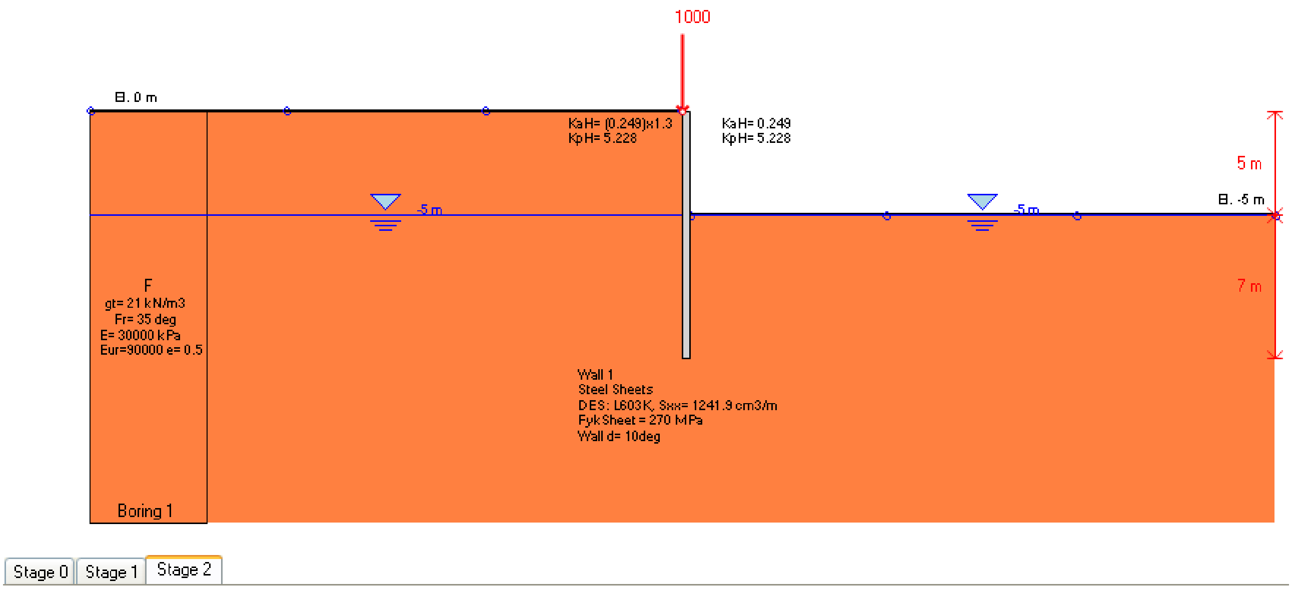
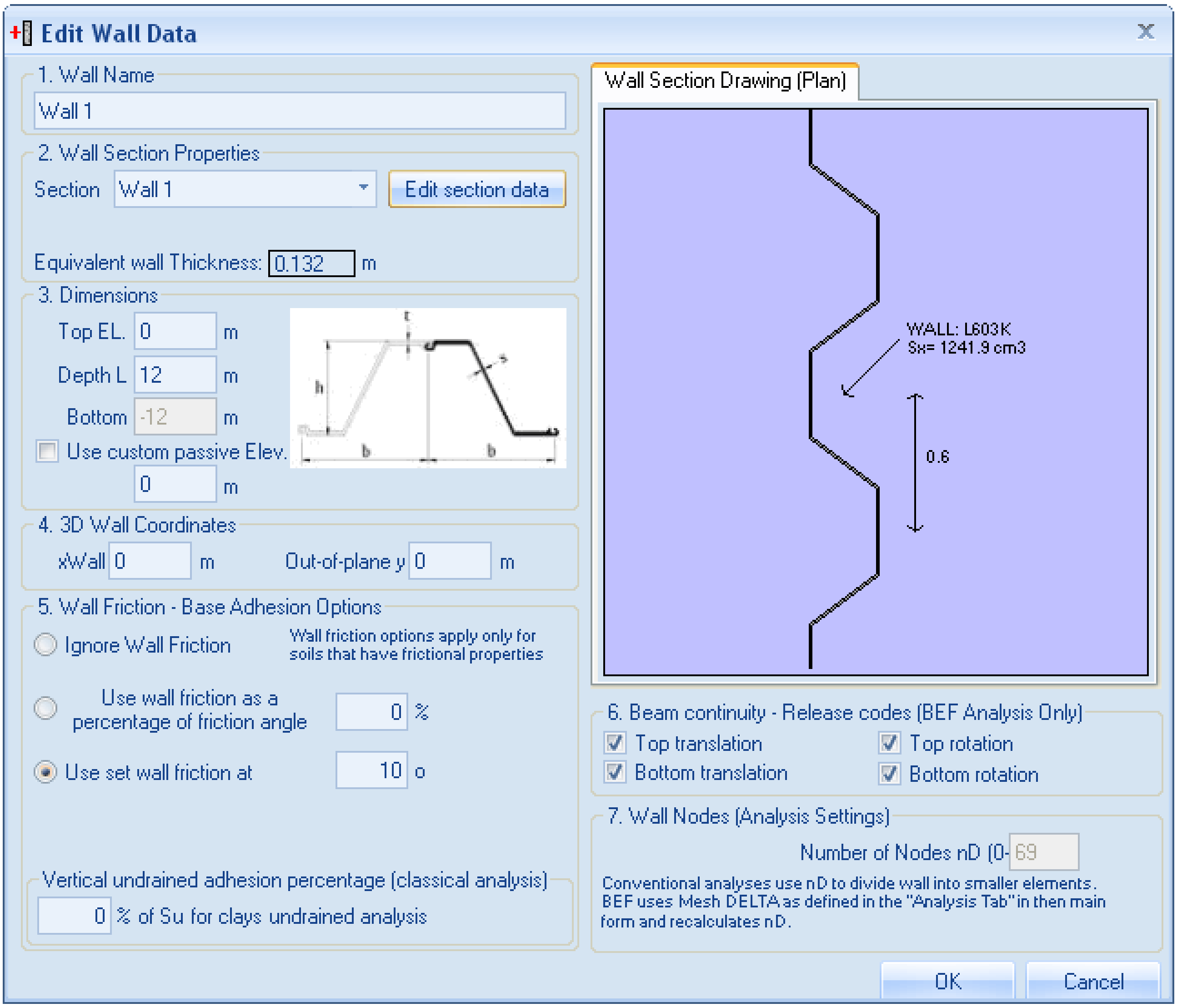
Sheet pile wall checking



Consider the example shown in the figure above.

It concerns a wall made up by a Larssen sheet pile wall; these are its features:

- Tipe: L603K
- Steel: S270GP

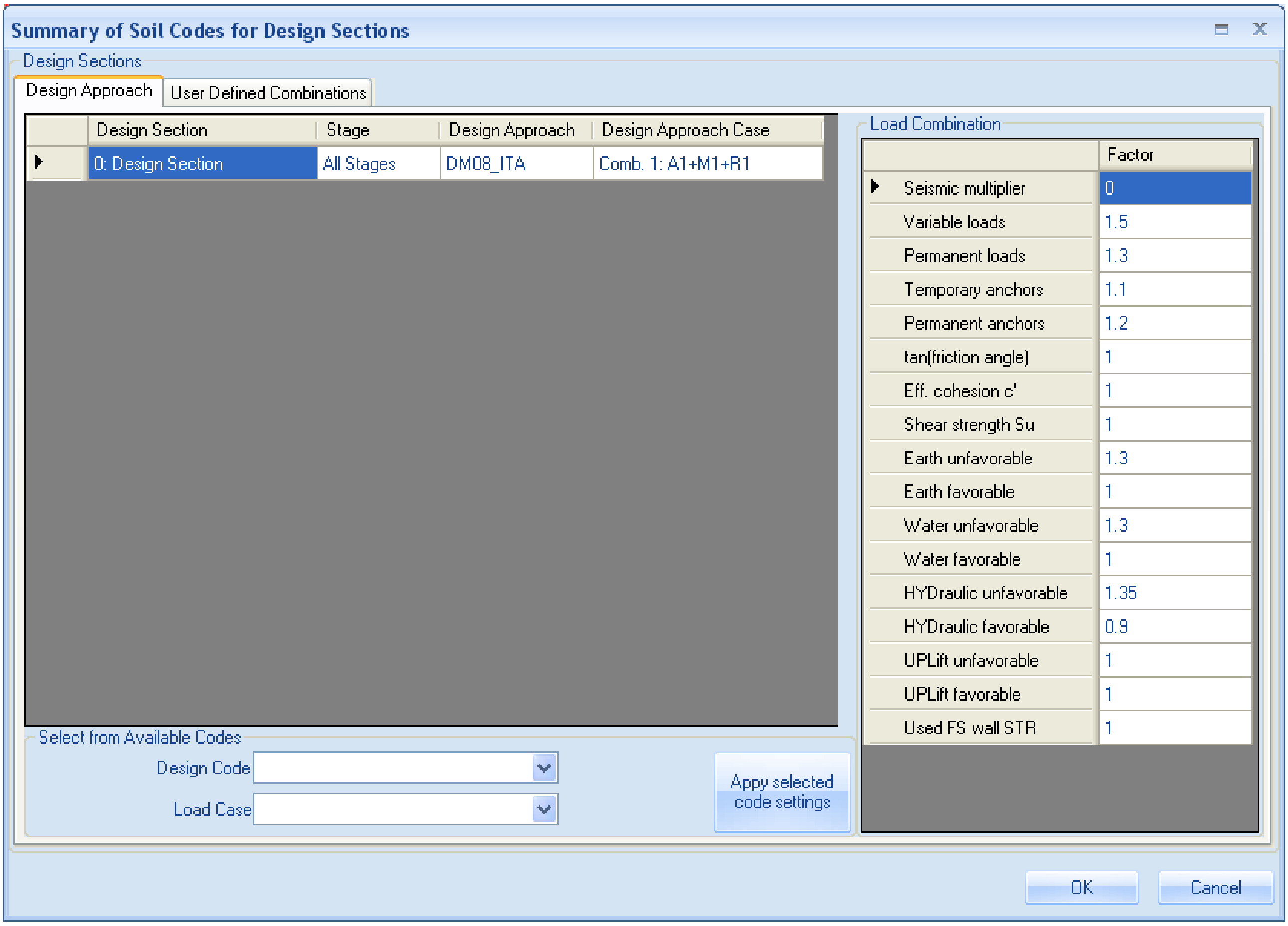


The Paratie Plus engine doesn't make SLS checks but only ULS checks.

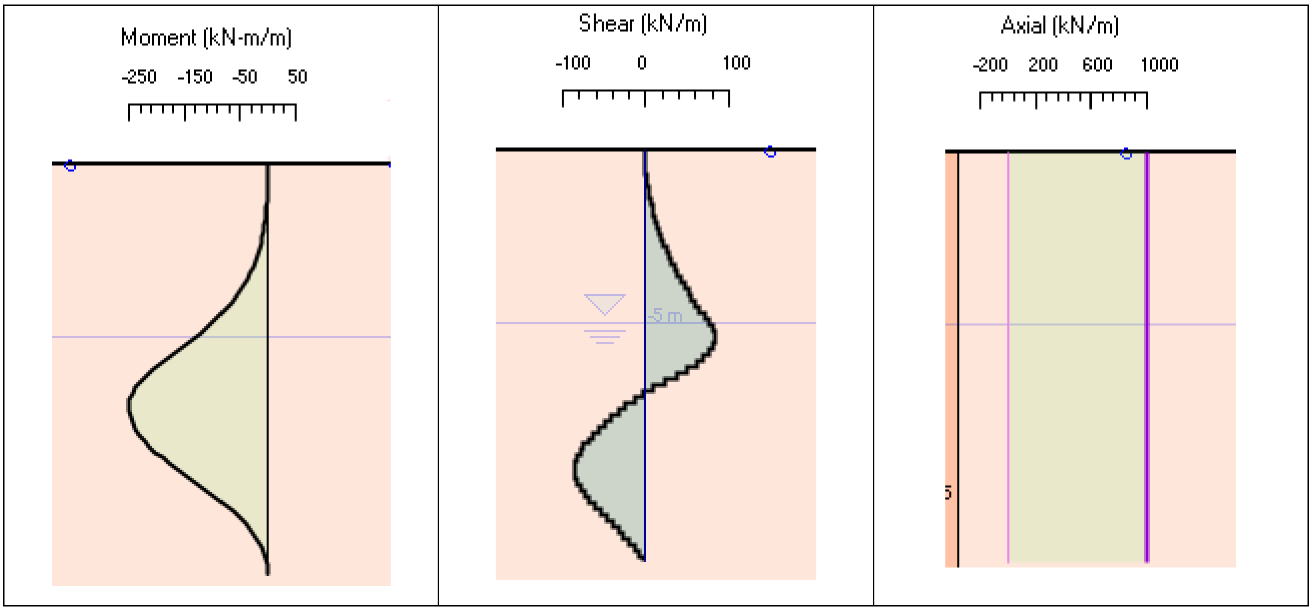
Checks are made according to UNI EN 1993 5:2002.

If DM2008 is selected under Design, the Italian code gamma safety coefficients will be used.

The model has been calculated using A1 + M1 + R1(DM2008) approach.



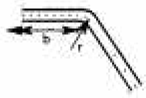
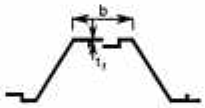
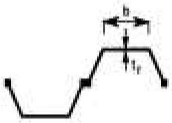
These are the result (concerning the third stage) of the analysis:



- *Classification of the section*

Referring to table 5.1 of UNI EN 1993 5:2002.

Table 5.1: Classification of cross-sections

<table>
<tr><th>Classification</th><th colspan="3">Z-profile</th><th colspan="4">U-profile</th></tr>
<tr><td></td><td colspan="3"></td><td colspan="4"></td></tr>
<tr><td>Class 1</td><td colspan="7">- the same boundaries apply as for class 2
- a rotation check has to be carried out (see note)</td></tr>
<tr><td>Class 2</td><td colspan="3">$\frac{b/t_f}{\varepsilon} \leq [45]$</td><td colspan="4">$\frac{b/t_f}{\varepsilon} \leq [37]$</td></tr>
<tr><td>Class 3</td><td colspan="3">$\frac{b/t_f}{\varepsilon} \leq [66]$</td><td colspan="4">$\frac{b/t_f}{\varepsilon} \leq [49]$</td></tr>
<tr><td rowspan="2">$\varepsilon = \sqrt{235/f_y}$</td><td>$f_y$ [N/mm²]</td><td>240</td><td>270</td><td>320</td><td>355</td><td>390</td><td>430</td></tr>
<tr><td>ε</td><td>0,99</td><td>0,93</td><td>0,86</td><td>0,81</td><td>0,78</td><td>0,74</td></tr>
</table>

Key:

b: width of the flat portion of the flange, measured between the corner radii, provided that the ratio r/t_f is not greater than [3,0]; otherwise a more precise approach should be used;
t_f: thickness of the flange for flanges with constant thickness;
r: midline radius of the corners between the webs and the flanges;
f_y: yield strength.

Note: For class 1 cross-sections it should be verified that the plastic rotation provided by the cross-section is not less than the plastic rotation required in the actual design case. Guidance for this verification (rotation check) is given in E.4.4.2.

The user can refer to the output file .EXT in folder Documents/DeepXcavTemporaryFiles/steel.

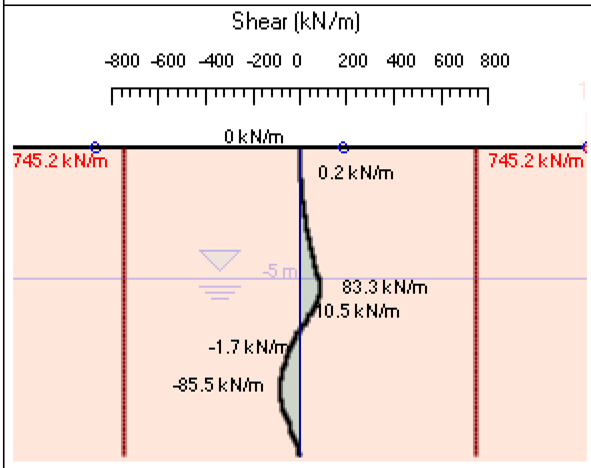
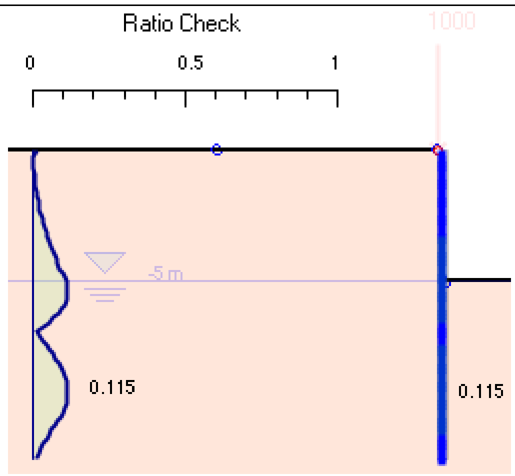
Section no. 82 at x= 7001.000 [mm]

selected class for current cross section = 2

- *Shear check*

The shear check is made according to paragraph 5.2.2 (5.4) of UNI EN 1993 5:2002.

The relults are shown both as resistant shear and as STR for each stage.

WALL SHEAR + CAP.S key	WALL SHEAR + RAT.S key
	

The user can refer to the output file .EXT in folder Documents/DeepXcavTemporaryFiles/steel for any element and any stage.

5.2.2(5.4) Shear resistance check

Z direction : Shear Area Av = 5014. mm2

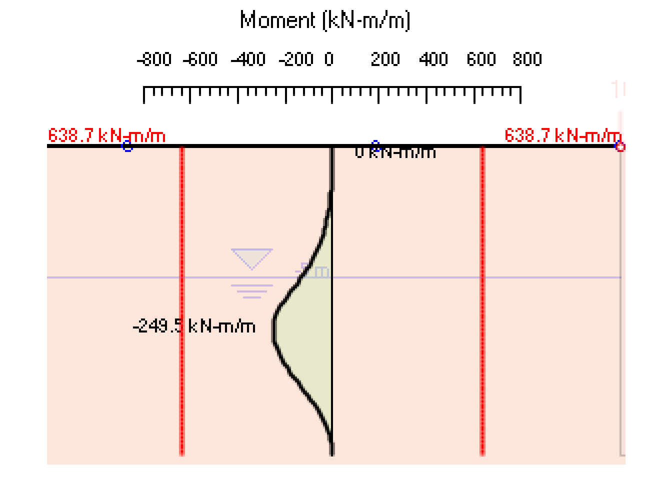
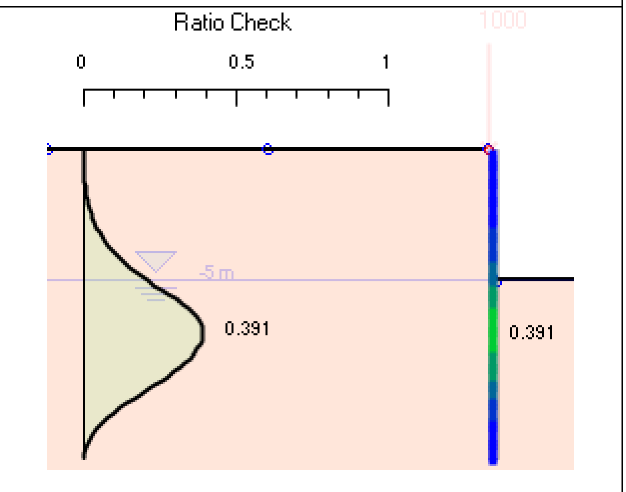
Vsd = -84.39 kN , VplRd = 744.4 kN, ratio = 0.1134

- *Bending moment check*

It's made according to paragraph 5.2.2 (5.2) of UNI EN 1993 5:2002.

The checker makes a classification of the section, as shown in the output file.

The relults are shown both as resistant shear and as STR for each stage.

WALL MOMENT + CAP.M key	WALL MOMENT + RAT.M key
	

Among the results reported in the extended summary at the end of the analysis, the maximum STR for each stage are included. The STR Moment wall ratio values are coincident with RAT.M values shown in the chief window of the model.

Extended vs Stage

	ll ear l/m)	Wall Shear (kN)	STR Combine Wall Ratio	STR Moment Wall Ratio	STR Shear Wall Ratio	Concrete Service Stress Wall Ratio FIC	Reinforcement Service Stress Ratio FIS	Max Support Reaction (kN/m)	Max Su Reactio
Stage 0		0	0	0	0	N/A	N/A	No supp...	No supp
Stage 1	47	85.47	0.391	0.391	0.115	N/A	N/A	No supp...	No supp
Stage 2	47	85.47	1.039	0.391	0.115	N/A	N/A	No supp...	No supp

The user can refer to the output file .EXT in folder Documents/DeepXcavTemporaryFiles/steel for any element and any stage.

The following is an extract of the output file concerning the most bending-stressed element in the last stage.

betab 1.000

Wply 0.2484E+07

fy 270.0

gammaM0 1.050

5.2.2(2): McRd= 0.6387E+09

Moment resistance: no need to consider shear reduction

- *Buckling check*

It's made according to paragraph 5.2.2 (5.2) of UNI EN 1993 5:2002.

This prescription is kept:

(1)P For combined bending and compression, member buckling need not be taken into account if:

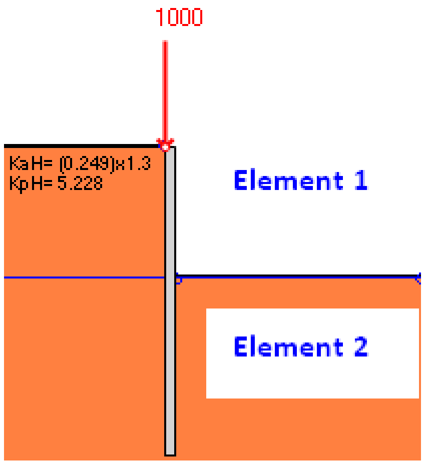
$$\frac{N_{Sd}}{N_{cr}} \leq [0,05] \quad \ldots (5.7)$$

The pile is divided into elements by te checker; the presence of supports, the elevetion of excavation and the bottom elevation of the wall are gathered.

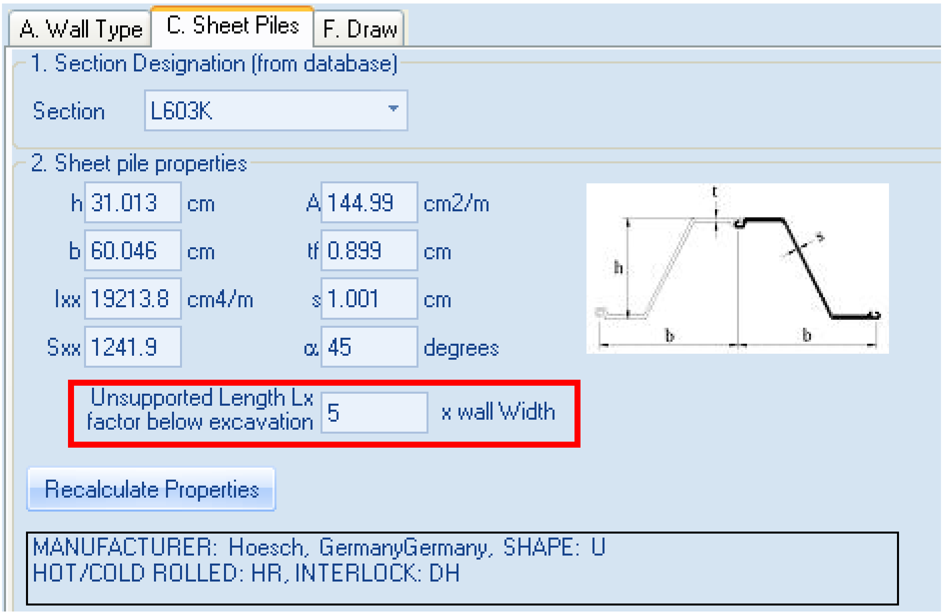
Under the elevation of excavation, in order to simulate the hydraulic heave, the wall is divided into smaller elements.

In the current model, then, the checker gathers:

	From elevation	To elevation	Beta
element 1	Surface	excavation depth	2
element 2	excavation depth	Wall bottom	little

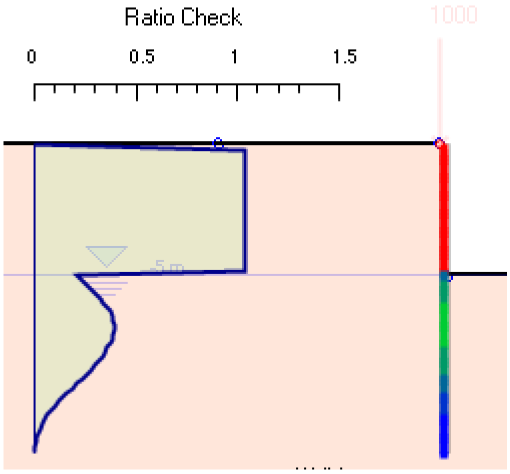


In Paratie Plus it’s possible to simulate the situation when the excavation depth support forms a bit lower than the excavation depth .



The default value is 5 time the total wall width. In this case the total width is like the boring diameter.

The buckling check results can be shown both using the COMB. Key and in the extended summary at the end of the analysis, for each excavation stage.



Extended vs Stage

	Wall Shear (kN)	STR Combine Wall Ratio	STR Moment Wall Ratio	STR Shear Wall Ratio	Concrete Service Stress Wall Ratio FIC	Reinforcement Service Stress Ratio FIS	Max Support Reaction (kN/m)	Max Support Reaction (kN)
Stage 0	0	0	0	0	N/A	N/A	No supp...	No supports
Stage 1	85.47	0.391	0.391	0.115	N/A	N/A	No supp...	No supports
Stage 2	85.47	1.039	0.391	0.115	N/A	N/A	No supp...	No supports

The results say that during the third stage the buckling check is not satisfied; the critical part of the wall is the one above the excavation.

It is possible to refer to the . EXT output file (folder Documents/DeepXcavTemporaryFiles/steel); it shows the buckling check for each element and step.

As for the second part of the wall, considering the unsupported lenght like 5*W (W= boring hole= 250mm)=1,25m, the buckling lenght is:

$l = l_0$ * Beta = 6,25 m * 2 = 13,10.

CSTVEREC3P: STABILITY CHECKS FOR PARTIAL SPAN NO. 2

zstart = 5000.000 [mm] zend= 12000.00 [mm] buckl. length about x-x = 1001.000 [mm]

As for the third part of the wall, Beta value is:

Beta = l / l_0 = 1 m / 7 m = 0,143

Finally here is an extract of the output file concrening he first element check, the critical one:

CSTVEREC3P: EQUIVALENT MOMENTS CALCULATION

Start calculation - Moment:Y Bracing:Z

TABLE B.3 : XMIN = 1.0000 XMAX = 5000.0

BXMIN= 0.0000 BXMAX= 0.12810E+09

X(1) = 0.0000 X(N) = 12000.

M(1) = 0.0000 M(N) = 0.0000

Table B.3 : ERR Q M - BILINEAR 0.11316E+18

" " : ERR Q M - PARABOLA CENTR. 0.12635E+18

Table B.3 : PSI 0.0000

" " ALPHA 0.12481

" " Cm unif. 0.40000

" " Cm conc. 0.40000

" " Cm avrg. 0.40000

" " Cm . 0.40000

Table B.3 : sway buck. mode = YES

" " Cm set to 0.90000

Annex B: TABLE B.3

Moment about axis: Y

Bracing in direction: Z

Equiv. uniform moment factor Cm = 0.90000

Max. bending moment (abs value) [kNm]= 128.10

End calculation - Moment:Y Bracing:Z

************ STABILITY CHECK ********

******* EUROCODE 3 PART 5 - 2007 ******

E = 0.2060E+06

I = 0.1921E+09

betad = 1.000

l = 0.1310E+05

Ncr = 0.2276E+07

lambda sup = 1.3114

lambda1 = 86.78

slenderness = 113.8

fi = 1.782 (6.3.1.2)

chi = 0.3346

NplRd = 0.3728E+07

MEd = 0.1281E+09

McRd = 0.6387E+09

MN,Rd = 0.6216E+09 (5.21)

SECTION 5.2.3 - BUCKLING RATIO (4) 5.13

Contribution from NEd : 1000. / 1247. = 0.802 +

Contribution from MEd : 147.3 / 621.6 = 0.237 +

Sum of above contributions = 1.039

CHI factor is calculated according to UNI EN 1993: 1-1:2005; in UNI EN 1993 5:2002 it's is clearly prescribed to use d buckling curve.

Besides, the prescription described in paragraph 5.2.3 (10) and 5.2.3 (11), concerning a resistant moment reduction when N_{sd} / $N_{pl,rd}$ ratio is too high, are rightly applied.

BUCKLING CHECK - UNI EN 1993 5:2002

INPUT	Nsd	1000000	N
	Msd	128100000	Nmm
	Mrd	638700000	Nmm
	fy	270	Mpa
	alfa	0,76	
	beta_A	1	
	E	206000	N/mm^2
	J	192140000	mm^4
	A	14499	mm^2
	Beta_D	1	
	L	13100	mm
	gamma_M0	1,05	
	gamma_M1	1,05	

OUTPUT	i	115	mm
	Ncr	**2276232**	N
	Nsd/Ncr	0,43932251	
	lambda	113,797161	
	lambda_1	86,7738351	
	lambda_segnato	1,311422514	
	Fi	1,782255061	
	Chi	0,334542862	
	Npl,rd	3728314	N
	Nsd/Npl,rd	0,268217731	N
	Mn,rd	621627815,4	Nmm
	Contribution Ned	0,802	

	Contribution Med	0,237
	Verifica_ratio (<1)	**1,039**