

## OPTIMIZATION OF THE STABILITY FACTORS OF HIGH CONCRETE RETAINING WALLS WITH REINFORCED CONCRETE CONSOLE

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### ABSTRACT

*Retaining concrete walls with reinforced concrete console are used for altitudes up to 10m, and their construction significantly reduces the weight of a concrete gravity retaining wall. Design and construction of reinforced concrete console on a high concrete retaining wall is about analyzing the position and dimensions of the console in relation to the top of the retaining wall. For the optimization analysis of the factors of stability of high concrete retaining walls with reinforced concrete console, the geostatic calculation for walls heights of 5m and 6m was done, with different position and width of reinforced concrete console. For an adequate analysis required soil parameters were adopted which are the same for all analyzed models of retaining walls with reinforced concrete console.*

**Keywords:** high concrete retaining wall, reinforced concrete console, soil parameters

### 1. RETAINING WALL CHARACTERISTICS

For the analyzed models of retaining walls of 5m and 6m heights with reinforced concrete console, the following characteristics were adopted:

- a) Front of the retaining wall is in the slope, actually the top of the wall is 50 cm thick, and section of the wall at the junction with foundation has a thickness of 60cm,
- b) Front overhang of the retaining wall foundation is 25cm,
- c) The width of foundation of analyzed models of retaining walls is 400cm,
- d) Thickness of reinforced concrete console is 30cm and has a constant cross section,
- e) Length of reinforced concrete console is variable and is 100cm, 150cm and 200cm
- f) Position of the reinforced concrete console from the ground surface behind the wall is 100cm and 200cm.

According to Eurocode 2 it is provided the same quality of concrete for all the analyzed models. In all analyzed cases the top of the retaining wall is 20cm higher than the ground behind the wall. Behind the retaining wall there is no additional external influences or additional burdens, which means that the retaining wall is only influenced by lateral soil pressure behind the wall.

## 2. SOIL CHARACTERISTICS

For all the analyzed models of high concrete retaining walls with reinforced concrete console, the same soil parameters in front, behind and beneath the supporting structure were adopted:

- The soil beneath the foundation structure of retaining wall is composed of clayey gravel and mixture of gravel, sand and clay, and the parameters of clayey gravel are  $\gamma=18,0 \text{ kN/m}^3$  ;  $c=20,0 \text{ kN/m}^2$  ;  $\varphi=33^\circ$ , while the parameters of gravel, sand and clay mixture are  $\gamma=20,0 \text{ kN/m}^3$  ;  $c=5,0 \text{ kN/m}^2$  ;  $\varphi=25^\circ$ ,
- The soil behind the retaining wall is composed of two layers, graded gravel and clayey gravel. Parameters of clayey gravel are  $\gamma=22,0 \text{ kN/m}^3$  ;  $c=0,0 \text{ kN/m}^2$  ;  $\varphi=25^\circ$ , and parameters of graded gravel are  $\gamma=18,0 \text{ kN/m}^3$  ;  $c=10,0 \text{ kN/m}^2$  ;  $\varphi=30^\circ$ ,
- The soil in front of the retaining wall is composed of graded gravel and clayey gravel, with parameters of clayey gravel of  $\gamma=20,0 \text{ kN/m}^3$  ;  $c=15,0 \text{ kN/m}^2$  ;  $\varphi=30^\circ$ .

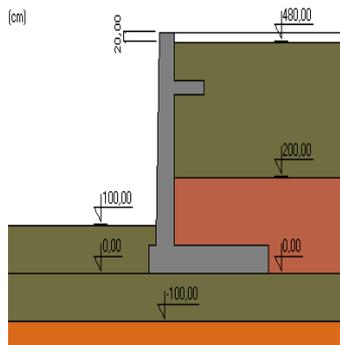


Figure 1. Characteristics of retaining wall and soil

## 3. ANALYSIS OF EXTERNAL STABILITY OF RETAINING WALL HEIGHT OF 5,0m

The position of reinforced concrete console is  $h=100\text{cm}$  from the ground surface. The analyzed cases were those ones with the console width of 100cm, 150cm and 200cm.

8			
7			
6			
5			
4			F
3			F
2			
1			
0			
	l=100	l=150c	l=200c
F	6,20	6,80	7,17
F	1,64	1,77	1,87

Figure 2. Safety factors for the wall with height of 500cm and the position of console of 100 cm from the ground surface.

Figure 2 shows the comparative results of safety factor on overturning  $F_s$  and safety factor on sliding  $F_s$  for different console widths. For the console width of 200 cm and at the distance of  $h=100 \text{ cm}$  from the ground surface there are the highest safety factors on overturning and sliding:  $F_s=7,177$  and  $F_s=1,878$ .

The position of reinforced concrete console from the ground surface is  $h=200\text{cm}$ . The analyzed cases were those ones with the console width of 100cm, 150cm and 200cm.

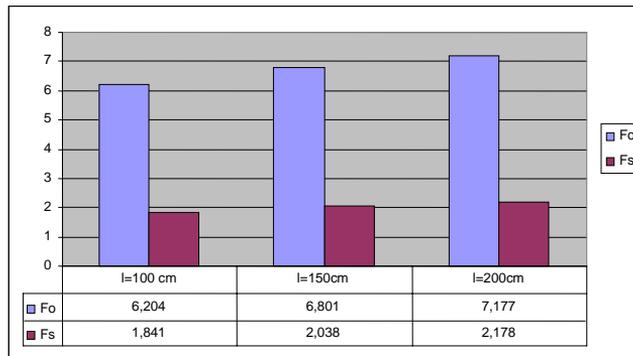


Figure 3. Safety factors for the wall with height of 500cm and the position of console of 200 cm from the ground surface.

Figure 3 shows the results of safety factors on overturning  $F_o$  and safety factors on sliding  $F_s$  for the console width of 200 cm at the distance of  $h=200\text{cm}$  from the ground surface. The highest results of safety factors on overturning and sliding are  $F_s=7,177$  and  $F_s=2,178$ , which was to be expected given the increasing weight of soil on the console, which is on greater depth than the ground surface.

#### 4. ANALYSIS OF EXTERNAL STABILITY OF RETAINING WALL HEIGHT OF 6,0m

The position of reinforced concrete console from the ground surface is  $h=100\text{cm}$ . The analyzed cases were those ones with the console width of 100cm, 150cm and 200cm.

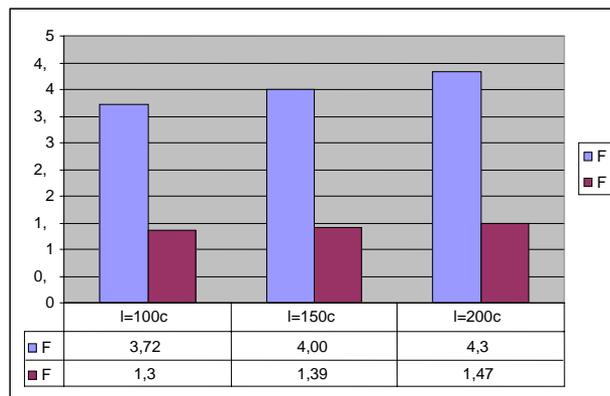


Figure 4. Safety factors for the wall with height of 600cm and the position of console of 100 cm from the ground surface.

Figure 4 shows the comparative results of safety factor on overturning  $F_s$  and safety factor on sliding  $F_s$  for different console widths. For the console width of 200 cm and at the distance of  $h=100\text{ cm}$  from the ground surface there are the highest safety factors on overturning and sliding:  $F_s=4,340$  and  $F_s=1,475$  that does not meet the conditions of stability for a given geometry of the retaining wall and soil parameters and the stability of the slide is not satisfactory for either the width of the console. For reasons of not meeting the conditions of stability of the slide, it is necessary to change the geometry of the foundation of the retaining wall with a sloped bottom edge of foundation, or increasing the width of the foundation.

The position of reinforced concrete console from the ground surface is  $h=200\text{cm}$ . The analyzed cases were those ones with the console width of 100cm, 150cm and 200cm.

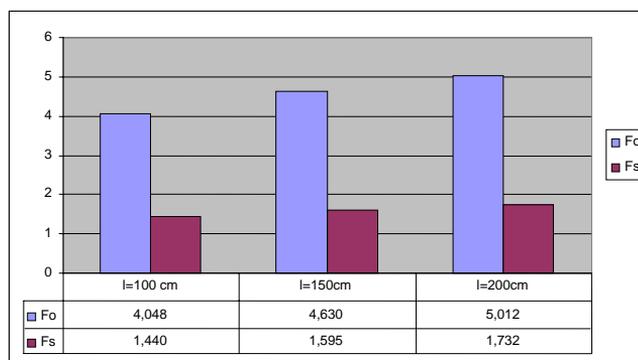


Figure 5. Safety factors for the wall with height of 600cm and the position of console of 200 cm from the ground surface.

Figure 5 shows the safety factor on overturning and sliding for the position of reinforced concrete console 200cm from the ground surface. We obtained the highest safety factors of overturning and sliding of  $F_s=5.012$  and  $F_s=1.732$ , while the sliding safety factor is not acceptable for the console width of 100cm and is  $F_s=1.440$ , which is at a distance of 200cm from the ground surface.

## 5. CONCLUSIONS

Analyzing the retaining concrete walls with height of 5.0 m and 6.0 m with reinforced concrete consoles that are at a distance of 100 cm and 200 cm of the ground surface and whose widths were 100cm, 150cm and 200cm with the adopted geometry of the retaining wall and the same soil parameters for all analyzed models, we conclude the following:

- Factors of safety on overturning and sliding of the retaining wall height of 5.0 m whose reinforced concrete console is at a distance of 100 cm of the surface ground, satisfy the conditions of stability.
- Factors of safety on overturning and sliding of the retaining wall height of 5.0 m whose reinforced concrete console is at a distance of 200 cm of the surface ground, satisfy the conditions of stability.
- Factors of safety on overturning and sliding of the retaining wall height of 6.0 m whose reinforced concrete console is at a distance of 100 cm of the surface ground, satisfy the conditions of stability, while the safety factors on sliding are not satisfactory for either analyzed width of the console.
- Factors of safety on overturning of the retaining wall height of 6.0 m, whose reinforced concrete console is at a distance of 200 cm of the surface ground, satisfy the conditions of stability, while the safety factor on sliding is not satisfactory for the width console of 100 cm. By increasing the width of the console to 150cm and 200cm, the vertical force or the weight of filling material on the console is increasing, which increases the safety factor of sliding as well.

## 6. REFERENCES

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