe Timbe Timbe Timbe Timbe	matical Mov matical Mov e Elements 3D 2D 2D Columns Beams 8 8 9 9 4 4 4 4 4 7 4 4 9 7 8 9 9 9 9 9 1 1 4 9 1 9 1 9 1 9 1 9 1 9 1	iel fel fel s s s s v columns bracings			
			bracings			_
	Drop	ab Panel				

▲ For convenience, you can initially choose the Layer "Flat Slab", immediately after the selection of the command line or Polyline, so the contour lines will belong to the correct layer without need to transfer.

 Respectively, in "Drop Panel" layer transfer the Lines that define the area around the columns, where will increase the thickness of the slab locally.

The "Drop Panels" are inserted optionally around the columns of the slab relieving the fatigue from drilling.



 Same procedure to transfer, in "Support Lines xx" and "Support Lines zz" the Lines that define the Support Lines.

These are lines insert in both X and Z directions between successive points of the slab. Usually connect column's nodes and end on the outline of the slab.





# 5.2 Calculation of design strips

Calculation of design strips

According to Annex I of EC2 flat slab is divided into design strips. These are the areas that are automatically created by the program on both sides of the Support Line, according to Figure I.1 of EC2.

Select the command Calculation of design strips and the program automatically creates them.

Each Design Strip is divided into sections along its length perpendicular to the Support Line. In each section SCADA integrates the internal forces of finite surface elements intersect. By completing this occur the bending moment around the axis of the section. This intensive value used to calculate the armature in each section.

# 5.3 Display X, Z



Select to display the Design Strips in both directions.





Design Strips along the Z axis



## 5.4 Diagrams X, Z

## Diagrams X

Select Diagrams in both directions to see the corresponding diagrams.





## Comparison to the results of CSI Safe 2014

After drawing the same design strips in the Safe (only Column strips are defined (containing the width of the middle strips) to be compatible with the definition of SCADA Pro) we take the following Bending moment diagrams. The diagrams of the two software look identical.







Let's pay closer attention to the strips 14-15 along X axis (numbering of the strips is shown in a previous figure). Safe 2014 reports a maximum value of bending moment equal to 254,3348 kNm at the middle of span 14.



The corresponding value computed in SCADA Pro is equal to 245.990 kNm, that is a difference of about 3% in the values of the two software (the above value can be found in the folder scades_FlatSlab of the project, file L_14.txt).

## 5.5 Results



This command opens the Results file through the Report.

Each page concerns a Strip Line.

Initially described the characteristics of the Strip.

							Page : 1
	S	trip Calc	ulations				
Description	Value	Units	Code	Description	Value	Units	Code
Floor	1			Starting point	corner	column	9.4.1&2
# of strip	1			Drop panel	Y	es	
Orientation	x-x			Thickness	182.88	(cm)	
Length	815.48	(cm)		Width		(cm)	
Concrete	C20/25			Finishing point	interna	column	9.4.1&2
fek	20	(MPa)	Table 3.1	Drop panel	Y	es	
Em	2.20	(MPa)	Table 3.1	Thickness	182.88	(cm)	
Steel	S400s			Width		(cm)	
f _{vk}	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 displayed the reinforcement results above and below in detail for each zone, dividing them into sub-zones.

- Left-Right -> red zone
- L-C R-C-> blu zone
- Center-> light blue zone





			Analysis	forcement				Тор		
		203.8	7 cm (Lstart)	407.74 cm (Lcentre)						
Zone	M (kNm)	Width (cm)	A _{s.rqd} (cm ² /m)	A _{e,prvd} (cm²/m)	Φ/s	M (kNm)	Width (cm)	A _{s.rqd} (cm ² /m)	A _{a.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
		203.8	7 cm (L _{end} )			ן				
Zone	M (kNm)	Width (cm)	A _{s.rqd} (cm ² /m)	A _{e.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	J				
			Analysis I	Results ar	nd Reint	forcement			Bot	tom
		203.8	7 cm (L _{start} )				407.74	cm (L _{centre} )		
Zone	M (kNm)	Width (cm)	A _{srqd} (cm ² /m)	A _{s.prvd} (cm ² /m)	Φ/s	M (kNm)	Width (cm)	A _{srqd} (cm²/m)	A _{s.grvd} (cm ² /m)	Ф/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
		203.8	7 cm (L _{end} )			]				
Zone	M (kNm)	Width (cm)	A _{s.rqd} (cm ² /m)	A _{e,prvd} (cm²/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. Punching shear checks



Added in the new version also the punching checks by EC2. The check is part of the check and design process of the flat slabs which runs automatically, but can also run as an individual check for any column. All data can be set automatically or even manually.

## 6.1 By Pick



Select By Pick command with the left mouse button show the node of a column and right-click to open the dialog box where you specify all the necessary parameters.

1 In this example we select the node of an Internal column, node 40.

Here are explanations for the other positions of the columns on the perimeter of the slab:

Basic Modeling Vie	w Tools Slabs Loads Analysis Post-Processor Members Design Drawings-Detailing Addons St	tyle - 🔒 🎛 - 🕕
🛴 EC2-EG3 1 (0) 🔹 ᡀ	💉 3 🗄 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
New Active Scenario Para- meters	Continuity Check- Results Node Design Buckling Check- Results Check Results Slab Strip Flat Results Steel Timber Masonny 2D of Beams * Reinforcement* * Reinforcement* * Reinforcement* * Reinforcement* * Design > Design	
Scenarios	Beams Capacity Design Columns Footings Slabs - Mesh Steel - Timber	
	2 / K L O O A X L / X X 🖓 🖓 🎟 🏛 🔯 X a 🛛 2   🔍 🔍 🤍 🔍 🖉 A 🖾 O A 🖾 O	
Project Data 🛛 🔍 🗡	The second s	0 ×
¥a - 🔉		
	Layer	Drop Panel
	Color	8
<u>k</u> 12 -0.00 -C	🕒 Start point	723.90, 300.00, 66
<u>k</u> 13 -0.00 -C		723.90
		300.00
<u>-</u> 15 -0.00 -C		662.94
	Punching Shear Check E	723.90, 300.00, 48
17 -0.00 -C		723.90
19 -0.00 -C	Control node Combinations	300.00
20 -0.00 -C	40 Combinations • ΔN(ht) 626.50 ΔMy(htm) 34.283 ΔM2(htm) 76.143	480.06
	Distributed Load (BV/m2)	
<u>k</u> 22 -0.00 -C		
<u>k</u> 23 -0.00 -C	Materias (Mira)	
🛓 24 -0.00 -C	Automatic v tok 20 tyk 400 Flat Slab v +	
<u>4</u> · 25 -0.00 -C	Loaded surface	
26 -0.00 -0		
27 0.00 -C		
29 -0.00 -0	Slab's elements Steel Reinforcements	
	Thidra Automatic v t(cm) 40.64 Automatic v External X v	
<u>4</u> 32 -0.00 -C	Abov © 10 / 15 © 10 / 15	
🛓 33 -300.00	bottom(cn 2 Below © 10 / 15 © 10 / 15	
	Coefficient B Reinforcement	
30 -300.00	Automatic approx V Type Radal V OK	
38 -300.00	Results	
39 -300.00	p 1.13 quartie Peletion of the Report Cancel	
40 -300.00		
< >		
🙀 Project 🚳 Project 🕢	III F	
Select node	WCS 814.3 , 571.1 , 300.0 ORTHO OSNAP SNAP GRID CROSSING INSIDE	



Punching Shear Check
Control node Combinations
40 Combinations    ΔN(dN) 626.50 ΔMy(dNm) 34.283 ΔMz(dNm) 76.143
Distributed Load. (dN/m2) 0
Materials (MPa) Outlines of floors
Automatic V IV Flat Slab
Loaded surface     Position of loaded surface       Automatic     c1(cm)     46     c2(cm)     46.00
Slab's elements Steel Reinforcements Thickne Automatic V 40.64 Automatic V External X V
Cover         Automatic         upper (m 2 bottom (or 2         X         Y         Abov         0         10         /         15           Below         0         0         /         15         0         0         /         15
Coefficient β Reinforcement
Automatic approx  Type Radial  Calculation OK
β 1.15 Number of radii per 4 Delation of the Perpert Cancel
Control node Automatically fill in with the number of the selected node and is not editable.
Combinations
Combinations   ΔN(kN) 626.50; ΔMy(kNm) 34.283; ΔMz(kNm) 76.143;
Distributed Load. (kN/m2) 0
In Combinations field:
- Choosing Combinations, the program finds automatically the combination that gives the
worst Axial resulting displaying AN value the with the corresponding moments
- Choosing User enables the user values for axial and moments in their respective fields
and the definition of a Distributed Load
Distributed Load (kN/m2) 50
that works "relieving" the slab at that point, so the shear
calculation be impaired relative to the original.
Shear force (V _{Ed/nt} ) 626.5 (kN)
Distributed load (p) 50.0 (kN/m ⁻ ) Reduced shear force (/) 478.8 (kN)
(KIV)
In this example we consider a single combination 1 20G + 1 600 and therefore the values of
the internal forces resulting from that place.
Materials (MPa) In the field Material coefficients fck and
Automatic K 20 fyk 400 fyk filled automatically with the
Automatic option or defined by the user
User with the User option.



Outlines of floors	In Outlines of Floors, choose the Layer containing the contour
Flat Slab	of the slab including the columns located in the outline.
Mathematical Model	Then select the layer Flat Slab that includes exactly the lines that
Surface Elements	define the event learning of the sleb
Moch 2D	define the overall contour of the slab.
Mech 2D	
Slabe-String	
Slabs-Surips	
Steel Columns	
Steel Columns	
Main Boams	
Main beams	
Furins	
Graenders Columns	
Secondary Columns	
Hor. Wind bracings	
Vert.Wind bracings	
Timber Orleans	
Timber Columns	
Timber Beams	
Timber top main beams	
Timber Purlins	
Timber Greendam, Columna	
Timber Secondary Columns	
Timber Hor. Wind bracings	
Timber vert. wind bracings	
Elat Slah	
Drop Panel	
Support Line xx	
Support Line zz	
perigramma	
perigrammaOpis	
Loaded surface	
	As loaded surface is defined the equivalent surface
Automatic CI(Ch) 46	of the selected column.
Automatic	
Circular	Steel Rei
Choosing:	
- Automatic the program	calculates the surface of any column-shaped by reduction in the
	the the second second to a diversitie of a second
equivalent rectangular v	with the corresponding dimensions c1 and c2.
- Rectangular, the user	defines his dimensions c1 and c2 for calculating the loaded
rectangular surface	
Circular the user define	or his diameter of for calculating the loaded sireular surface
- Circular, the user define	is mis manneter of tor calculating the loaded circular sufface
Position of loaded surface	

- surface of any column-shaped by reduction in the sponding dimensions c1 and c2.
- mensions c1 and c2 for calculating the loaded
- c1 for calculating the loaded circular surface

Position of loa	ded surface
Automatic	ax 0 ay 0
Automatic	
Interior	
Side 1	
Side 2	xternal X 🗸
Side 3	·
Side 4	10 / 15
Salient 1	10 / 15
Salient 2	10 / 15
Salient 3	10 / 15
Salient 4	
Reentrant 1	
Reentrant 2	
Reentrant 3	ОК
Reentrant 4	

The Position of loaded surface may be determined either automatically or selectively. It depends on the contour of the slab and the position of the selected column in it.



The proposed positions are:

- Interior
  - Side: 4 directions
  - Salient: 4 directions
  - Reentrant: 4 directions

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











Selection External X or Y determines the direction of the outer reinforcement of the slab longitudinal reinforcement mesh (either for the up or down mesh).



Coefficient β Automatic appro: Υ Automatic approxima Automatic theoretical User The Coefficient  $\boldsymbol{\beta}$  for punching calculation, can be calculated automatically in two ways:

- Automatic approximation or
- Automatic theoretical.

1. The Approximation way is a function of the position of the loaded area and the ax, ay.

1. The Theoretical way is a function of the Moments My, Mz.

User selection allows the introduction of any value for the coefficient  $\beta$ .

Reinforcement								
Туре	Radial	l≪.						
	Radial	13						
Number o	Cruciform							
quartile								

Finally, in Reinforcement set the layout type of punching reinforcement choosing between Radial and Cruciform. For the Radial layout set the number of radii per quartile.

In the figure below the black box contains one quartile of the radial layout. The first perimeter has three radii of reinforcement, while there is an increase on the 3rd perimeter to 5 radii due to distance limitations set by the code. SCADA Pro automatically checks whether the distance limitations are satisfied on the first perimeter, and increases the number of radii when needed (even when the user's choice is not enough for the first perimeter).





Calculation The Calculation command performs all the necessary checks to punch, taking into account all the above parameters.

Results 😺 This command displays the results file:											
Input Data											
Description	Value	Units	Description	Value	Units						
Level - Storey	1		Eccntr. factor (	1.150							
# ofnode	40		Slab depth	40.6	(cm)						
Combination	1		Cover of reinforcement	2.0	(cm)						
Shear force (V _{Ed,Init.} )	626.5	(kN)	Reaction (autor laure)	10	()						
Distributed load (p)	0.0	(kN/m ² )	Bar size (outer layer)	10	(iiiii)						
Reduced shear force (VEd,fn.)	626.5	(kN)	Spacing of bars (outer layer)	15.0	(cm)						
Bending moment (M _x )	34.3	(kNm)	Reading (as a set laws)	10	()						
Bending moment (M _r )	76.1	(kNm)	Bar size (second layer)	10	(mm)						
Shape of loaded area	Rectangular		Spacing of bars (second	15.0	()						
c length (along x axis)	46.0	(cm)	layer)	15.0	(cm)						
c ₂ length (along y axis)	46.0	(cm)	Concrete (fex)	20.0	(MPa)						
c diameter		(cm)	Steel (f _{yk} )	400.0	(MPa)						
Position of loaded area	Interior		Reinforcement pattern	Radial							
Dist. of slab perim. along x (a _x )		(cm)	# of radii of reinforcement in a	2							
Dist. of slab perim. along y (ay)		(cm)	quadrant (circular pattern)	2							

**Input Data**: list of all elements identified in the previous window and required to punching check.

**Punching Reinforcement Layout**: according to predetermined parameters and if, there is reinforcement requirement.

In this example there is no requirement to punching reinforcement, so there is no reinforcement schematic arrangement (a random radial layout with two perimeters is also included just for observation).





#### In Check results there are two different checks:

							Page : 2					
	Check results											
Description	Value	Units	EC2	Description	Value	Units	EC2					
Effective depth of slab (d)	37.6	(cm)	(eq6.32)	Basic control perimeter	657.0	(cm)	(fig6.15)					
area (u ₀ )	184.0	(cm)	(eq6.53)	Design value of the	0.291	(MPa)	(eq6.38)					
Design value of the shear stress at u ₀ (v _{Ed,0} )	1.040	(MPa)	(eq6.38)	Punch. shear resistance			· · · ·					
Maximum punching shear resistance (V _{Rd,max} )	3.680	(MPa)	(eq6.53)	without shear reinforcement (v _{Rd.c} )	0.356	(MPa)	(eq6.47)					
				Constant (vmin)	0.356	(MPa)	(eq6.3)					
$1^{\text{st}}$ check: $v_{\text{Ed,0}} \leq v_{\text{Rd,max}}$	Sufficie	ency		$2^{nd}$ check: $v_{Ed,1} \leq v_{Rd,c}$	No reinforcement is required		is					
							Page : 2					
			Check re	sults								
Description	Value	Units	EC2	Description	Value	Units	EC2					
Effective depth of slab (d)	37.6	(cm)	(eq6.32)	Basic control perimeter	657.0	(cm)	(fig6.15)					
area (u _o )	184.0	(cm)	(eq6.53)	Design value of the	0 744	(MPa)	(eq6.38)					
Design value of the shear stress at u ₀ (v _{Ed0} )	2.657	(MPa)	(eq6.38)	Punch. shear resistance		( 4)	(040.00)					
Maximum punching shear resistance (VRd,max)	3.680	(MPa)	(eq6.53)	without shear reinforcement (v _{Rd,c} )	0.356	(MPa)	(eq6.47)					
				Constant (vmin)	0.356	(MPa)	(eq6.3)					
$1^{\text{st}}$ check: $v_{\text{Ed,0}} \leq v_{\text{Rd,max}}$	Sufficie	ency		$2^{nd}$ check: $v_{Ed,1} \leq v_{Rd,c}$	Reinforcement necess - add punching shear reinforcement - increase slab longitu reinforcement		cessary: ear ngitudinal					

If the 1st check presents *Sufficiency*, then the 2nd check specifies the requirement or not of punching reinforcement.

							Page : 2				
	Check results										
Description	Value	Units	EC2	Description	Value	Units	EC2				
Effective depth of slab (d)	37.6	(cm)	(eq6.32)	Basic control perimeter	657.0	(cm)	(fig6 15)				
Perimeter of the loaded	184.0	(cm)	(606 53)	(u1)	037.0	(ciii)	(1190.13)				
area (u _o )	104.0	(ciii)	(eq0.55)	Design value of the	1 860	(MPa)	(eq6 38)				
Design value of the shear	6 642	(MPa)	(eg6 38)	shear stress at u ₁ (v _{Ed,1} )	1.000	(ivii u)	(040.00)				
stress at u ₀ (v _{Ed,0} )	0.042	(ivii a)	(eq0.50)	Punch. shear resistance							
Maximum punching shear resistance (v _{Rd,max} )	3.680	(MPa)	(eq6.53)	reinforcement (V _{Rd,c} )	0.356	(MPa)	(eq6.47)				
	Insuffic	ient.		Constant (vmin)	0.356	(MPa)	(eq6.3)				
$1^{st}$ check: $v_{Ed,0} \leq v_{Rd,max}$	- increa area - increa - use o guality	ise size o ise slab o f concrete	f the loaded lepth e of a higher	2 nd check: v _{Ea.1} ≤ v _{Ra,c}							

If the 1st check presents *Insufficiency*, then the 2nd check is not performed and some interventions are proposed for the slab.

As mentioned before, in this example (node 40 shown in the figure below), the level of loading in not as high as to need punching shear reinforcement. In other words, the 2nd check is sufficient too.







Safe 2014 also provides with a capacity ratio for the columns (figure below). For the current case the capacity ratio computed is 0.783 (difference between software of about 4%). Let's consider the column situated two places below along Z (node 38). Safe calculates a capacity ratio equal to 1.071 (see figure below).



SCADA also computes a capacity ration above 1.0 (equal to 0.394/0.356 = 1.11) meaning that punching shear reinforcement is needed. The results are presented below:



					Page :
		Input	Data		
Description	Value	Units	Description	Value	Units
Level - Storey	1		Econtr. factor (B) (EC2-6.4.3)	1 150	
# of node	38		Slab depth	40.6	(cm)
Combination	1		Cover of reinforcement	2.0	(cm)
Shear force (Vectorit)	846.7	(kN)			
Distributed load (p)	0.0	(kN/m ² )	Bar size (outer layer)	10	(mm)
Reduced shear force (V _{Edfin} )	846.7	(kN)	Spacing of bars (outer layer)	15.0	(cm)
Bending moment (M _x )	-32.7	(kNm)	Develop (considered)	40	(
Bending moment (My)	104.4	(kNm)	Bar size (second layer)	10	(mm)
Shape of loaded area	Rectangular		Spacing of bars (second	45.0	
1 length (along x axis)	46.0	(cm)	layer)	15.0	(cm)
2 length (along y axis)	46.0	(cm)	Concrete (f _{ck} )	20.0	(MPa
c diameter		(cm)	Steel (f,k)	400.0	(MPa
Position of loaded area	Interior		Reinforcement pattern	Radial	
Dist. of slab perim. along $x (a_x)$		(cm)	# of radii of reinforcement in a	2	
Dist. of slab perim. along y (a,)		(cm)	quadrant (circular pattern)	2	
		<u> </u>	$\mathbf{b}$		
		<b>\</b>	7 /		

The first page of the results shows the input data as well as the reinforcement layout. The choice here was radial arrangement with two radii per quartile.



												Page : 2			
						С	heck re	sults							
Descript	ion		alue	Un	its		=C2	Descripti	on	Value	Units	EC2			
Effective	depth of slai	b (d)	37.6	(cm) (eq6.32)		Basic con	trol perimeter	657.0	(cm)	(fig6.15)					
Perimete area (u ₀ )	r of the load	ed 1	84.0	(CI	m)	(ed	q6.53)	Design va	lue of the	0.394	(MPa)	(6.06.38)			
Design v stress at	alue of the s u _o (v _{ed.o} )	hear 1	.406	(MI	Pa)	(e	q6.38)	shear stre Punch. sh	ss at u ₁ (v _{ed,1} ) ear resistance	0.004	(ivir a)	(640.00)			
Maximun resistanc	n punching s e (v _{Rdmax} )	hear 3	.680	(M	Pa)	(ex	q6.53)	without sh reinforcem	iear ient (v _{Rd,c} )	0.356	(MPa)	(eq6.47)			
$1^{\text{d}}$ check: $v_{\text{Ed,0}} \leq v_{\text{Rd,max}}$ Si			ufficiency			Constant $(v_{min})$ $2^{nd}$ check: $v_{Ed,1} \leq v_{Rd,c}$		0.356 (MPa) (e Reinforcement necess - add punching shear reinforcement - increase slab longitu reinforcement		(eq6.3) cessary: lear ngitudinal					
						De	tailing r	esults							
Descript	ion		Valu	ue	Uni	its	EC2	Περιγραφ	ń	Tiuń	Μονάδες	EC2			
Perimete	f United		727	7.0	(cn	n)	(eq6.54)	Distance (	(d ₁ )		(cm)				
(a) - Dist	ance of 1 st n	erimeter					(- 1 )	Distance (	(d_)		(cm)				
of reinfor loaded a	cement from	the	18	.8	(cn	n)		Angle (φ)		90.0	•				
Limit: 0.3·d ≤ a	i ≤ 0.5 d		11.3<=a<=18.8		=a<=18.8 (9.4.3) (starce between link legs on the last 9		(s _{tlæt} ) - Tangential distance between link legs on the last		(s _{tiæt} ) - Tangential distance between link legs on the last		(s _{tlæt} ) - Tangential distance between link legs on the last		91.8	(cm)	
(f) - Dista perimete from une	ance of last r of reinforce	ment	56.	.6	(cn	n)		perimeter		75.3	(cm)				
Limit: k·c	i= 1.5·d		56	.5	(cn	n)	(6.4.5)	(f ) Effective		15.5	(cm)				
(s _r ) - Rad	dial distance	of the	28	.0	(cn	n)		design str punching	ength of shear reinf.	344.1	(MPa)	(000 52)			
Limit: 0.7	'5∙d		28	.2	(cn	n)	(9.4.3)	(A _{ew,1} ) - N	ecessary	1.532	(cm ² )	(640.02)			
(s _{t1} ) - Ta between perimete	ngential dist link legs on r	ance the u ₁	91.	.8	(cn	n)		(A _{sw,min} ) - Minimum area of a link leg		1.532	(cm ² )	(eq9.11)			
Limit: 1.5	d		56	.5	(cn	n)	(9.4.3)	Diameter	of link leg	14	(mm)				
Distance Distance	(p) (d ₁ )		18	.1 9	(cn	n)		chosen Area of lin	k lea		()				
Distance	(d ₂ )		9.	9	(cn	n)		chosen		1.539	(cm ² )				
			Gro	oupi	ng o	fpur	nching s	hear reinf	orcement						
Group	Number of lines	Ф (mm)	N	luml leg:	ber of s on l	f link line	He	hight of Perimeter wh nk leg 1 st link leg (cm)		ere the Distance of the link leg		of the 1 st rom the area			
1	8	14			2			36.6	1		18.	32			
2	4	14			1			36.6	2		46.	32			
							1								

The second page shows the two checks as well as the detailing results.

Legs  $\Phi$ 14 are computed (diameter of 14 mm) while in the table at the bottom of the page, the reinforcement is presented into groups of lines of reinforcement, with a certain number of link legs on line (this is a useful way of presentation in case a prefabricated system of reinforcement is chosen – stud-rail punching shear reinforcement).

In this case 8 lines with two link legs and four lines with one link leg are chosen. The two successive link legs in the eight lines are at a distance  $s_r$  (28 cm as the table shows).



The 3rd page shows the Legend containing characteristics in accordance with the position of the Loaded Surface.





The smaller link leg may be proposed if the user chooses for more radii per quartile. For example, when five radii are chosen then the arrangement besides is proposed, and the table of reinforcement shows one group of lines containing 2  $\Phi$ 8 link legs each, at a distance 28 cm.

	Grouping of punching shear reinforcement													
Group	Number of lines	Φ (mm)	Number of link legs on line	Height of link leg (cm)	Perimeter where the 1 st link leg of the line stands	Distance of the 1 ^{et} link leg from the loaded area								
1	20	8	2	36.6	1	18.82								

For the same column, when the user decides to raise the load level and chooses a  $\Delta N = 1400$  kN (user value), then the radial arrangement with three radii per quartile gives  $\Phi 16$  link legs (84 link legs).



