Reinforced concrete check in Paratie Plus

Consider the following example concerning a rectangular diaphragm:

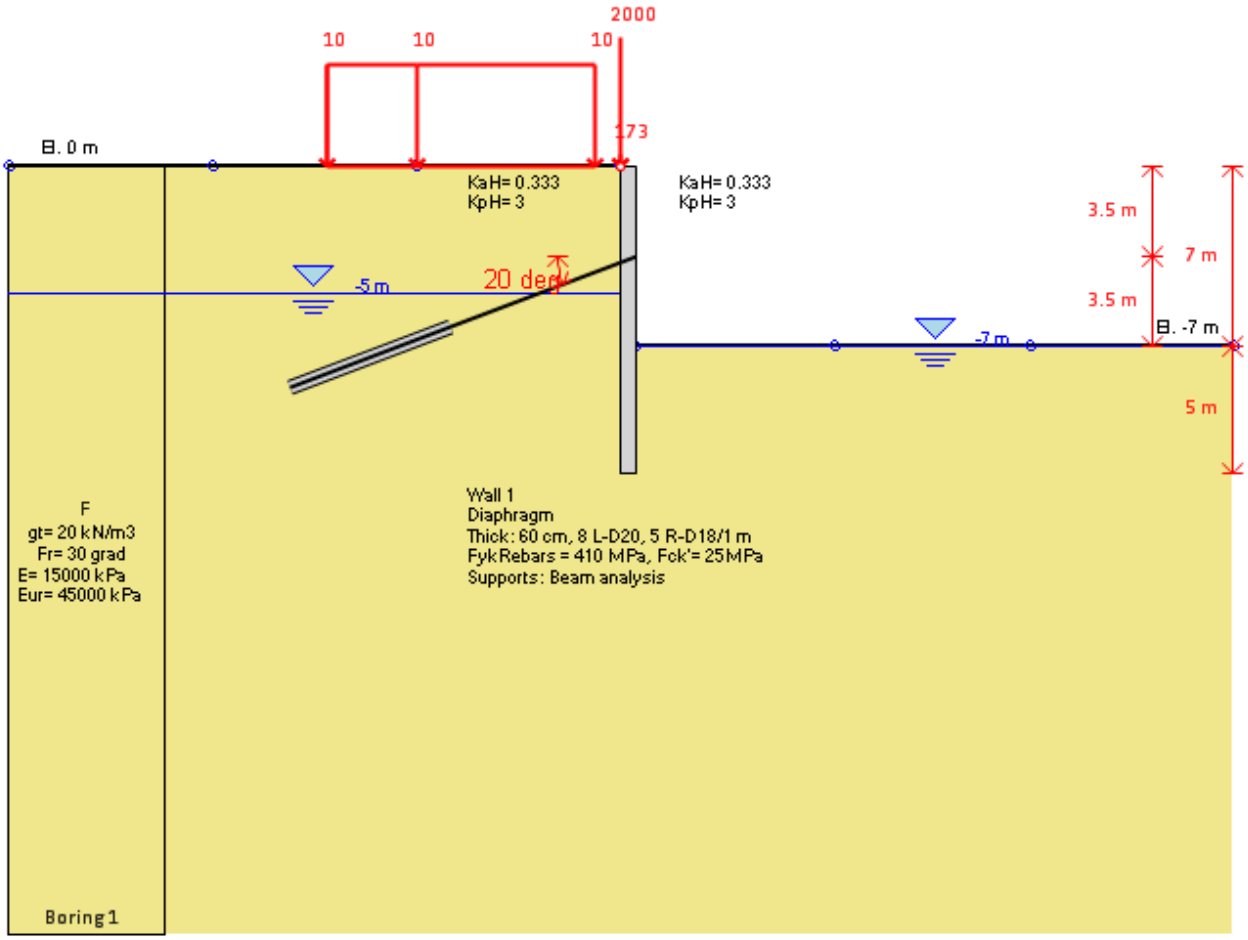
Thickness: 0,6 m

Conc: C25/30

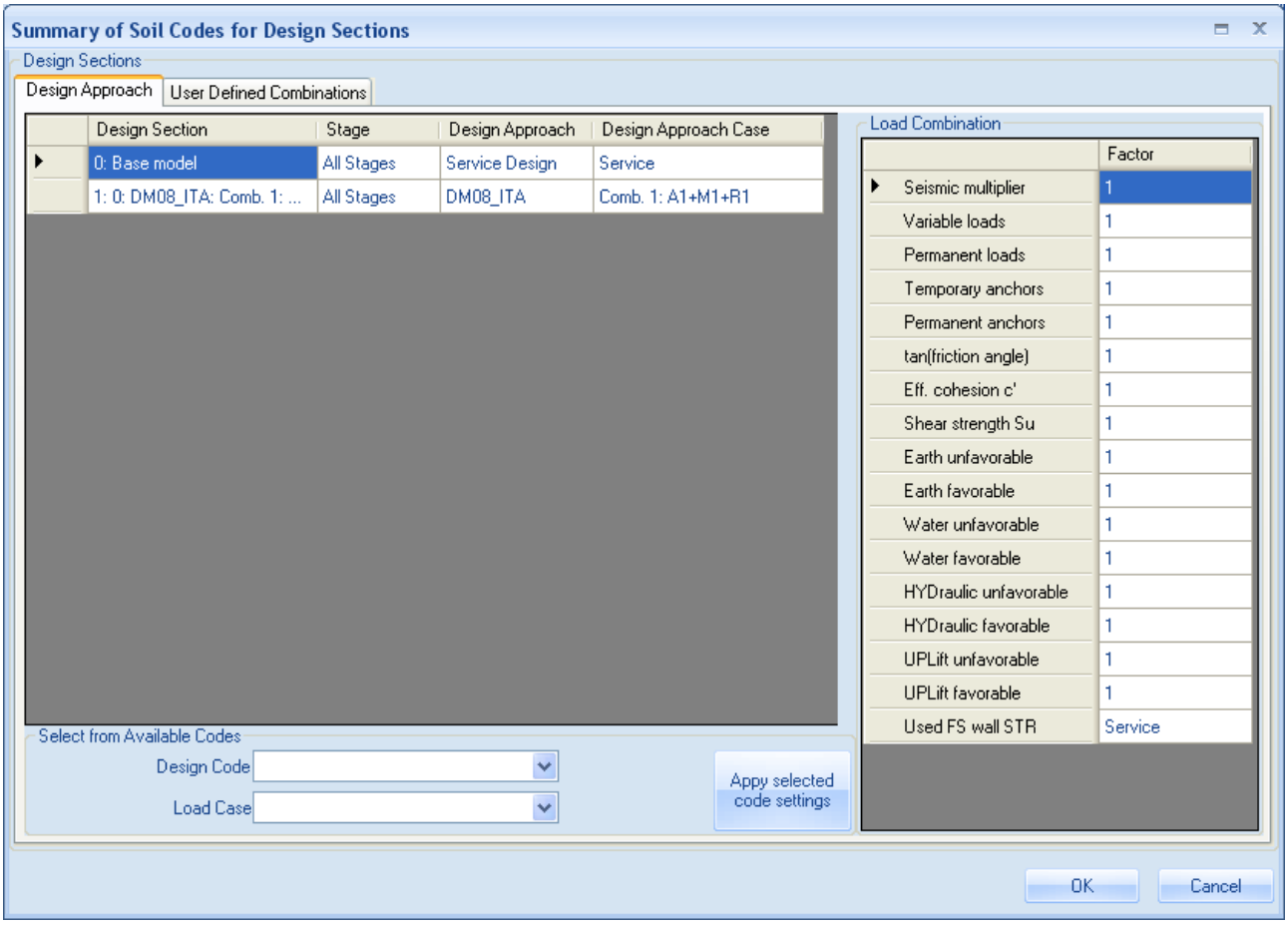
Reinforcement bars: B450C

Longitudinal reinforcement: 6 PHI 16 + 6 PHI 18.

Shear reinforcement: PHI 10 / 20 cm.



This document concerns the file *diaframma.deep* in which two design approaches have been considered: a base model SLS and the approach A1 + M1 + R1 prescribed by DM2008 ULS.



1. *SLS (Base model):*

- *Steel and concrete stress check*

The external file *0-WL0.cou*, that can be found in the folder Documents\ DeepXcavTemporaryFiles\ Concrete (where the first number refers to the design approach).

SLS checks are made for a rare combination (Par. 4.1.2.2.5.1 DM2008) and are made for every design approach defines as SLS. BASE MODEL DEFAULT SETTING IS SLS.

Sigma_c $\leq$ 0,6 fck

Sigma_s ≤ 0,8 fyk

In the analysis summary results in terms of stress ratio can be found:

FIC (concrete stress ratio) = Sigma_c_{max} / 0,6 fck

FIS (steel stress ratio) = Sigma_s_{max} / 0,8 fyk

In the extended summary for the base model the values of these ratio for each excavation can be found:

Extended vs Stage

	TR pment all atio	STR Shear Wall Ratio	Concrete Service Stress Wall Ratio FIC	Reinforcement Service Stress Ratio FIS	Max Support Reaction (kN/m)	Max Support Reaction (kN)	Critical Support Check	STR Support Ratio	Support Geotech Capacity Ratio (pull
Stage 0		0	0.02	0.005	0	0	0	N/A	N/A
Stage 1	22	0.167	0.55	0.629	0	0	0	N/A	N/A
Stage 2	97	0.28	0.445	0.446	166.7	500.1	4.093	0.552	4.093
Stage 3	97	0.362	0.599	0.576	191.05	573.15	4.691	0.633	4.691
Stage 4	86	0.362	0.473	0.114	191.05	573.15	4.691	0.633	4.691

The same values can be found in the output file called *0-WL0.cou* (thet is automatically created in the folder Documents\ DeepXcavTemporaryFiles\ Concrete when the analysis is over). In this file FIC and FIS values are reported for every wall section an for every excavation step.

An extract is reported as an example:

EL	Gr	Sez	Lc	N1	M2	M3	FIC	FIS
1	0	1	1	-173.000	1.00000	0.0	0.02	0.01
1	0	2	1	-173.000	1.00000	0.0	0.02	0.01
2	0	1	1	-173.000	1.00000	0.0	0.02	0.01
2	0	2	1	-173.000	1.00000	0.0	0.02	0.01
3	0	1	1	-173.000	1.00000	0.0	0.02	0.01

……

3034	0	2	1	-238.381	1.00000	0.0	0.03	0.01
3035	0	1	1	-238.381	-214.420	0.0	0.59	0.57
3035	0	2	1	-238.381	1.00000	0.0	0.03	0.01
3036	0	1	1	-238.381	-216.910	0.0	0.60	0.58

Meaning of EL. :

First number (3): Step

Last numbers: (36): number of the node of the mesh.

- *Cracking*

Paratie Plus makes a cracking check for the rectangular concrete elements, for any approach that has been defined as SLS.

This check is made accoring to paragraph 4.1.2.2.4. of DM2008.

The user has to specify the ultimate cracks width (depending on the loads combination and on the exposure class) and choose whether to make a short term or long term check. The kind of check affects the Kp factor prescrbed by the code. The table 4.1.IV - DM2008 is reported:

Gruppi di esigenze	Condizioni ambientali	Combinazione di azioni	Armatura			
			Sensibile		Poco sensibile	
			Stato limite	w_d	Stato limite	w_d
a	Ordinarie	frequente	ap. fessure	$\leq w_2$	ap. fessure	$\leq w_3$
		quasi permanente	ap. fessure	$\leq w_1$	ap. fessure	$\leq w_2$
b	Aggressive	frequente	ap. fessure	$\leq w_1$	ap. fessure	$\leq w_2$
		quasi permanente	decompressione	-	ap. fessure	$\leq w_1$
c	Molto aggressive	frequente	formazione fessure	-	ap. fessure	$\leq w_1$
		quasi permanente	decompressione	-	ap. fessure	$\leq w_1$

w_1, w_2, w_3 sono definiti al § 4.1.2.2.4.1, il valore di calcolo w_d, è definito al § 4.1.2.2.4.6.

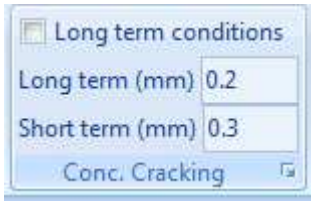
Requirement class	Environmental conditions	Actions combination	Reinforcement			
			Sensitive		Not very sensitive	
			L.S.	w_d	L.S.	w_d
a	standard	frequent	cracks width	$\leq w_2$	cracks width	$\leq w_3$
		almost permanent	cracks width	$\leq w_1$	cracks width	$\leq w_1$
b	aggressive	frequent	cracks width	$\leq w_1$	cracks width	$\leq w_1$
		almost permanent	decompression	/	cracks width	$\leq w_1$
c	very aggressive	frequent	cracks creation	/	cracks width	$\leq w_1$
		almost permanent	decompression	/	cracks width	$\leq w_1$

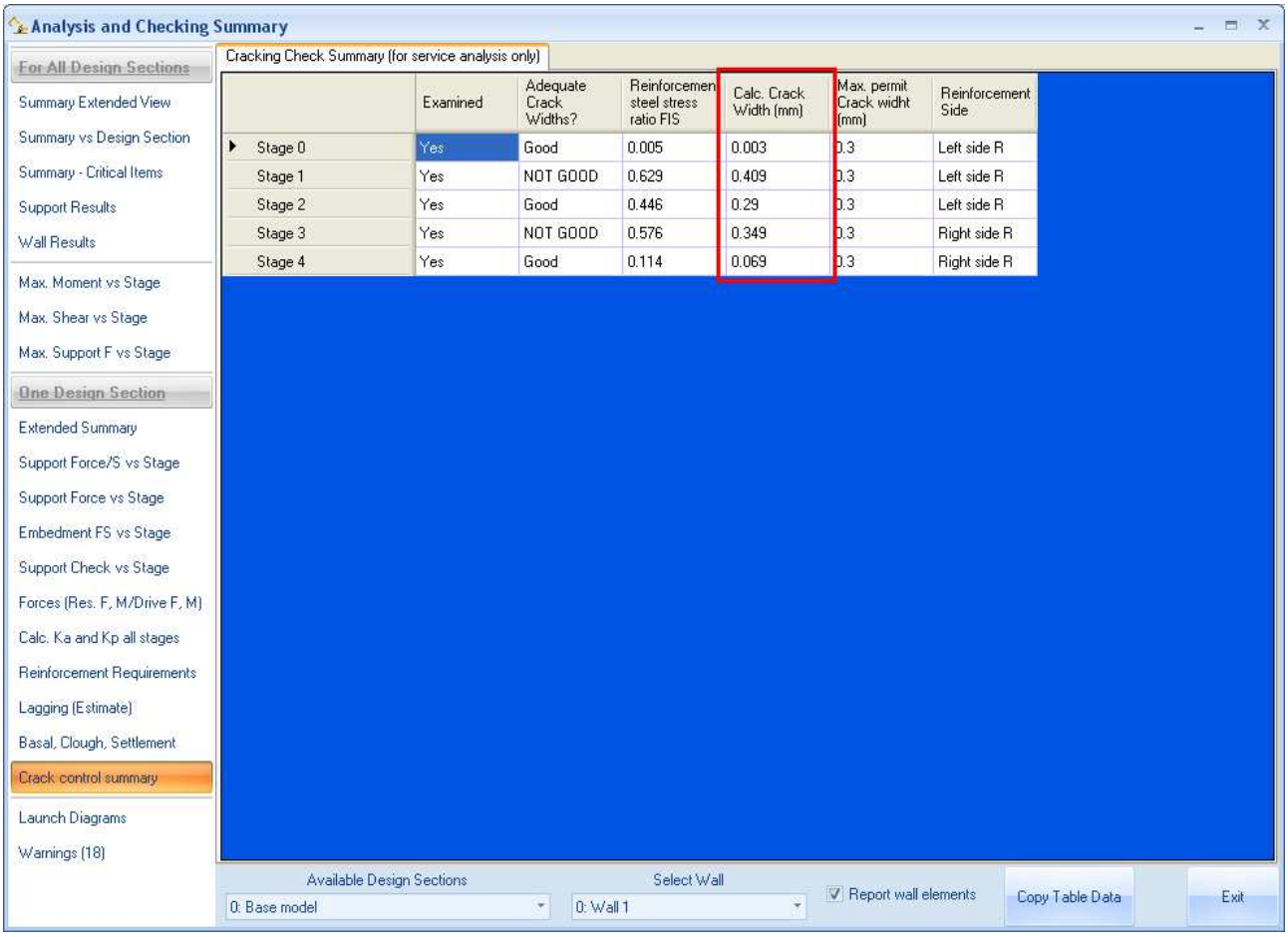
w_1, w_2, w_3 are defined in paragraph 4.1.2.2.4.1, w_d in paragraph 4.1.2.2.4.6

Cracks width value is calculated according to the paragraph C4.1.2.2.4.6 of the Circular issued on date 02/02/09.

In the extended summary results in terms of cracks width for each excavation step can be found.

In this case a short term check has been chosen and the ultimate cracks width selected is 0,3 mm.





The user can also refer to an external scratch file *0-WL0.CRACK* (in the folder Documents \ DeepXcavTemporaryFiles\ Concrete) where the chief steps of check and the coefficients (that define the ultimate crack width) values are reported.

The used formula is

$wd = 1{,}7\ wm = \varepsilon m * \Delta smax$

- εm is the average unit buckling of the reinforcement bars.
- $\Delta smax$ is the maximum distance between cracks .

Here it is an extract concerning stage 3:

* Examine Cracking for Wall 0 stage 3

-Section width Bc = 1 m.

-Section Effect depth .d = 0.53 m.

-Section height h = 0.6 m.

-Cover to center of bars c = 0.07 m.

-Bar Diameter .PHI = 0.018 m.

-Area of Tensile Steel .Astl =0.001527 m^2.

-. fcm = fck+8(MPa) = 33 MPa?

-. fctm = 0.30*fck^(2/3)= 2.56496392001505 MPa.(fck<=C50/60)

-. fct.eff = fctm (by 28 days).

-. Sigma_s = 207.72 MPa.

-. Ac.eff = 2.5*Bc*(h-d) =0.175m^2.

-. Rho_p.eff= As/Ac.eff = 0.00872571428571429

-. Alpha_e = Es/Ecm = 6.67174990468929

-. kt = 0.6 (for short term loading.).

-. (Eps_sm-Eps_cm) = (Sigma_s-kt*fct.eff/Rho_p.eff*(1+Alpha_e*Rho_p.eff))/Es=

- = 0.000100378841376611

>= 0.6*Sigma_s/Es = 0.000593485714285714

- = 0.000593485714285714

-. Bond coefficient(k1) = 0.8

-. Strain distribution coefficient(k2) = 0.5

-. NAD Value (k3) = 3.4

-. NAD Value (k4) = 0.425

-. c = 0.07 m.

-. Phi = 0.018 m.

-. S_r.max = k3*c + k1*k2*k4*Phi/Rho_p.eff = 0.588687622789784 m.

-. wk = S_r.max * (Eps_sm-Eps_cm) = 0.349377694302554 mm.

wk > 0.3 mm. ---> N.G !

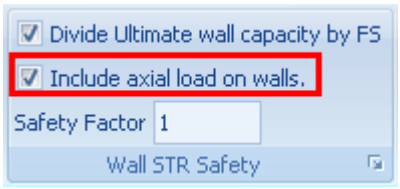
* End Cracking for Wall 0 stage 3

2. *ULS (Comb1 A1+M1+R1)*

- *Combined bending-compression check (resistance domain)*

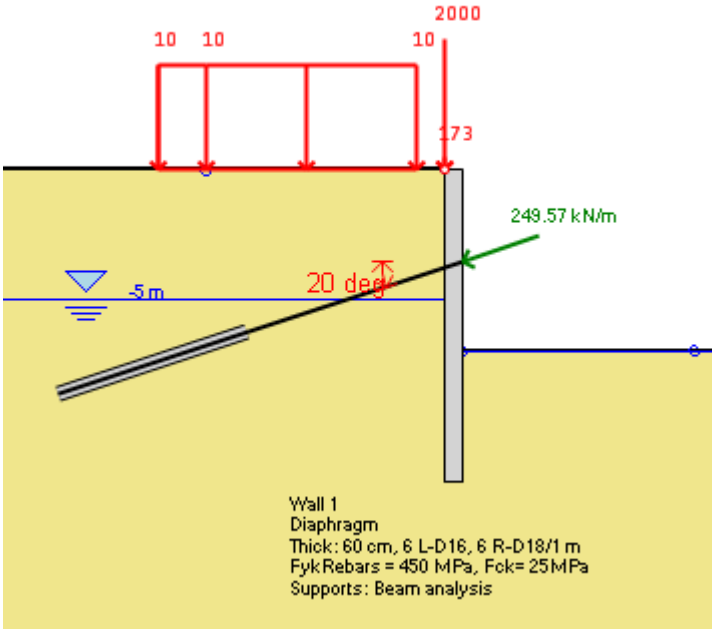
Paratie Plus makes a combined bending-compression check with resistance domain both if DM2008 and EC2 are used.

The user can choose whether to include axial load (under the Design menu)



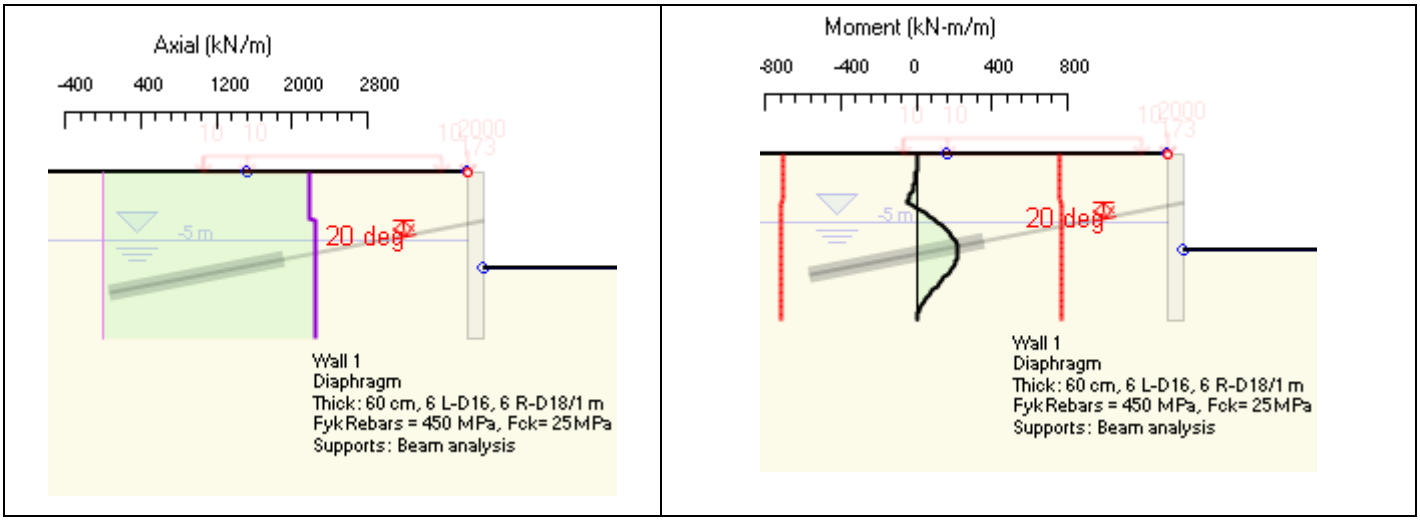
Wall weight is not considered: the user has to add it as external load.

Consider stage 4.



Ned = 2000 kN/m + 173 kN/m + 249.57 * cos (90-20) = 2258 kN/m

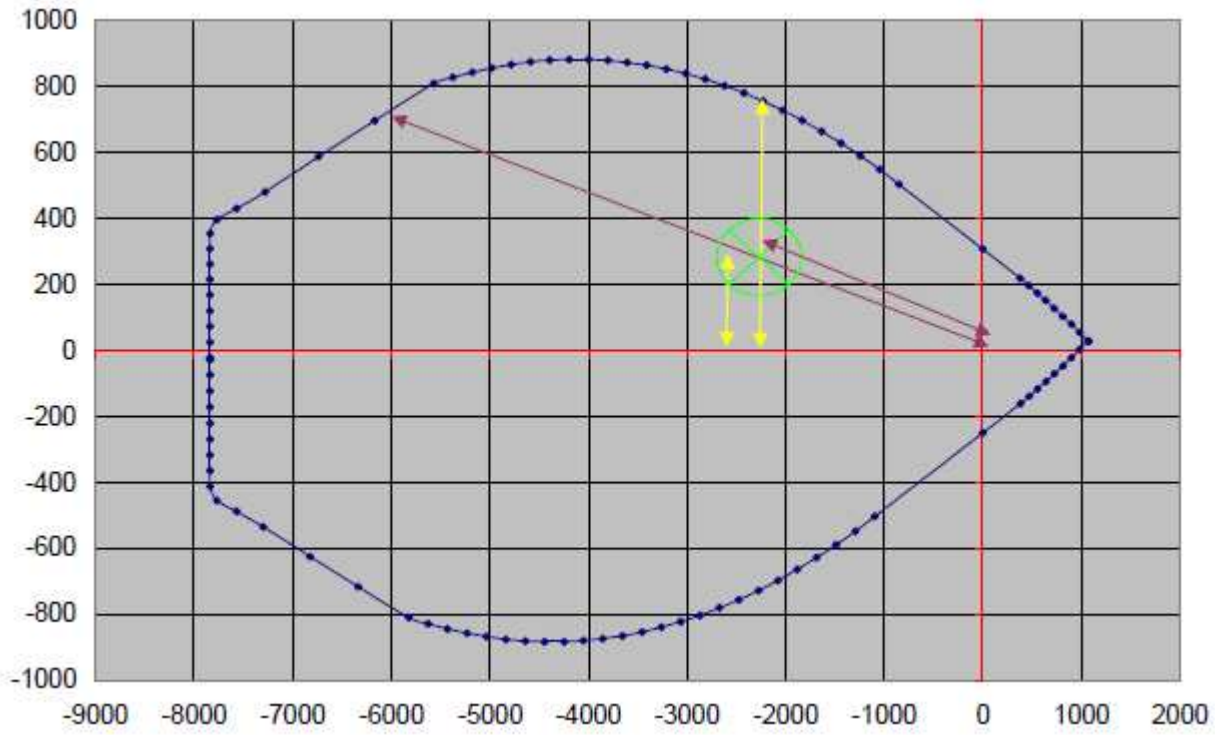
Med = 285.9 kN*m/m



The domain and the resistant check are so made up:

	DM2008	**EC2: 2005**
Mrd	Mrd = Mrd (Ned) ≥ Med	Mrd = Mrd (Ned) ≥ Med
Domain Cut – off	Paragraph 4.1.2.1.1.1 DM2008. The compression design resistance, using not prefabricated plane elements can be reduced to 8 fcd.	Minimum eccentricity: max (h/30; 20 mm).

Resistance domain according to DM2008



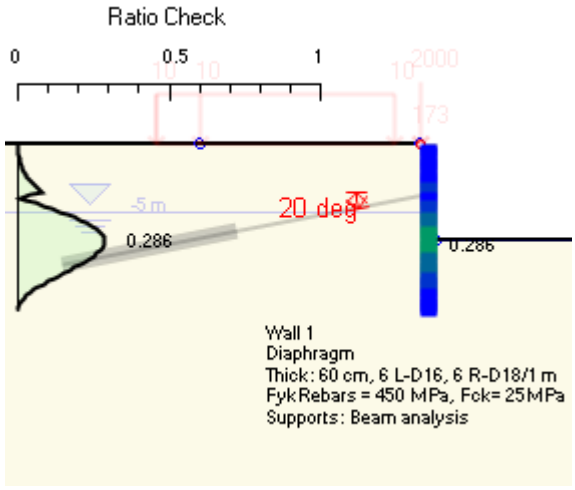
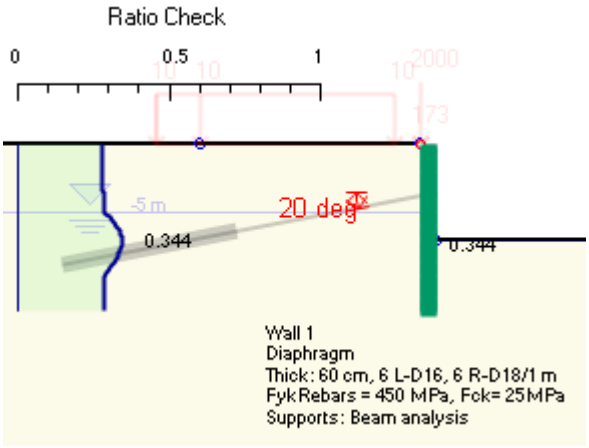
	Stress
	N = const. check
	e = const. check

The resistance domain is not given by the software but can be made up using Excel (cfr page 10)

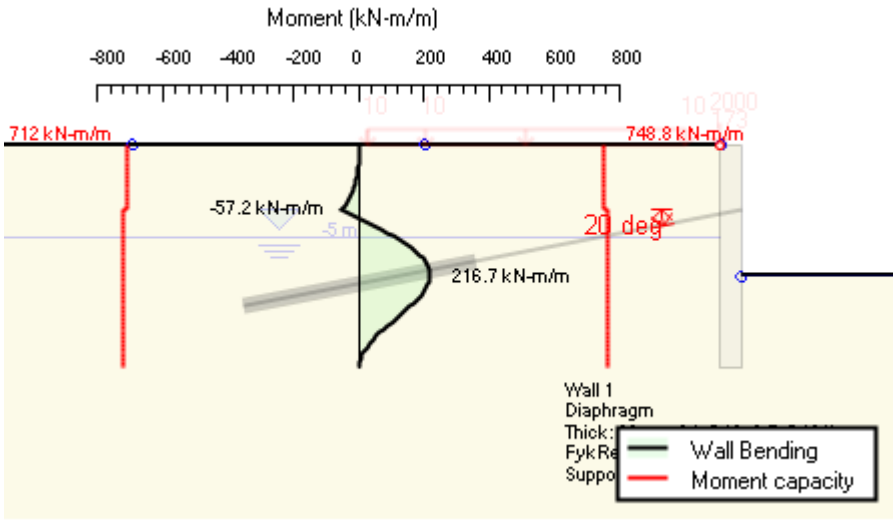
The Combined Ratio and Moment Ratio can be shown for each excavation step (here the values referring to stage 4) and are reported also in the summary of the analysis:

STR M. (stage 4) = N = const. check = 0.384

COMB. (stage 4) = max (STR (N=const) ; STR (e = const)) = 0.398

STR.MN	COMB
	

Resistant moments in stage 4:



The external file *0-WL0.cou* in the folder Documents \ DeepXcavTemporaryFiles\ Concrete (where the first number is referred to the design approach) can be consulted.

In the file .cou values of 100 points that make up the resistance domain can be found.

According to the code selected under the Design menu a resistance domain in keeping with the code prescriptions is created; both the domains (according to DM2008 and EC2) show a Cut – off in the highest compression zone. It is created according to the prescriptions shown in the table in page 8.

An extract of the file .cou is reported:

```
 *** P O S T P R O C E S S O R   C. A. VER. ***
 ================================================

                    Rev.  8.3  6-09
                    Ce.A.S. s.r.l.
                    Centro di Analisi Strutturale
                    V.le Giustiniano 10
                    20129 M I L A N O

** Dominio di interazione M-N sezione W0     -X **

 del   200311  103338   normativa NTC


 Dati sezione da archivio sezioni 1-WL0.cse

 R'bk  =       30.120
 Rak   =      450.000
 Es    =   206000.000
 legge sig/eps calcestr: stress-block
 b1    =       23.000
```

b2 = 23.000

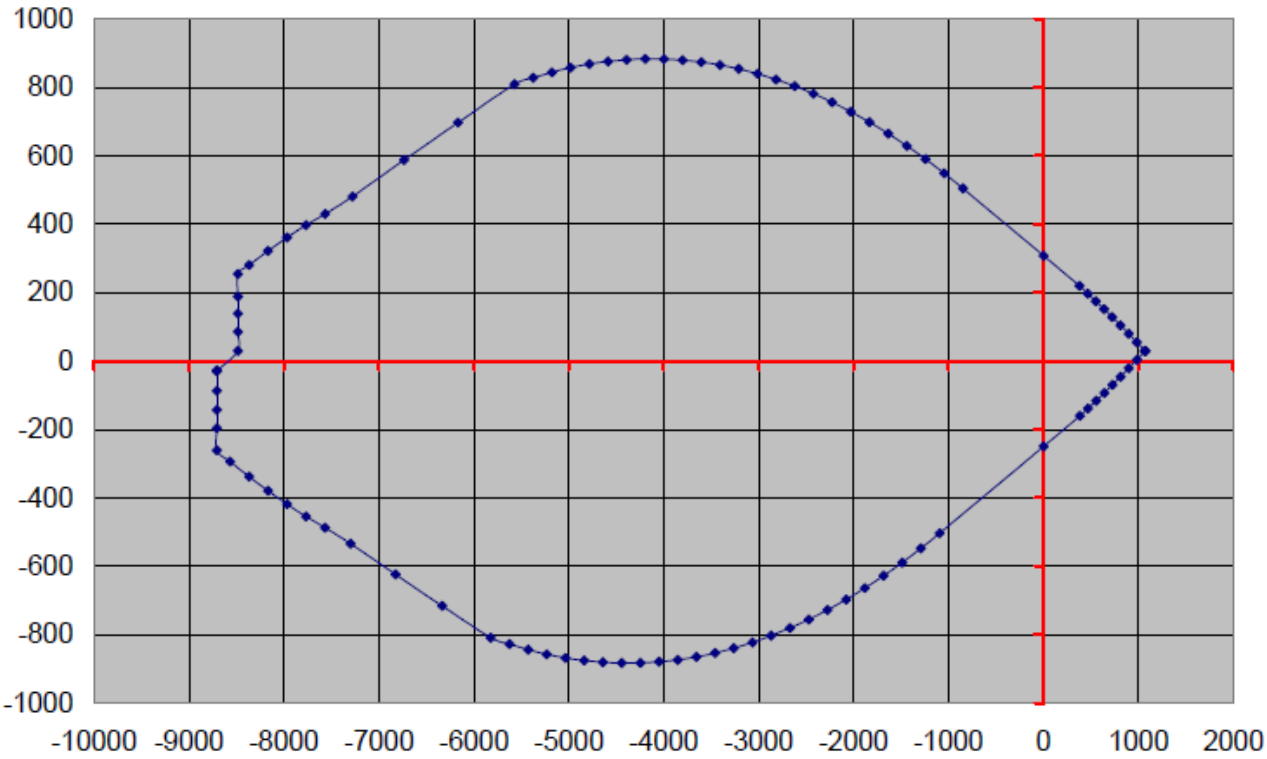
w = 100.000

h = 60.000

p	N	M	ecc.
1	-7838.531	-28.840	0.004
2	-7838.531	-23.623	0.003
3	-7838.531	24.932	-0.003
4	-7838.531	73.188	-0.009
5	-7838.531	121.126	-0.015
6	-7838.531	168.726	-0.022
7	-7838.531	215.961	-0.028
8	-7838.531	262.806	-0.034
9	-7838.531	309.233	-0.039
10	-7838.531	355.210	-0.045

……

Resistance domain according to EC2:2004



This resistance domain cut-off is made up in a different way compared to DM08, in fact the minimum eccentricity is considered..

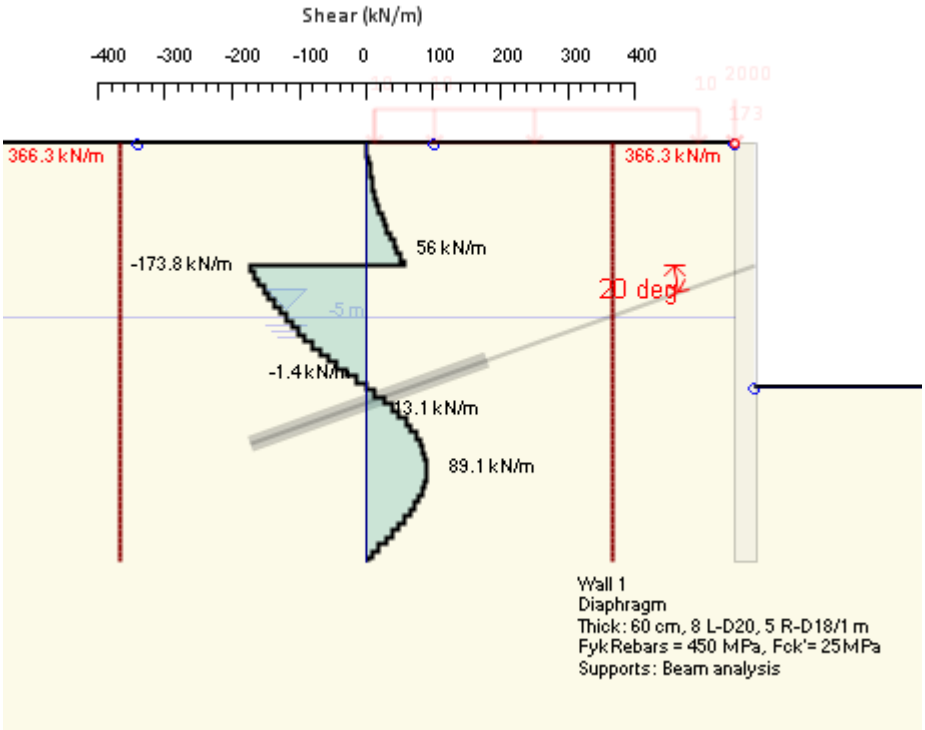
- *Diaphragm shear check*

DM2008 prescribes, referring to shear check:

1. Resistance for elements devoid of shear reinforcement (4.1.2.1.3.1) Vrdcc
2. Resistance for elements having shear reinforcement; it is the minumum between the design traction shear resistance Vrsd and the compression shear resistance Vrdc (4.1.2.1.3.2).

Paratie Plus gives as shear resistance this value:

Vrd = max { Vrdcc ; min (Vrsd, Vrdc) }



The file *0-WL0.rat* (in the folder Documents \ DeepXcavTemporaryFiles\ Concrete) reports the ultimate shear values listed above for each section and design approach.

Here it is an extract concerning section 19 (maximum shear section in step 4) for every directions. The interestin direction is the third.

ENAME 4019
ESECT 1W0 0.0000
RATIOVTC 1 0.000 0.898 0.000
SCAPACI1 1 174298.86 193488.59 0.0000000
SCAPACI2 1 2067492.2 1992303.4 0.47914358E+09
SCAPACI3 1 633548.50 366304.91 0.13523512E+09
RATIOVT 1 0.000 0.475 0.000
RATIO 1 0.100 9.00 15.00 0.00
ESECT 2W0 1.0000
RATIOVTC 1 0.000 0.290 0.000
SCAPACI1 1 174298.86 193488.59 0.0000000
SCAPACI2 1 2067492.2 1992303.4 0.51018243E+09
SCAPACI3 1 633548.50 366304.91 0.21800536E+09
RATIOVT 1 0.000 0.153 0.000
RATIO 1 0.266 9.00 15.00 0.00

SCAPACI1 = Vrdcc = 193 kN/m
SCAPACI2 = Vrdc = 1992 kN/m
SCAPACI3 = Vrsd = 366 kN/m

So $Vrd = \max\{ Vrdcc ; \min(Vrsd, Vrdc) \} = 366$ kN/m

It is possible to refer to a complete output file about shear check called VERTV (folder Documents \ DeepXcavTemporaryFiles\ Concrete).
Values reported in this file are expressed in kg: so the user has to moltiplicate them for the gravity acceleration in order to find the same numbers of the file .rat.

fyt,fct,rbkt,rakt : 4587.156 254.8420 307.0336

4587.156

sigsamt,tauc0t,tauc1t : 0.0000000E+00 0.0000000E+00 0.0000000E+00

gammac,gammas : 1.500000 1.150000

fcd,fctd,fyd : 169.8947 12.10614 3988.831

area minima staffe (2,3) : 9.000000 15.00000

Asl : 0.0000000E+00

rol2 = 0.0000000E+00

rol3 = 0.0000000E+00

-------- NTC 6.2.2

---- dir. 2

hu,b = 91.66700 60.00000

k = 1.467098

Vmin = 0.3109760

sigma,cp = 3.0867944E-03

VRd,c(6.2a) = 25.95000

VRd,c(6.2b) = 17454.66

---- dir. 3

hu,b = 53.00000 100.0000

k = 1.614295

Vmin = 0.3589322

sigma,cp = 3.2032884E-03

VRd,c(6.2a) = 25.95000

VRd,c(6.2b) = 19410.80

-------- NTC 4.1.2.1.3.2

alfa,c = 0.0000000E+00

nu1 = 0.5000000

VRd,max (6.9) dir.2 = 210284.3

VRd,max (6.9) dir.3 = 202636.9

VRd,s (6.8) dir.2 = 64581.91

VRd,s (6.8) dir.3 = 37339.95

fyt,fct,rbkt,rakt : 4587.156 254.8420 307.0336

4587.156

sigsamt,tauc0t,tauc1t : 0.0000000E+00 0.0000000E+00 0.0000000E+00

gammac,gammas : 1.500000 1.150000

fcd,fctd,fyd : 169.8947 12.10614 3988.831

area minima staffe (2,3) : 9.000000 15.00000

Asl : 0.0000000E+00

rol2 = 0.0000000E+00

rol3 = 0.0000000E+00

3. *Shear reinforcements minima*

- *Static minima*

Paratie Plus calculates reinforcement minima both for the static case and (if the option is selected) for the seismic case.

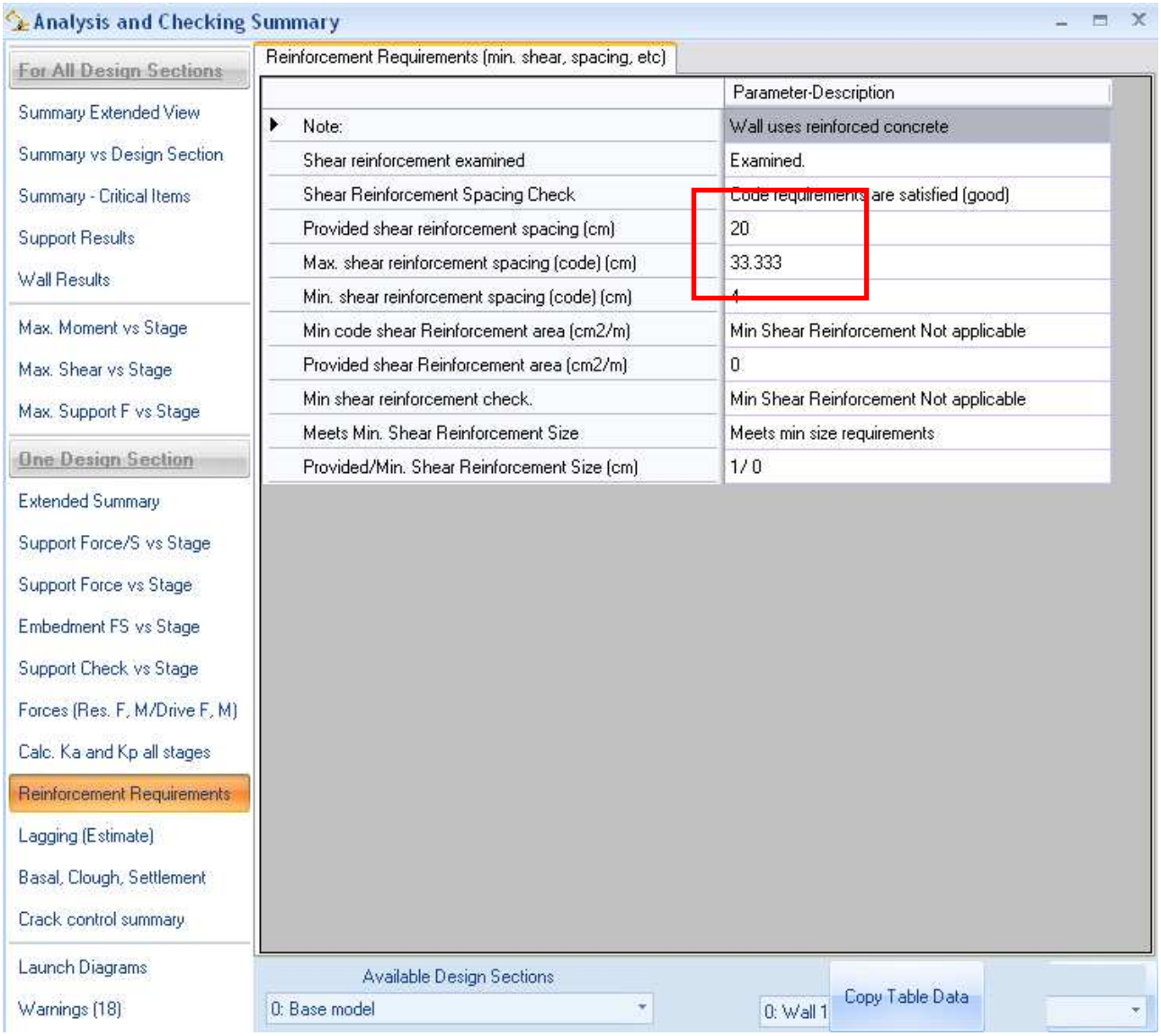
Static minima are taken from paragraph 4.1.6.1.1. of DM2008.

Le travi devono prevedere armatura trasversale costituita da staffe con sezione complessiva non inferiore ad A_{st} = 1,5 b mm^2/m essendo b lo spessore minimo dell'anima in millimetri, con un minimo di tre staffe al metro e comunque passo non superiore a 0,8 volte l'altezza utile della sezione.

Beams must have shear reinforcements composed by straps having a overall section not lower than A=1,5 b [mm^2/m] being b the minimum web width, calculated in millimeters, with a minimum of three straps for each meter and however with an horizontal spacenon higher than 0,8 times the effective height of the section.

In the model the minimun horizontal space is:

s = min (1000/3;0.8*60) = 33.3 cm.



- *Seismic minima*

When the user chooses to calculate seismic minima , these will be given only for the approaches that include the seismic load and only when a seismic load is actually set.

The paragraph *7.4.6.2.1* of DM2008 – *Shear reinforcements* is applied.

Armature trasversali

Nelle zone critiche devono essere previste staffe di contenimento. La prima staffa di contenimento deve distare non più di 5 cm dalla sezione a filo pilastro; le successive devono essere disposte ad un passo non superiore alla minore tra le grandezze seguenti:

- un quarto dell'altezza utile della sezione trasversale;
- 175 mm e 225 mm, rispettivamente per CD"A" e CD "B";
- 6 volte e 8 volte il diametro minimo delle barre longitudinali considerate ai fini delle verifiche, rispettivamente per CD"A" e CD "B"
- 24 volte il diametro delle armature trasversali.

Per staffa di contenimento si intende una staffa rettangolare, circolare o a spirale, di diametro minimo 6 mm, con ganci a 135° prolungati per almeno 10 diametri alle due estremità. I ganci devono essere assicurati alle barre longitudinali.

Shear reinforcements

In critical patches restraint straps must be prescribed. The first restraint strap can't be more than 5 cm away from the section near to the pillar; the next must be placed with pitch not higher than the minimum of the following quantities:

-a quarter of the effective height of the transversal section

-175 mm and 225 mm respectively for CD "A" end CD "B"

-6 and 8 times the minnimum diameter of the longitudinal reinforcement considerated for the checks respectively for CD "A" end CD "B"

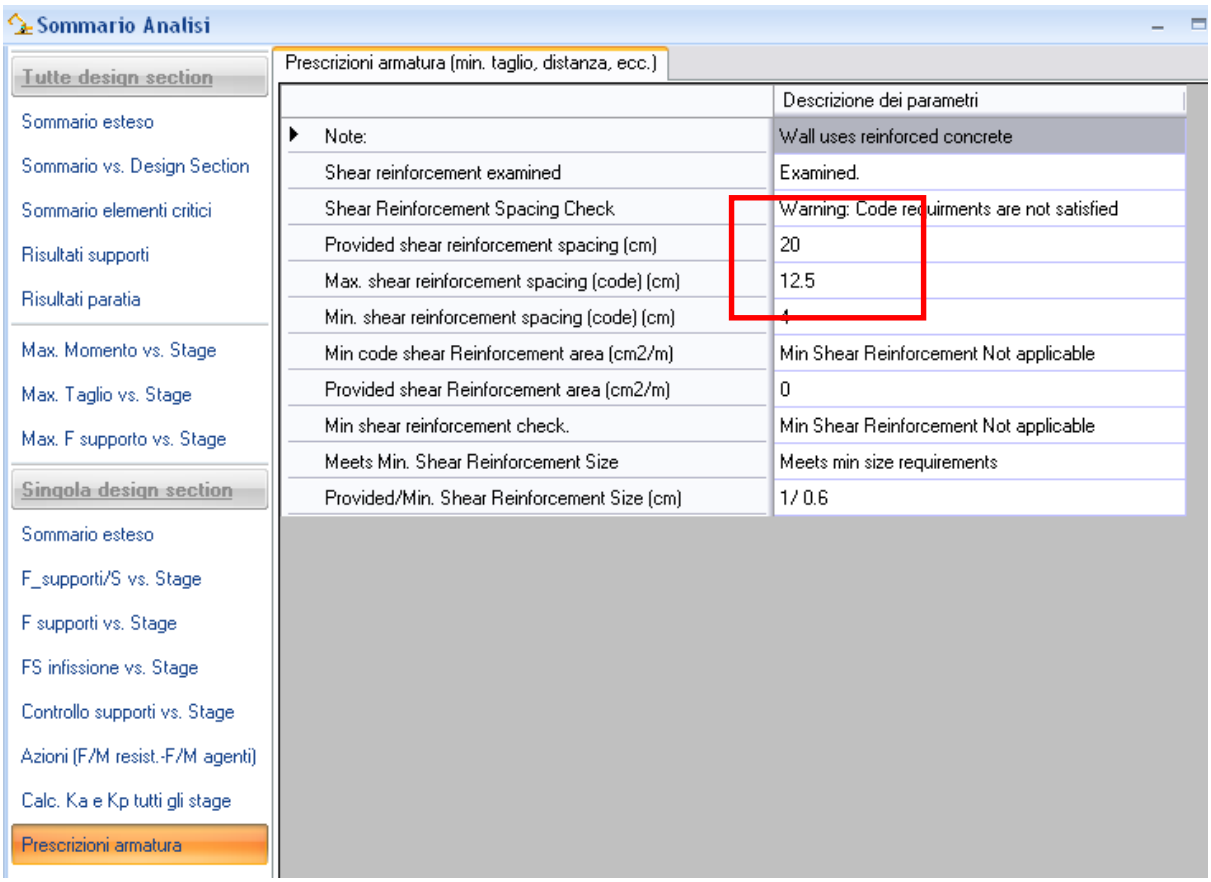
-24 times the shear reinforcement diameter

"Restraint strap" is a rectangular, circular or spiral strap which minimum diameter is 6mm, with stretched to 10 diameters hooks (135° bent). Hooks must be tied up to the longitudinal reinforcement.

Adding a 5th step and applying any seismic load, the software gives reinforcement prescription as shown below. Consider that the wall ductility class is B; there is no possibility to change this option by now.

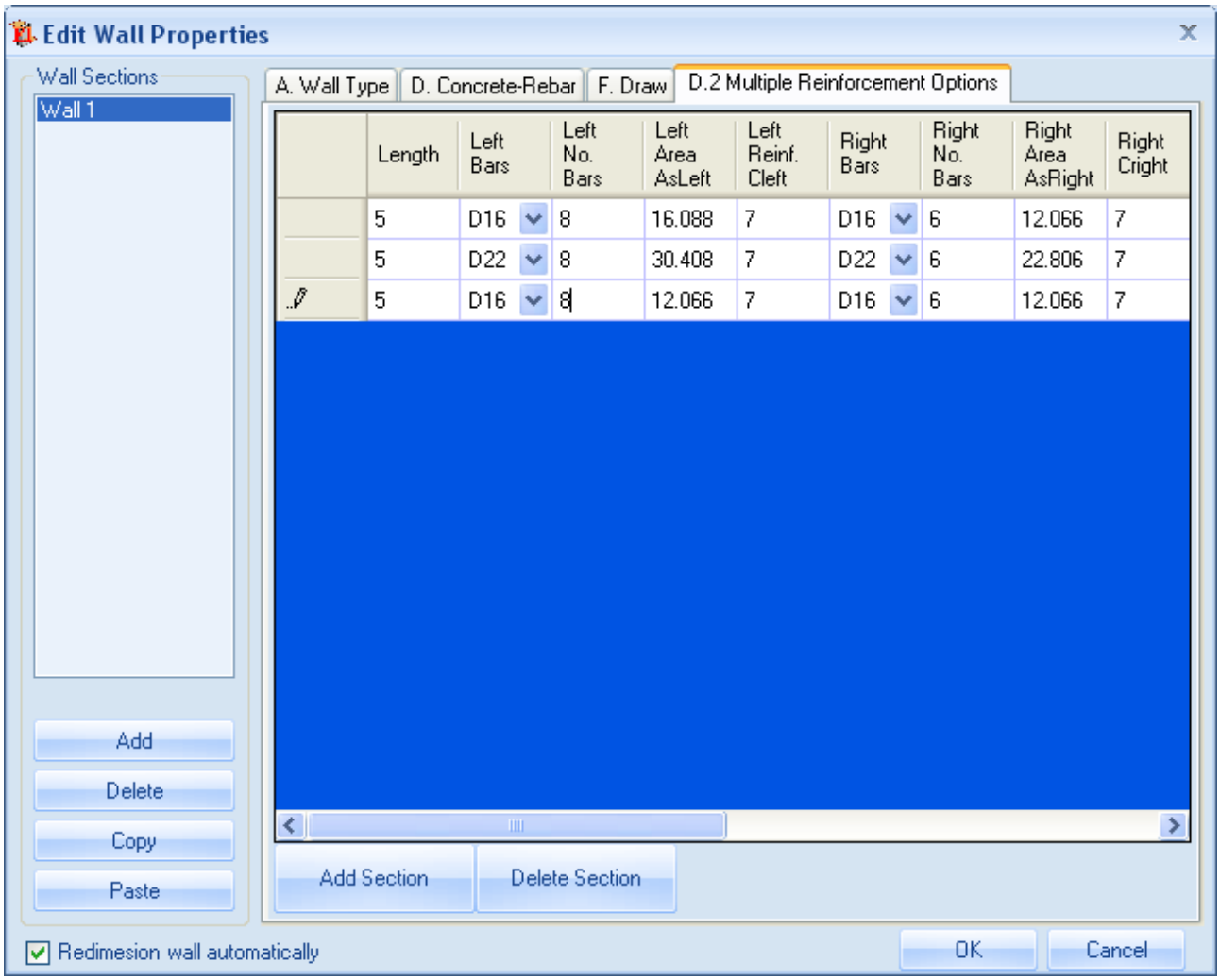
In the given example the largest pitch is:

s = min (125; 530/4; 8*354.5; 24* 78.5) = 125 mm.



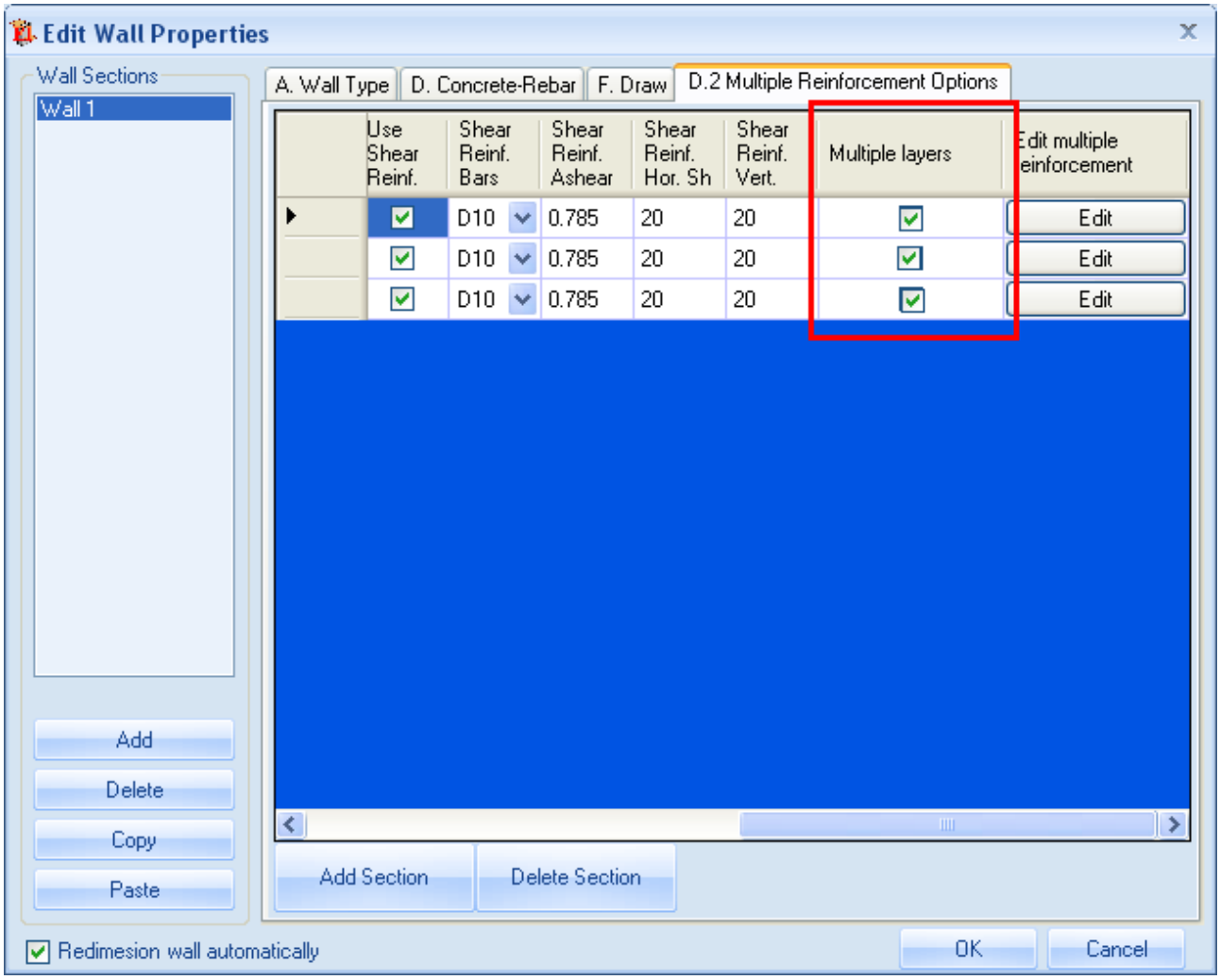
- *Additional notes*

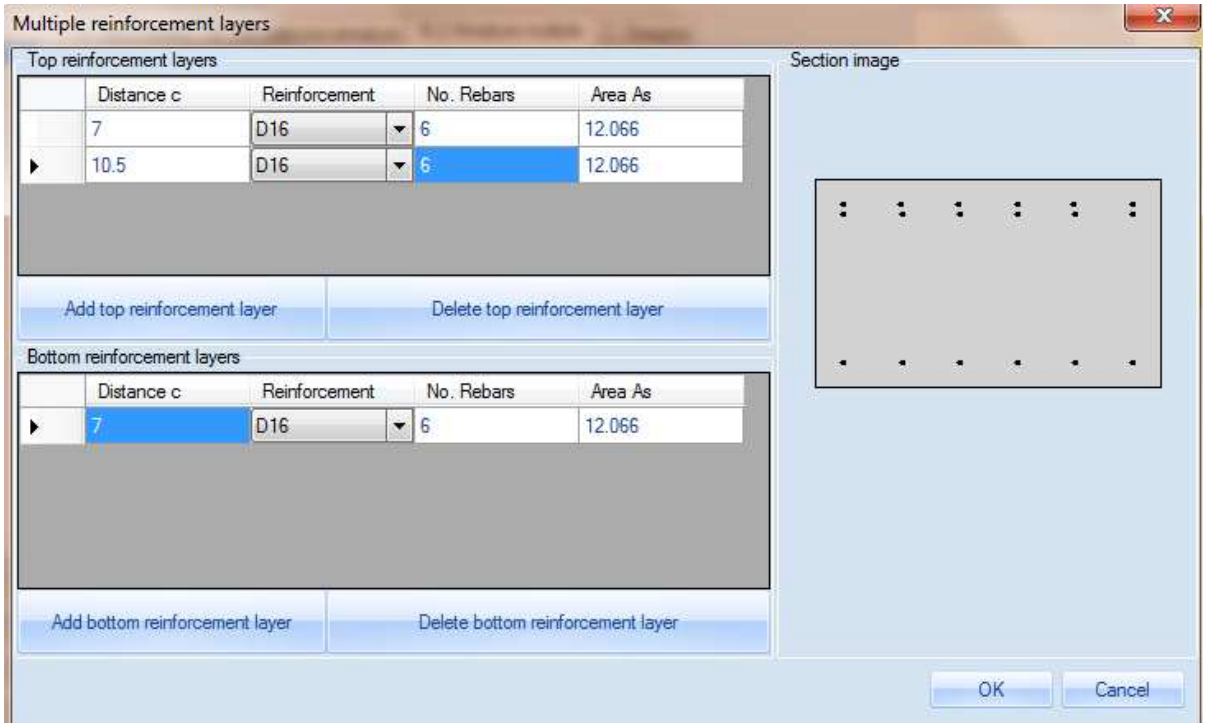
1. If the user decides to vary the reinforcement along the wall, he will find in the file .COU as much domains as the number of sections created.

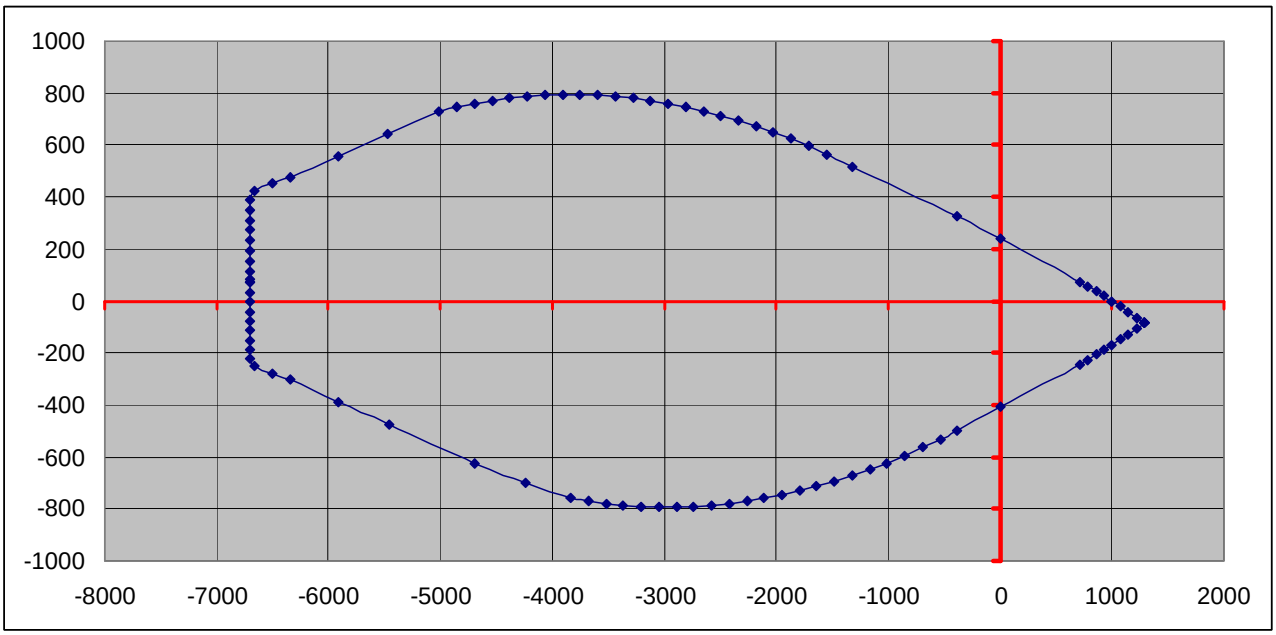


3. If the user choose to use a double line of bars top means the left side of the wall whilest bottom the right side.

   In the file .COU the points consituting the dominion values can be found.




Multiple reinforcement layers
Top reinforcement layers
Distance c
Reinforcement
No. Rebars
Area As
7
D16
6
12.066
10.5
D16
6
12.066
Add top reinforcement layer
Delete top reinforcement layer
Bottom reinforcement layers
Distance c
Reinforcement
No. Rebars
Area As
7
D16
6
12.066
Add bottom reinforcement layer
Delete bottom reinforcement layer
Section image
OK
Cancel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