Global Stability of the Soil
Slip Circle Calculation

User manual

Software for
Architecture,
Engineering and
Construction

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1. Introduction

1.1. Global stability phenomenon

As a consequence of the elevation level generated by the retaining elements, the soil has a tendency to level itself. Hence the possibility of there being an instability issue is induced to the soil mass which the shear resistance of the soil will oppose.

This type of instability can be classified into two large groups: **landslides** (the unstable mass falls) and **displacements** (the unstable mass moves). A typical case amongst the last of these categories is sliding, whereby a soil mass slides with respect to another when the shear resistance is exceeded along the separation zone. This sliding action can follow flat, curved or jagged surfaces, or any combination of those mentioned.

Therefore, the global stability safety of all retaining structures should be checked.

Generally speaking, circular displacement surfaces are studied, whereby the circle requiring the greatest soil resistance has to be found, or similarly, possesses a minimum safety coefficient against sliding, where this coefficient is the ratio between the shear resistance of the soil and the shear resistance it has to develop.

The forces that tend to make the soil mass unstable are, mainly, its self weight, the retaining element, the surcharges contained within the circle, seismic excitation and any other externally destabilising force.

To determine the worst case slip circle the data of the problem must be known, i.e. the difference in level (slope), the properties of the retaining element, the soil layer profile, group of loads on the retaining element and soil, and finally, the election of a method whose formula is adequate for the problem in question.

The following diagrams illustrate the global stability problem dealt with in this section:

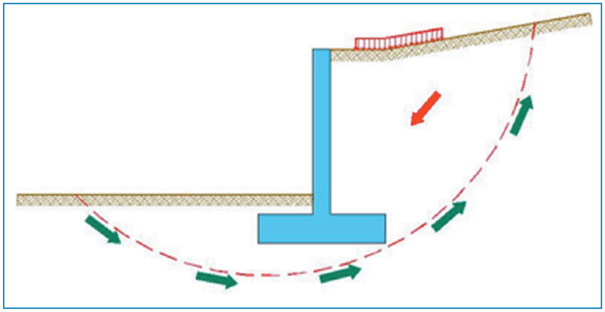

Fig. 1.1

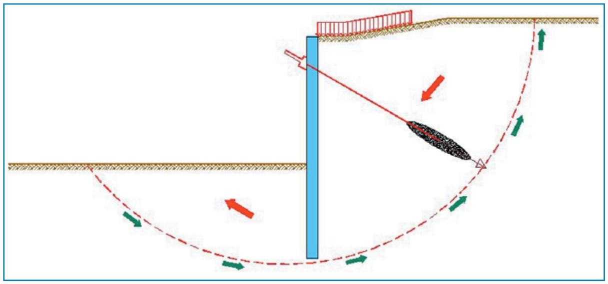

Fig. 1.2

1.2. Calculation of the safety coefficient against circular sliding

As has been mentioned earlier, the safety coefficient a potentially unstable soil mass has against the circular sliding phenomenon, can be evaluated as the ratio between the effect of the stabilising loads to the destabilising loads.

This may be expressed in terms of moments:

$$F = \frac{\sum M_S}{\sum M_D}$$

Where:
ΣM_S: Sum of the moments produced by the stabilising loads with respect to the centre of the circle being studied.
ΣM_D: Sum of the moments produced by the destabilising loads with respect to the centre of the circle being studied.

This safety coefficient can be associated to different parameters, such as the soil resistance, the surcharge values, seismic excitation, etc., depending on the values of these parameters used in the formulas. In other words, the safety coefficient obtained will provide a value of the required shear resistance of the soil, the excess surcharge which may act on the soil, or the maximum seismic excitation accepted by the system, etc.

1.3. Calculation methods

Currently, various methods exist to calculate the safety coefficient of a potentially unstable mass against circular sliding. Generally, these methods consist in proposing a slip surface and study its equilibrium, depending on the load system that is developed. This study consists in subdividing the sliding soil mass into small geometric portions, so that a simple calculation can be carried out of the loads to which these are exposed to.

Once the loads acting on the soil mass have been identified, and based on a series of combinations, the corresponding equilibrium equations are established, from which, with a more or less complex previous analysis depending on the method used, the value of the safety coefficient for the circle being studied will be obtained.

This procedure is repeated for a sufficiently large number of possible slip circles varying their radius and their spatial position. Each one will provide a safety coefficient, of which the minimum value will be the safety coefficient of the system.

To draw these circles, an orthogonal X-Y mesh is usually used as a base. Each and every possible slip circle with increasing radius is drawn on the mesh. Figure 1.3 shows a generic circle with radius R whose centre is point ‘o’ of the orthogonal mesh.

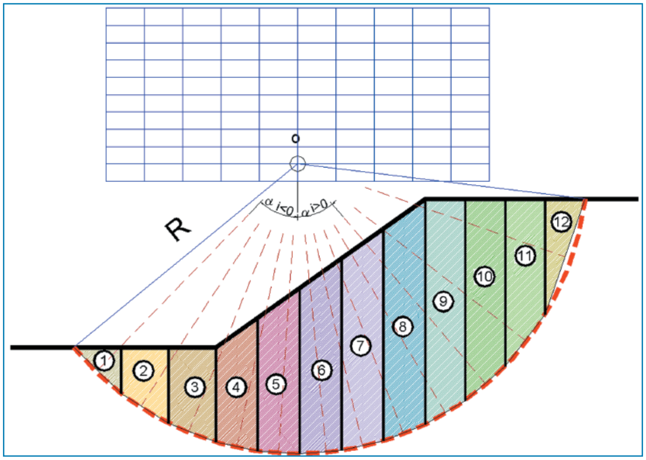

Fig. 1.3

1.4. Method of slices (Simplified Bishop's Method)

This method consists of analysing the equilibrium of a soil mass which follows a circular slip surface. To do so, a circle is drawn on the transverse section of the soil and the mass contained within this circle is subdivided into slices.

Based on the free body diagram of each generic slice 'i', a shown in Figure 1.4, the mathematical formula of the method is obtained.

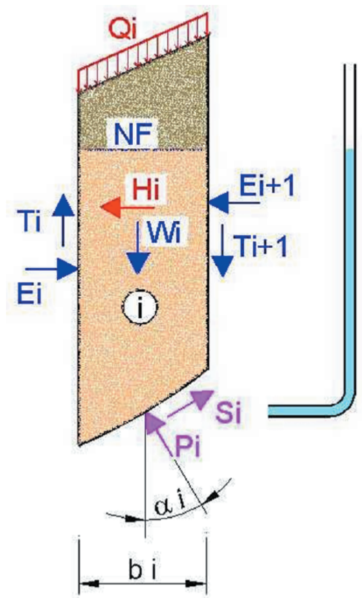

Fig. 1.4

For a specific slope, the equation used to obtain the safety coefficient 'F' of a circle with radius R (which may or may not have applied surcharges 'Q') is the following[1]:

[1] It is recommended Bibliography references I and IV indicated at the end of this manual be consulted for further information on the formulas used.

$$F = \frac{\sum_{i=1}^{i=n}\left[\frac{c_i \times b_i + (W_i + Q_i - u_i \times b_i) \times \tan\phi_i}{m\alpha_i}\right]}{\sum_{i=1}^{i=n} W_i \times \sin\alpha} \quad (1)$$

Where:

$$m\alpha = \cos\alpha_i \times \left(1 + \frac{\tan\phi_i \times \tan\alpha_i}{F}\right) \quad (2)$$

b_i: width of slice 'i'
c_i: soil cohesion value at the mid point of the base of slice 'i'
$\tan\phi_i$: value of the tangent of the internal friction angle of the soil at the mid point of slice 'i'
α_i: value of the angle between the straight line joining the centre of the circle with the mid point of slice 'i' with respect to the vertical plane.
W_i: sum of the weight of all the soil layers lying above the mid point of the base of slice 'i'
Q_i: resultant pressure due to the loads acting on the soil above the mid point of the base of slice 'i'
u_i: value of the pore overpressure at the mid point of the base of slice 'i'

It is assumed that the forces between slices are null, i.e. $\{\Delta T_i\} = 0$ and $\{\Delta E_i\} = 0$.

The previous equation is implicit in F and so is solved by means of successive iterations, starting with an initial value of F = F1 which is introduced in equation (2) and is compared with value F2 which is obtained from equation (1). If values F1 and F2 are not sufficiently close to one another, a new iteration is carried out starting with the value of F2 in equation (2) and so on, until the values converge at a final value for the safety factor, F.

2. Considerations and calculation methods

2.1. Analysis hypothesis

As in all analyses, the hypotheses or assumptions on which they are based on first have to be defined. To do so, specific conditions have to be taken into account such as the presence of a retaining element, water table, loads at the top of the retaining element etc. The hypotheses that have been contemplated in the program when calculating the slip circle are detailed below:

- The method used to calculate the worst case safety coefficient is the Method of Slices, also known as the Simplified Bishop's Method, which assumes there are no forces between the slices, i.e. $\{\Delta T_i\} = 0$ and $\{\Delta E_i\} = 0$. To view the limits and validity of the method, we recommend the reference bibliography be consulted.
- The soil is taken as being homogenous and there are no predominating blocks in its composition.
- The shear resistance of the soil is that indicated in the Mohr-Coulomb equation, i.e.: $\tau = c + (\sigma - \mu)\tan\phi$
- Flat deformation is taken into account, hence the study is carried out for a unit width of the system.
- The unstable mass follows a potential slip surface with a circular path.
- No soil phenomena such as detachments, collapse, liquefaction, irregularities such as joints, erosion due to fluids, cave-ins due to natural currents, etc. are considered.
- The layers are considered to be perfectly horizontal along their entire length, and the lowest layer is assumed to extend to a semi-infinite level.
- The soil density of a layer will be that of the apparent or submerged density, depending on whether the layer is above or below the water table.
- Deep circles which penetrate into soil are analysed; those that penetrate into rock layers are not.
- Circles which lie partly on the outer limits of the soil and do not penetrate soil are not considered.
- Stresses due to capillary action in the soil mass are not considered.
- The water table will be considered as being in horizontal equilibrium.
- In the case of embedded retaining walls, any loads the anchors and struts exert on the wall are not considered, i.e. the equilibrium is analysed without the contribution of these elements. If the coefficient obtained using this extreme hypothesis is reasonable, it implies that the contribution of these support elements is not, strictly, necessary. If the coefficient obtained is not satisfactory, these elements will be required and must be designed to resist the loads required to obtain global stability. Safety coefficients are not analysed in those phases where floor slabs are present as it is considered that executing a building does not allow for the development of the slip circle.
- In the case of generic embedded retaining walls, circles which cross the wall are not contemplated and its specific weight is considered as being null.
- The horizontal seismic coefficient (fraction of the acceleration due to gravity) is considered to be uniform with height.

- The program assumes the live loads acting on the soil have a depth diffusion of 30º with respect to the vertical plane.
- The program considers that the shear resistance of the element at the circle surface with any circle is that of the characteristic shear resistance of the material specified by the corresponding code or, the characteristic tensile resistance if the shear resistance is not specified. For concrete elements, the corresponding resistances of mass concrete are considered.
- The program does not consider the bearing pressures of the soil due to the retaining element or applied loads at the top of the wall acting on the slip surface being studied. This situation is generally conservative as a smaller safety coefficient is obtained than if these pressures were to be considered. Generally speaking, excluding those cases in which loads of great value have been applied to the element, the difference between the coefficients will be small.
- For load combinations with seismic action, a static analysis is undertaken and the program considers the horizontal loads produced by the soil mass system multiplied by the seismic acceleration defined by the user and the load vectors of the top of the wall corresponding to the combination with seismic loading. Any influence the seismic acceleration may have on the defined live loads is ignored.

2.2. Adaptation of the method of slices (Simplified Bishop's Method)

The previously described method has been adapted to the most varied and complex conditions that are presented when studying the slip circle in structural retaining elements. To do so, the criteria established in reference II of the bibliography has been followed.

Equation (1) becomes equation (3):

$$F = \frac{\sum_{i=1}^{i=n}\left[c_i \times b_i + \left(W_i + Wh_i + Q_i - u_i x b_i\right) \times \tan\phi\right] + \frac{M\tau_M}{R} + \frac{\sum_m ME_m}{R}}{\sum_{i=1}^{i=n}\left[\left(W_i + Wh_i\right) \times \sin\alpha_i\right] + \frac{\sum_k MD_k}{R}} \quad (3)$$

Where:

$$m\alpha_i = \cos\alpha_i \times \left(1 + \frac{\tan\phi_i \times \tan\alpha_i}{F}\right) \quad (4)$$

Only those slices which obey the following inequality are considered in the sliding mass equilibrium:

$$\left(1 + \frac{\tan\phi_i \times \tan\alpha_i}{F}\right) \geq 0.10 \quad (5)$$

b_i: width of slice 'i' (the minimum value is taken between R/10 and 1.00 m).
c_i: value of the cohesion of the soil at the mid-point of the base of slice 'i'.
$\tan\phi_i$: tangent of the internal friction angle of the soil at the mid-point of the base of slice 'i'.
α_i: angle between the straight line joining the centre of the circle and the mid-point of the base of slice 'i' with respect to the vertical plane.
W_i: sum of the weight of all the soil layers lying over the mid-point of slice 'i'. The apparent or submerged densities of the soil are considered depending on whether they are above or below the water table elevation.
Wh_i: weight of the water located above the surface of slice 'i' if the water table is present.
Q_i: resultant of the pressure produced by the surcharges acting on the soil at the mid-point of the base of slice 'i'.
ui: value of the pore overpressure at the mid-point of the base of slice 'i'. This value is null as the program considers that the pore pressure is equal to the hydrostatic pressure.
$M\tau_M$: moment produced by the shear resistance of the retaining element with respect to the centre of the circle, when the circle crosses it.
ΣMD_k: sum of the 'k' moments of the external unbalancing loads with respect to the centre of the circle.

ΣME_m: sum of the 'm' moments of the external balancing loads with respect to the centre of the circle.

As was said previously, the previous equation is implicit in F, and so is resolved by successive iterations. Generally, convergence to a final safety coefficient occurs quickly, nonetheless, if the number of iterations reaches the limit value of 50 iterations, the program issues a warning in the check report. This iteration limit value is reached when the system presents a particular situation which unstabilises the equilibrium convergence (for example when peculiar soil densities are present, etc.)

The iterations conclude when the difference between the calculated safety coefficient in iteration 'j' and that calculated in iteration 'j+1' is less than or equal to 0.001:

$$\left(\left|F_j - F_{j+1}\right| \leq 0.001\right)$$

2.3. Calculation process

The process used by the program to establish the slip circle with the minimum safety coefficient consists of defining a preliminary point mesh in the transverse section being studied. These will be the centres of the circles that will be analysed. This preliminary mesh of centres covers a horizontal width of 4 times the retaining height and a vertical height of 2 times the retaining height. If the soil has a berm on the backfill side, the height of the mesh is increased by adding twice the height of the berm. Each of the sides of this first mesh is split into 10 divisions.

Once the group of representative circles of each node of the mesh are calculated, the point possessing the smallest safety coefficient 'P1' is found. Another mesh, only this time smaller, is defined whose centre is point 'P1'. The process is repeated to obtain the minimum coefficient 'P2'. This continues until 3 meshes, cycles or approximations have been reached whereby the minimum safety coefficient from all those calculated has been found, whose centre will be point 'P3' of the third iteration. The dimensions of the 2nd and 3rd mesh are 0.4 times the dimensions of the previous mesh and the sides of each of these is split into 6 divisions.

Circles with increasing radii are drawn at each point of the mesh, beginning with a minimum radius so that it penetrates the soil 0.5 m and reaching a maximum radius which will be the largest of the following:

- Minimum radius + 2 metres
- Radius that reaches the deepest layer + 2 times the soil retaining height.
- Radius that reaches the elevation of the deepest point of the retaining element + soil retaining height.

Nonetheless, once the value of the radius reaches the elevation of the deepest layer defined by the user, if the safety coefficients of the next 10 circles increase, the program will not further penetrate the soil with more circles. When the opposite occurs, the program continues drawing circles with increasing radius until this condition is met.

Before calculating the safety coefficient of the proposed circle, various validation controls are carried out. In other words, some circles may be rejected or ignored, such as those that penetrate in a rock layer, those that do not contain a soil elevation change in its surface, those containing areas that do not cut through soil, those whose centre elevation is such that intercept with the soil at points whose elevation is higher than that of the centre.

The following figures display examples of circles which may be ignored or rejected:

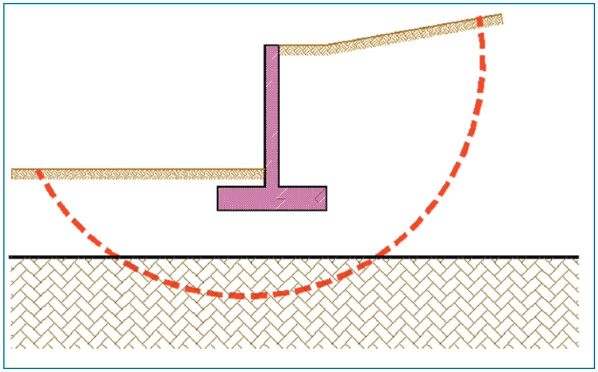

Fig. 2.1. Circle not valid because of penetration into the rock layer

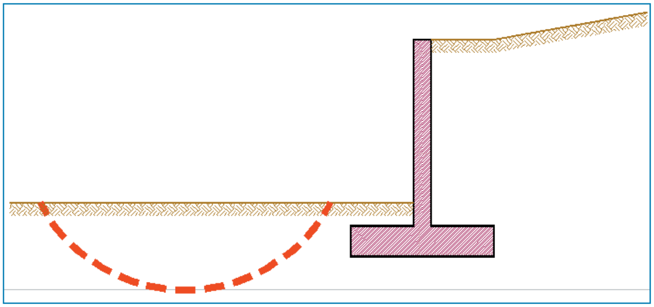

Fig. 2.2. Circle not valid because it does not contain a soil elevation change

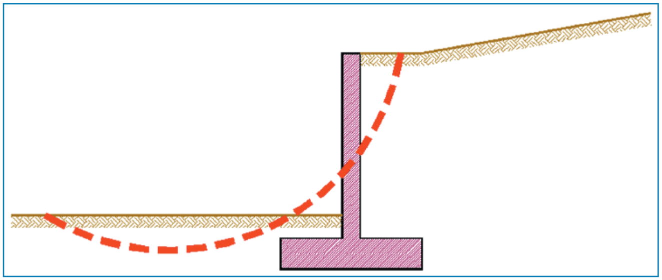

Fig. 2.3. Circle not valid because part of it does not cut through a soil layer

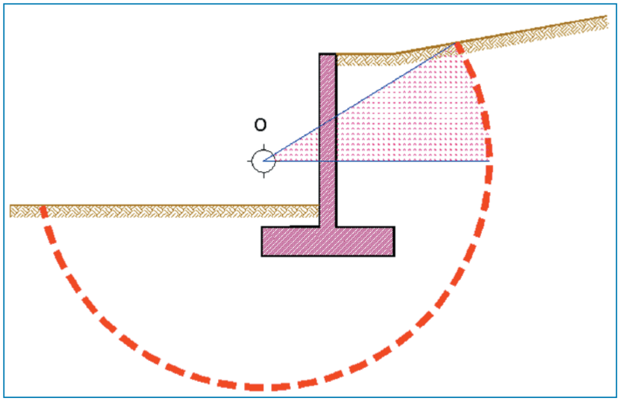

Fig. 2.4. Circle not valid because the centre of the circle lies below some of the intersection points of the circle with the soil.

3. Reference bibliography

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V. **FOUNDATIONS. W.E.** Schulze and K. Simmer. Ed. Blume.

4. Example 1. Reinforced concrete walls

4.1. Worst case slip circle of a cantilever wall

4.1.1. Problem data

Observe the following figure. The task consists in checking the value of the minimum safety coefficient obtained using the **Reinforced Concrete Cantilever Walls** program.

Using the program, a worst case safety factor of 1.699 is obtained with the safety coefficient contour map for the proposed slip circles displayed in figure 4.2.

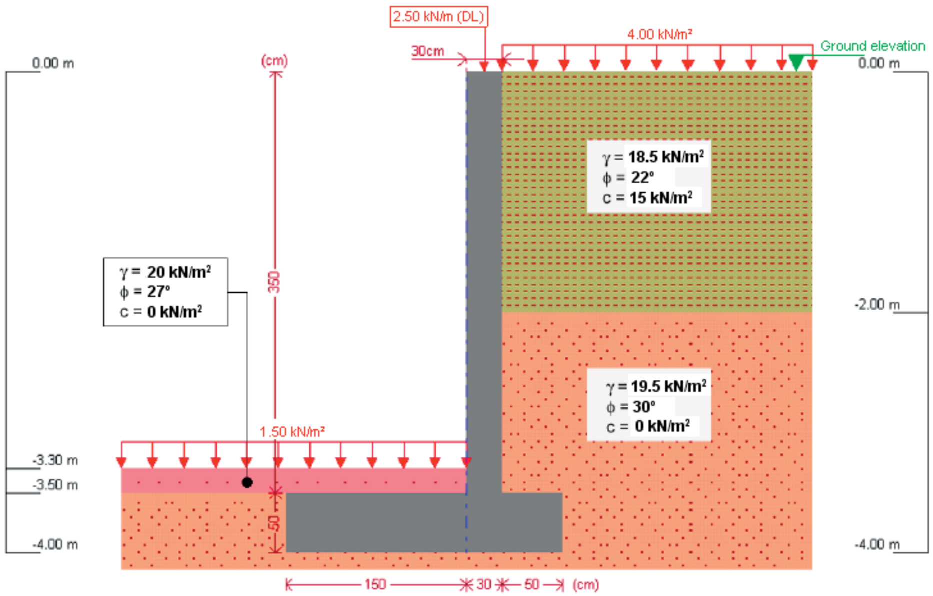

Fig. 4.1

4.1.2. Program results

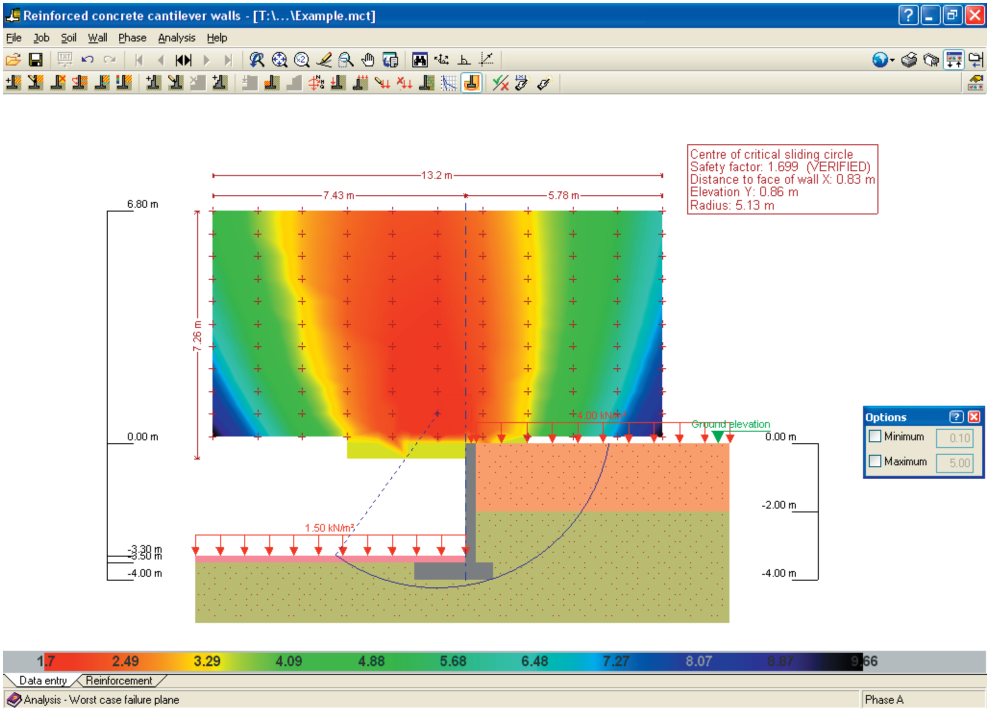

Fig. 4.2

To develop the problem, the slip circle in question is first of all drawn on the soil. It is then subdivided into slices or strips as shown in figure 4.3.

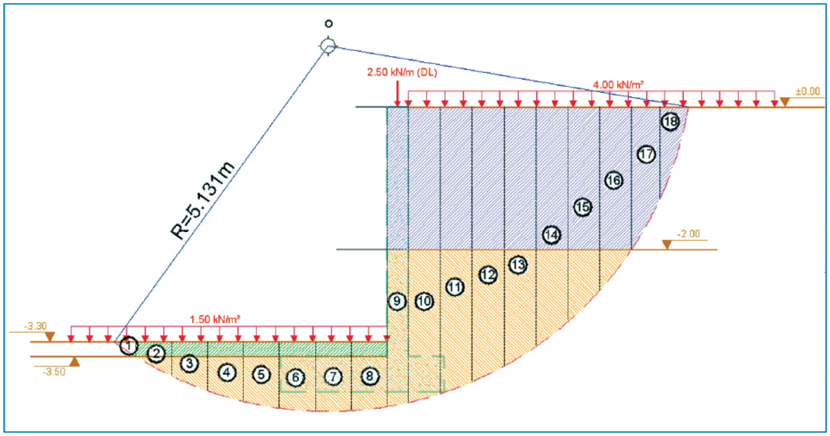

Fig 4.3

4.1.3. Calculations to compare with results of the program

A spreadsheet is used to compare the results of the programs which allows for the iteration process to be carried out to establish the safety coefficient of the circle being analysed.

Moment calculation of elements other than the soil:

Wall

Area of the wall (m) $= 2.03 \times 0.50 + 3.50 \times 0.30 = 2.20$ m^2

Specific weight of the wall[1] $= 6.0$ kN/m^3

X coordinate of the centre of gravity of the wall =-0.11136 m

Moment due to the weight of the wall =
$= 2.20$ m$^2 \times 6.0$ kN/m$^3 \times (0.825$ m $- 0.11136$ m$) = 9.42$ kN/m

[1]The specific weight of the wall is taken as 25.0 kN/m^2 minus the pondered mean specific weight of the soil along the height of the wall. The reason for this subtraction is because the existence of the wall is not considered in the method of slices, and so the effective weight must be taken as the difference in weight between the wall and the soil.

Surcharges

- Backfill

  Length of load on the backfill within the circle = $= (4.23384$ m $- 0.30$ m $) = 3.9338$ m

  Resultant of the load acting on the backfill = $= 3.9338$ m $\times 4.0$ kN/m$^2 = 15.7352$ kN/m

  Moment due to the load acting on the backfill = $= (0.5 \times 3.9338$ m $+ 0.30$ m $+ 0.825$ m$) \times 15.7352$ kN/m = $= 48.6517$ kNm/m

  Moment due to the load acting on the backfill / R= $= 48.6517$ kNm/m / 5.131 m $= 9.48121$ kNm/m

- Infill

  Length of load on the infill within the circle $= 3.82933$ m

  Resultant of the load acting on the infill= $= 3.82933$ m $\times 1.5$ kN/m$^2 = 5.74399$ kN/m

  Moment due to the load acting on the infill= $= (-0.5 \times 3.82933$ m $+ 0.825$ m$) \times 5.74399$ kN/m = $= -6.2590$ kNm/m

Moment due to the load acting on the infill / R = = -6.2590 kNm/m / 5.131 m = -1.2198 kNm/m

Moment due to the loads / R = = (48.6517 kNm/m – 6.2590 kN/m) / 5.131 m = = 8.2621 kNm/m

Load at top of the wall

Moment due to the vertical load at the top of the wall = = 2.5 kN/m × (0.825 m + 0.15 m) = 2.4375 kNm/m

Moment due to the vertical load at the top of the wall / R = = 2.4375 / 5.131 = 0.4751 kNm/m

The spreadsheet used to carry out the check is displayed below. This table shows the data of the slices and the values calculated above.

Conclusion

As can be seen, the calculation provides the same safety coefficient for the circle as the program, i.e.:

Safety coefficient = 1.699

Job: Reinforced concrete cantilever wall example

Infill top soil	Backfill top soil
Elev = -3,30 m Ø = 27,0º γ = 20,00 kN/m³ c = 0,00 kN/m²	Elev = 0,00 m Ø = 22,0º γ = 18,50 kN/m³ c = 15,00 kN/m²
Infill bottom soil	**Backfill bottom soil**
Elev = -3,50 m Ø = 30,0º γ = 19,50 kN/m³ c = 0,00 kN/m²	Elev = -2,00 m Ø = 30,0º γ = 19,50 kN/m³ c = 0,00 kN/m²

Worst case slip circle
X = -0,825 m
Elev = 0,860 m
R = 5,131 m

Unit radius moments:
Moment due to the effective weight of the wall= 1,690 kNm/m
Moment due to backfill loads= 9,481 kNm/m
Moment due to infill loads= -1,220 kNm/m
Resultant moment = 8,261 kNm/m
Moment due to load at top of wall= 0,475 kNm/m

Safety Coeff. = 1,699

Slice Nº	X [m]	Elev [m]	Zone	b [m]	α [º]	tan α	cos α	sin α	W [kN/m]	Δ loads [kN/m]	c * b [kN/m]	tan Ø	tan Ø*(W+Δloads) [kN/m]	m α	Numerator	Denominator
1	-3,6801	-3,4000	Infill	0,2984	-33,8306º	-0,67022	0,83069	-0,55674	0,5968	0,4476	0,0000	0,50953	0,5322	0,6637	0,8018	-0,3323
2	-3,2787	-3,6376	Infill	0,5044	-28,6151º	-0,54556	0,87786	-0,47892	3,3711	0,7566	0,0000	0,57735	2,3831	0,7151	3,3327	-1,6145
3	-2,7743	-3,8789	Infill	0,5044	-22,3591º	-0,41133	0,92482	-0,38041	5,7449	0,7566	0,0000	0,57735	3,7536	0,7955	4,7185	-2,1854
4	-2,2699	-4,0568	Infill	0,5044	-16,3762º	-0,29387	0,95943	-0,28194	7,4943	0,7566	0,0000	0,57735	4,7637	0,8636	5,5161	-2,1130
5	-1,7655	-4,1780	Infill	0,5044	-10,5739º	-0,18667	0,98302	-0,18350	8,6864	0,7566	0,0000	0,57735	5,4519	0,9206	5,9218	-1,5940
6	-1,2610	-4,2466	Infill	0,5044	-4,8805º	-0,08539	0,99637	-0,08508	9,3613	0,7566	0,0000	0,57735	5,8416	0,9675	6,0381	-0,7964
7	-0,7566	-4,2648	Infill	0,5044	0,7644º	0,01334	0,99991	0,01334	9,5400	0,7566	0,0000	0,57735	5,9448	1,0044	5,9185	0,1273
8	-0,2522	-4,2330	Infill	0,5044	6,4168º	0,11247	0,99374	0,11176	9,2279	0,7566	0,0000	0,57735	5,7646	1,0317	5,5873	1,0313
9	0,1500	-4,1756	Backfill	0,3000	10,9580º	0,19362	0,98177	0,19009	23,8274	1,2000	0,0000	0,57735	14,4496	1,0464	13,8092	4,5294
10	0,5240	-4,0855	Backfill	0,4479	15,2572º	0,27277	0,96475	0,26315	34,7895	1,7917	0,0000	0,57735	21,1202	1,0542	20,0343	9,1549
11	0,9719	-3,9406	Backfill	0,4479	20,5213º	0,37431	0,93654	0,35056	33,5236	1,7917	0,0000	0,57735	20,3893	1,0557	19,3136	11,7519
12	1,4198	-3,7476	Backfill	0,4479	25,9752º	0,48720	0,89898	0,43798	31,8383	1,7917	0,0000	0,57735	19,4163	1,0479	18,5296	13,9446
13	1,8678	-3,5002	Backfill	0,4479	31,6985º	0,61758	0,85082	0,52545	29,6771	1,7917	0,0000	0,57735	18,1685	1,0294	17,6492	15,5938
14	2,3157	-3,1881	Backfill	0,4479	37,8057º	0,77584	0,79009	0,61299	26,9512	1,7917	0,0000	0,57735	16,5948	0,9984	16,6205	16,5207
15	2,7636	-2,7944	Backfill	0,4479	44,4794º	0,98199	0,71350	0,70065	23,5125	1,7917	0,0000	0,57735	14,6094	0,9517	15,3516	16,4741
16	3,2115	-2,2872	Backfill	0,4479	52,0569º	1,28256	0,61488	0,78862	19,0824	1,7917	0,0000	0,57735	12,0517	0,8829	13,6496	15,0488
17	3,6351	-1,6446	Backfill	0,3992	60,6834º	1,78077	0,48963	0,87193	12,1446	1,5967	5,9875	0,40403	5,5519	0,6970	16,5551	10,5893
18	4,0343	-0,6446	Backfill	0,3992	72,7958º	3,22964	0,29578	0,95526	4,7600	1,5967	5,9875	0,40403	2,5683	0,5230	16,3592	4,5470
														Totals -->	205,7068	110,6776
															205,707	**121,104**

Safety Coeff. = 1,699
Tolerance 0,0000

Fig. 4.4

5. Example 2. Embedded retaining walls

5.1. Worst case slip circle for any phase of a retaining wall

5.1.1. Problem data

Observe the following figure. The task consists in checking the value of the minimum safety coefficient obtained using the **Embedded retaining walls** program.

Using the program, a worst case safety factor of 3.726 is obtained with the safety coefficient contour map for the proposed slip circles displayed in figure 5.2.

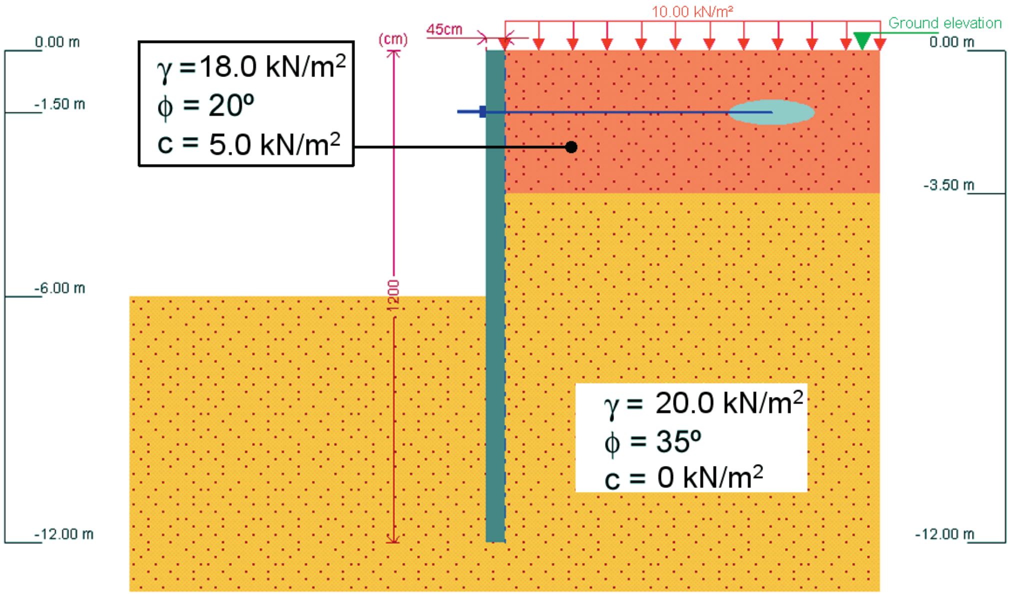

Fig. 5.1

5.1.2. Program results

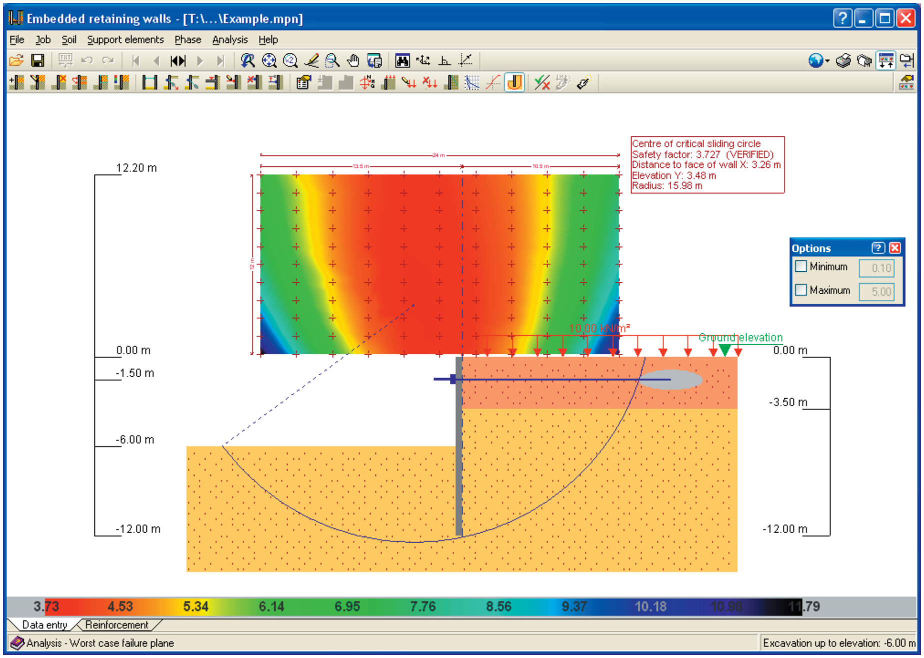

Fig. 5.2

To develop the problem, the slip circle in question is first of all drawn on the soil. It is then subdivided into slices or strips as shown in figure 5.3.

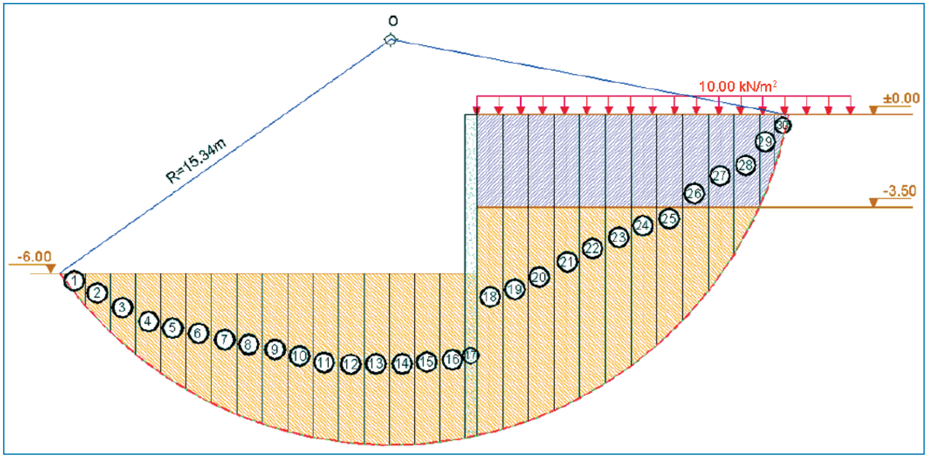

Fig. 5.3

5.1.3. Calculations to compare with results of the program

Once again, a spreadsheet is used to compare the results of the programs which allows for the iteration process to be carried out to establish the safety coefficient of the circle being analysed.

Moment calculation of elements other than the soil:

Wall

Area of the wall = (0.45×12) m^2 = 5.40 m^2

Specific weight of the wall [1] = 5.583 kN/m^3

> [1] The specific weight of the wall is taken as 25.0 kN/m^2 minus the pondered mean specific weight of the soil along the height of the wall. The reason for this subtraction is because the existence of the wall is not considered in the method of slices, and so the effective weight must be taken as the difference in weight between the wall and the soil.

X coordinate of the centre of gravity of the wall = -0.225 m

Moment due to the weight of the wall =
= 5.40 m^2 × 5.583 kN/m3 × (3.26 m – 0.225 m)=
= 9.15 kN/m

Surcharges

- Backfill

  Length of load on the backfill within the circle = 11.8148 m

  Resultant of the load acting on the backfill =
  = 11.8148 × 10 kN/m^2 = 118.148 kN/m

  Moment due to the load acting on the backfill =
  = (0.5 × 11.8148 m + 3.26 m) × 118.148 kN/m
  = 1083.110 kNm/m

  Moment due to the loads acting on the backfill / R =
  = 1083.110 kN/m / 15.34 m = 70.607 kNm/m

The spreadsheet used to carry out the check is displayed below. This table shows the data of the slices and the values calculated above.

Conclusion

As can be seen, the calculation provides the same safety coefficient for the circle as the program, i.e.:

Safety coefficient = 3.726

Job: Embedded retaining wall example

Infill top soil	Backfill top soil
Elev = -10000,00 m Ø = 0,0º γ = 0,00 kN/m³ c = 0,00 kN/m²	Elev = 0,00 m Ø = 20,0º γ = 18,00 kN/m³ c = 5,00 kN/m²
Infill bottom soil	**Backfill bottom soil**
Elev = -6,00 m Ø = 35,0º γ = 20,00 kN/m³ c = 0,00 kN/m²	Elev = -3,50 m Ø = 35,0º γ = 20,00 kN/m³ c = 0,00 kN/m²

Worst case slip circle
X = -3,260 m
Elev = 2,840 m
R = 15,340 m

Moment due to the effective weight of the wall = 5,458 kN·m/m
Moment due to backfill loads = 70,607 kN·m/m
Moment due to infill loads = 0,000 kN·m/m
Resultant moment = 70,607 kN·m/m
Moment due to load at top of wall = 0,000 kN·m/m
Unit radius moments

Safety Coeff. = 3,726

Slice Nº	X [m]	Elev [m]	Zone	b [m]	α [º]	tan α	cos α	sin α	W [kN/m]	Δ loads [kN/m]	c * b [kN/m]	tan Ø	tan Ø*(W+Δ loads) [kN/m]	m α	Numerator	Denorminator
1	-15,3172	-6,6118	Infill	0,9592	-51,9066º	-1,27565	0,61695	-0,78701	11,7361	0,0000	0,0000	0,70021	8,2177	0,4690	17,5200	-9,2364
2	-14,3580	-7,7272	Infill	0,9592	-46,4033º	-1,05023	0,68958	-0,72421	33,1344	0,0000	0,0000	0,70021	23,2010	0,5535	41,9184	-23,9963
3	-13,3988	-8,6540	Infill	0,9592	-41,4155º	-0,88210	0,74993	-0,66151	50,9120	0,0000	0,0000	0,70021	35,6490	0,6256	56,9822	-33,6791
4	-12,4396	-9,4356	Infill	0,9592	-36,7889º	-0,74779	0,80085	-0,59887	65,9072	0,0000	0,0000	0,70021	46,1487	0,6883	67,0470	-39,4698
5	-11,4805	-10,0990	Infill	0,9592	-32,4289º	-0,63533	0,84406	-0,53625	78,6321	0,0000	0,0000	0,70021	55,0588	0,7433	74,0753	-42,1667
6	-10,5213	-10,6616	Infill	0,9592	-28,2719º	-0,53781	0,88071	-0,47366	89,4251	0,0000	0,0000	0,70021	62,6161	0,7917	79,0909	-42,3567
7	-9,5621	-11,1358	Infill	0,9592	-24,2722º	-0,45093	0,91160	-0,41107	98,5216	0,0000	0,0000	0,70021	68,9856	0,8344	82,6817	-40,4994
8	-8,6030	-11,5303	Infill	0,9592	-20,3954º	-0,37180	0,93731	-0,34850	106,0909	0,0000	0,0000	0,70021	74,2856	0,8718	85,2077	-36,9723
9	-7,6438	-11,8518	Infill	0,9592	-16,6143º	-0,29838	0,95825	-0,28593	112,2567	0,0000	0,0000	0,70021	78,6030	0,9045	86,9004	-32,0972
10	-6,6846	-12,1047	Infill	0,9592	-12,9066º	-0,22915	0,97474	-0,22336	117,1101	0,0000	0,0000	0,70021	82,0014	0,9328	87,9126	-26,1580
11	-5,7254	-12,2928	Infill	0,9592	-9,2534º	-0,16292	0,98699	-0,16080	120,7172	0,0000	0,0000	0,70021	84,5271	0,9568	88,3465	-19,4114
12	-4,7663	-12,4183	Infill	0,9592	-5,6379º	-0,09872	0,99516	-0,09824	123,1243	0,0000	0,0000	0,70021	86,2126	0,9767	88,2692	-12,0958
13	-3,8071	-12,4827	Infill	0,9592	-2,0449º	-0,03571	0,99936	-0,03568	124,3610	0,0000	0,0000	0,70021	87,0785	0,9927	87,7226	-4,4375
14	-2,8479	-12,4870	Infill	0,9592	1,5400º	0,02689	0,99964	0,02688	124,4422	0,0000	0,0000	0,70021	87,1353	1,0047	86,7286	3,3445
15	-1,8888	-12,4310	Infill	0,9592	5,1311º	0,08979	0,99599	0,08943	123,3687	0,0000	0,0000	0,70021	86,3837	1,0128	85,2920	11,0334
16	-0,9296	-12,3142	Infill	0,9592	8,7425º	0,15378	0,98838	0,15199	121,1278	0,0000	0,0000	0,70021	84,8146	1,0169	83,4013	18,4106
17	-0,2250	-12,1950	Infill	0,4500	11,4125º	0,20186	0,98023	0,19787	55,7551	0,0000	0,0000	0,70021	39,0402	1,0174	38,3720	11,0323
18	0,4868	-12,0269	Backfill	0,9735	14,1451º	0,25202	0,96968	0,24438	227,3504	9,7350	0,0000	0,70021	166,0090	1,0156	163,4583	55,5595
19	1,4603	-11,7467	Backfill	0,9735	17,9315º	0,32360	0,95143	0,30788	221,8953	9,7350	0,0000	0,70021	162,1893	1,0093	160,6974	68,3172
20	2,4338	-11,3945	Backfill	0,9735	21,8012º	0,40000	0,92848	0,37139	215,0377	9,7350	0,0000	0,70021	157,3875	0,9983	157,6601	79,8623
21	3,4073	-10,9647	Backfill	0,9735	25,7791º	0,48297	0,90048	0,43490	206,6698	9,7350	0,0000	0,70021	151,5283	0,9822	154,2732	89,8812
22	4,3808	-10,4498	Backfill	0,9735	29,8961º	0,57493	0,86693	0,49843	196,6439	9,7350	0,0000	0,70021	144,5081	0,9606	150,4354	98,0129
23	5,3543	-9,8393	Backfill	0,9735	34,1921º	0,67940	0,82716	0,56197	184,7565	9,7350	0,0000	0,70021	136,1844	0,9328	146,0005	103,8275
24	6,3278	-9,1183	Backfill	0,9735	38,7215º	0,80177	0,78020	0,62554	170,7194	9,7350	0,0000	0,70021	126,3555	0,8978	140,7468	106,7910
25	7,3013	-8,2651	Backfill	0,9735	43,5621º	0,95103	0,72463	0,68914	154,1080	9,7350	0,0000	0,70021	114,7241	0,8541	134,3161	106,2021
26	8,2748	-7,2455	Backfill	0,9735	48,8349º	1,14370	0,65823	0,75282	134,2561	9,7350	0,0000	0,70021	100,8237	0,7997	126,0762	101,0702
27	9,2483	-6,0001	Backfill	0,9735	54,7497º	1,41495	0,57715	0,81664	110,0076	9,7350	0,0000	0,70021	83,8447	0,7306	114,7586	89,8364
28	10,2218	-4,4057	Backfill	0,9735	61,7445º	1,86066	0,47340	0,88085	78,9644	9,7350	0,0000	0,70021	62,1080	0,6389	97,2050	69,5554
29	10,9851	-2,8017	Backfill	0,5531	68,3943º	2,52498	0,36822	0,92974	27,8948	5,5314	2,7657	0,36397	12,1661	0,4590	32,5285	25,9349
30	11,5382	-1,0517	Backfill	0,5531	75,2659º	3,80255	0,25433	0,96712	10,4709	5,5314	2,7657	0,36397	5,8244	0,3488	24,6270	10,1266
														Totals -->	2840,2517	686,2214
															2840,252	**762,286**

Safety Coeff. = 3,726
Tolerance = 0,0000

Fig. 5.4