DETERMINATION OF POSSIBILITIES OF THE ACTIVE LATERAL EARTH PRESSURE ON ABUTMENT WALLS OF ENLARGED ROADWAYS

Carmen Georgeta FLOREA, Adrian Alexandru DRESCHER*, Vlad Alexandru FLOREA**

Roads are often the object of modernisation works, especially widening works. Therefore, where the slope needs reinforcements, the determination of a redesign of abutment walls is compulsory.

Keywords: reinforcement, slope, abutment wall, lateral active pressure.

Introduction

Slope reinforcement works of roadways imply the design of works in order to support them.

The common practice is to stabilise the slope with backfill or embankment concrete wall comprising the following operations:

1. Creating the charging platform;
2. Digging and supporting the embankment;
3. Foundation execution;
4. Elevation execution;
5. Back drainage execution;

The concrete reinforcement works for the construction of backfilling and embankment walls need to be correlated both with the necessities required by the improvement of geometric elements of the trajectory as well as with the need of eliminating the danger from unstable slope areas and are executed where the centre of the designed road has moved either towards the surety or the slope and no other reinforcement works can be made. Therefore, the area is geotechnically analysed, highlighting the nature of the terrain. The paper analyses the possibility to design and execution of reinforcement works for the support of a right slope of a national road in Hunedoara County the roadway of which needs to be widened. The high eclecticism of the material in the area, namely rock fragments in sandy mass, makes the establishment of resistance characteristics difficult through laboratory trials on unaffected samples, and with a representative characteristic of results. It is difficult to collect samples from such an unaffected material, and in the same time to ensure a corresponding scale factor in order to be able to model the load behaviour of the clay-bearing sandy rock fragments, (the dimension of the usual samples are comparable to rock fragments).

The geotechnical resistance characteristics of these materials (dusty sand mixed with cement and sandy clay comprising rock fragments) are mainly given by fine cohesive earth in their composition, being the ones to give their geological behaviour to water. Therefore, the design solution was made starting from the resistance characteristics of the soil which had been indirectly established through parametric determinations, considering at first the physical characteristics of the material and STAS 3300/1-85 recommendations.

Considering, both the nature and configuration of the terrain, with slopes of approximately 40°, the stability and conditions for ensuring it necessary for excavations required by the concrete abutment wall, were imposed.

The determination of the stability to sliding has been made using the Bishop method.

Verifying the stability to sliding implied as well the determination of resistance characteristics of the soil and establishing them by a parametric determination. The static and pseudostatic determination was made for the seismic acceleration a = 0.08g, (the configuration of the ground being that preceding the execution of reinforcement works), the purpose of which is to verify the resistance characteristics of the ground and establishing them using a parametric determination.

The determination was made for the profile presented in figure 1 considering an unfavourable configuration of the ground. The minimum value of this basic characteristic of the ground – cohesion – considering the limit assurance of sliding stability, resulted in this step:

$$c = 35 \text{ kPa}$$

Classifying the soil in the studied area as soft rocks characterised by resistance parameters mentioned above, implies the use of backfill slopes as it is mentioned in the speciality literature, of a 1:1 ratio for slopes of 5.0m. Due to terrain configuration, the excavation necessary for the abutment wall requires in its turn extra-excavation towards he peak of the slope. Adopting the solution using backfill slopes depends on their required geometry; a total volume of extra-excavation of approximately 450 m^3/ml with 3.0m berms between the backfillings. Adopting a backfill slope of 2:1, and considering the temporary characteristic of the excavation, the total volume would reduce to

* *University of Petroşani*

approximately 300 m^3/ml. Another thing remaining to be done, besides these excavation volumes, is the wall emplacement. These excavations reach somewhere around 10m while their supports in order to maintain traffic conditions in the area, represent a great problem.

Therefore, the method of the wall on a certain segment will be completed with a support method made with anchored plates (for areas with large heights, over 4.0m). This kind of solution reduces the volume of the excavation to approximately 26 m^3/ml and facilitates the execution, on steps, downward, with no important implications on ensuring the requirements of the traffic.

Designing an abutment wall

Geotechnically speaking, on the studied place, an abutment wall in reinforced concrete will be designed (Figure 1) which will meet the resistance and stability for such civil construction elements. The steps taken for the determinations are the following:

1. Determining the active pressure (in Coulomb's hypothesis);
2. The determination of the resultants of the active pressures acting on the wall;
3. Checking the abutment wall for:
   a) Stability to tilting;
   b) Stability to sliding;
   c) Pressures on the bearing surface of the foundation of the wall.
4. Determining the reinforcement of the abutment.

Form characteristics of the abutment wall correspond to those presented in Figure 1.

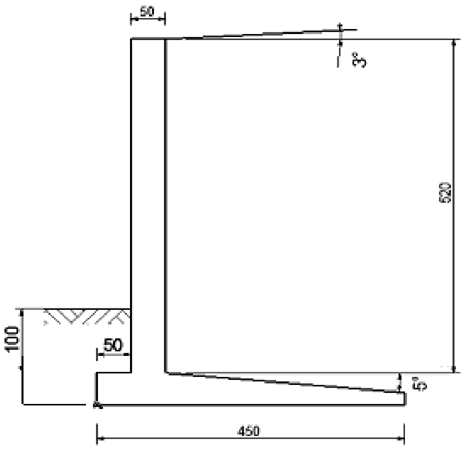

Figure 1 Abutment wall profile

H – Elevation height – 5.2 m
D – Foundation height – 1.0 m

Determining the coefficients of active lateral earth pressure (k_a)

k_a coefficients are used for the determination of earth's pressure on the element of construction, considering the layers of the material placed behind the abutment wall.

The design of the wall is made on the layers of the drilling considering its inclination at an angle β = 3°.

$$k_a = \frac{\sin^2(\theta+\varphi)}{\sin^2\theta \cdot \sin(\theta-\delta)\cdot\left[1+\sqrt{\frac{\sin(\varphi+\delta)\cdot\sin(\varphi-\beta)}{\sin(\theta-\delta)\cdot\sin(\theta+\beta)}}\right]^2}$$

where: φ – is the internal friction angle of the ground

θ – the inclination angle of the bearing surface of the foundation

δ – the inclination angle of the lateral earth pressure

Replacing them in relation (1) the values of the coefficient of pressure will be obtained:

For layer S1 (Figure 2) :

$h_1 = 1.70$ m ;

where h_1 is the height of layer 1

$\theta_1 = 90^\circ$;

$\varphi_1 = 17.60^\circ$;

$\delta_1 = \frac{1}{3}\varphi_1 = \frac{1}{3}\cdot 17.60^\circ = 5.87^\circ$

$\beta = 3^\circ$

$$k_{a1} = \frac{\sin^2(90^\circ+17.6^\circ)}{\sin^2 90^\circ\cdot\sin(90^\circ-5.87^\circ)\cdot\left[\left(1+\sqrt{\frac{\sin(17.6^\circ+5.87^\circ)\cdot\sin(17.6^\circ-3^\circ)}{\sin(90^\circ-5.87^\circ)\cdot\sin(90^\circ+3^\circ)}}\right)^2\right]} = 0.5259$$

for layer S2 (Figure 2):

$h_2 = 2.00$ m ;

where h_2 is the height of layer 2

$\theta_2 = 90^\circ$;

$\varphi_2 = 18.20^\circ$;

$\delta_2 = \frac{1}{3}\varphi_2 = \frac{1}{3}\cdot 18.20^\circ = 6.07^\circ$

$\beta = 3^\circ$

$$k_{a2} = \frac{\sin^2(90^\circ+18.2^\circ)}{\sin^2 90^\circ\cdot\sin(90^\circ-6.07^\circ)\cdot\left[\left(1+\sqrt{\frac{\sin(18.2^\circ+6.07^\circ)\cdot\sin(18.2^\circ-3^\circ)}{\sin(90^\circ-6.07^\circ)\cdot\sin(90^\circ+3^\circ)}}\right)^2\right]} = 0.5135$$

for layer S3 (Figure 2)

$h_3 = 1.50$ m;

where h_2 is the height of layer 2

$\theta_3 = 90^\circ$;

$\varphi_3 = 20.20^\circ$;

$\delta_3 = \frac{1}{3}\varphi_3 = \frac{1}{3}\cdot 20.20^\circ = 6.73^\circ$

$\beta = 3^\circ$

$$k_{a3} = \frac{\sin^2(90^\circ+20.2^\circ)}{\sin^2 90^\circ\cdot\sin(90^\circ-6.73^\circ)\cdot\left[\left(1+\sqrt{\frac{\sin(20.2^\circ+6.73^\circ)\cdot\sin(20.2^\circ-3^\circ)}{\sin(90^\circ-6.73^\circ)\cdot\sin(90^\circ+3^\circ)}}\right)^2\right]} = 0.4743$$

for layer S′3 (Figure 2)

$h'_3 = 0.306$ m;

where h'_3 is the height of layer $3'$

$\theta'_3 = 85^\circ$;

$\varphi'_3 = 20.20^\circ$;

$\delta'_3 = \frac{1}{3}\varphi'_3 = \frac{1}{3}\cdot 20.20^\circ = 6.73^\circ$

$\beta = 3^\circ$

$$k'_{a3} = \frac{\sin^2(85^\circ + 20.2^\circ)}{\sin^2 85^\circ \cdot \sin(85^\circ - 6.73^\circ)\cdot\left[\left(1+\sqrt{\frac{\sin(20.2^\circ + 6.73^\circ)\cdot\sin(20.2^\circ - 3^\circ)}{\sin(85^\circ - 6.73^\circ)\cdot\sin(85^\circ + 3^\circ)}}\right)^2\right]} = 0.5107$$

for layer $S''3$ (Figure 2)

$h''_3 = 0,194$ m ;

where h''_3 is the height of layer $3''$

$\theta''_3 = 90^\circ$;

$\varphi''_3 = 20.20^\circ$;

$\delta''_3 = \frac{1}{3}\varphi''_3 = \frac{1}{3}\cdot 20.20^\circ = 6.73^\circ$

$\beta = 3^\circ$

$$k''_{a3} = \frac{\sin^2(90^\circ + 20.2^\circ)}{\sin^2 90^\circ \cdot \sin(90^\circ - 6.73^\circ)\cdot\left[\left(1+\sqrt{\frac{\sin(20.2^\circ + 6.73^\circ)\cdot\sin(20.2^\circ - 3^\circ)}{\sin(90^\circ - 6.73^\circ)\cdot\sin(90^\circ + 3^\circ)}}\right)^2\right]} = 0.4743$$

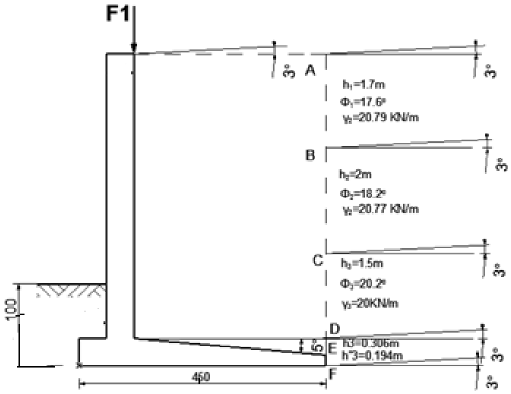

Figure 2 Layer of materials acting on the abutment wall (AB, BC, CD, DE, EF)

Establishing the distribution of the active lateral earth pressure

The determination of the active lateral earth pressure resultants acting on the abutment wall

Establishing the active pressures (p_a), as well as the total active lateral push, (P_a) is made analytically.

a) Establishing the distribution of the active pressure

$$p_a = \gamma \cdot h \cdot k_a \cdot \frac{\sin\theta}{\cos\delta}$$

For layer S1 (Figure 3):

$$p^1{}_{aA} = \gamma_1 \cdot h_0 \cdot k_{a1} \cdot \frac{\sin\theta_1}{\cos\delta_1} = 0$$

$$p^1{}_{aB} = \gamma_1 \cdot h_1 \cdot k_{a1} \cdot \frac{\sin\theta_1}{\cos\delta_1} = 20.79 \cdot 1.7 \cdot 0.5259 \cdot \frac{\sin 90^\circ}{\cos 5.87^\circ} = 18.68 kN/m^2$$

For layer S2 (Figure 3):

$$p^2{}_{aB} = \gamma_2 \cdot h_{e1} \cdot k_{a2} \cdot \frac{\sin\theta_2}{\cos\delta_2} = 20.77 \cdot 1.71 \cdot 0.5135 \cdot \frac{\sin 90^\circ}{\cos 6.07^\circ} = 18.34 kN/m^2$$

$$h_{e1} = \frac{\gamma_1 \cdot h_1}{\gamma_2} \cdot \frac{\sin\theta_2}{\sin(\theta_2 + \beta)} = \frac{20.79 \cdot 1.7}{20.77} \cdot \frac{\sin 90^\circ}{\sin(90^\circ + 3^\circ)} = 1.71 m$$

$$p^2{}_{aC} = \gamma_2 \cdot (h_{e1} + h_2) \cdot k_{a2} \cdot \frac{\sin\theta_2}{\cos\delta_2}$$

$$= 20.77 \cdot (1.71 + 2) \cdot 0.5135 \cdot \frac{\sin 90^\circ}{\cos 6.07^\circ} = 39.79 kN/m^2$$

For layer S3 (Figure 3):

$$p^3{}_{aC} = \gamma_3 \cdot h_{e2} \cdot k_{a3} \cdot \frac{\sin\theta_3}{\cos\delta_3} =$$

$$20 \cdot 3,85 \cdot 0,4743 \cdot \frac{\sin 90^\circ}{\cos 6,73^\circ} = 36,78 kN/m^2$$

$$h_{e2} = \frac{\gamma_1 \cdot h_1 + \gamma_2 \cdot h_2}{\gamma_3} \cdot \frac{\sin\theta_3}{\sin(\theta_3 + \beta)} =$$

$$\frac{20.79 \cdot 1.7 + 20.77 \cdot 2}{20} \cdot \frac{\sin 90^\circ}{\sin(90^\circ + 3^\circ)} = 3.85 m$$

$$p^3{}_{aD} = \gamma_3 \cdot (h_{e2} + h_3) \cdot k_{a3} \cdot \frac{\sin\theta_3}{\cos\delta_3} =$$

$$20 \cdot (3.85 + 1.5) \cdot 0.4734 \cdot \frac{\sin 90^\circ}{\cos 6.73^\circ} = 48.23 kN/m^2$$

For layer $S'3$ (Figure 3):

$$p'^3_{aD} = \gamma_3 \cdot h'_{e2} \cdot k'_{a3} \cdot \frac{\sin\theta'_3}{\cos\delta'_3} =$$

$$20 \cdot 5.35 \cdot 0.5107 \cdot \frac{\sin 90^\circ}{\cos 6.73^\circ} = 55.02 kN/m^2$$

$$h'_{e2} = \frac{\gamma_1 \cdot h_1 + \gamma_2 \cdot h_2 + \gamma_3 \cdot h_3}{\gamma'_3} \cdot \frac{\sin\theta'_3}{\sin(\theta'_3 + \beta)} =$$

$$\frac{20.79 \cdot 1.7 + 20.77 \cdot 2 + 20 \cdot 1.5}{20} \cdot \frac{\sin 90^\circ}{\sin(90^\circ + 3^\circ)} = 5.35 m$$

$$p'^3_{aE} = \gamma_3 \cdot (h'_{e2} + h'_3) \cdot k'_{a3} \cdot \frac{\sin\theta'_3}{\cos\delta'_3} =$$

$$20 \cdot (5.35 + 0.306) \cdot 0.5107 \cdot \frac{\sin 90^\circ}{\cos 6.73^\circ} = 91.12 kN/m^2$$

For layer $S''3$ (Figure 3):

$$p''^3_{aE} = \gamma_3 \cdot h''_{e2} \cdot k''_{a3} \cdot \frac{\sin\theta''_3}{\cos\delta''_3} =$$

$$20 \cdot 5.66 \cdot 0.4743 \cdot \frac{\sin 90^\circ}{\cos 6.73^\circ} = 54.06 kN/m^2$$

$$h''_{e2} = \frac{\gamma_1 \cdot h_1 + \gamma_2 \cdot h_2 + \gamma_3 \cdot h_3 + \gamma'_3 \cdot h'_3}{\gamma_3} \cdot \frac{\sin\theta''_3}{\sin(\theta''_3 + \beta)} =$$

$$\frac{20.79 \cdot 1.7 + 20.77 \cdot 2 + 20 \cdot 1.5 + 20 \cdot 0.306}{20} \cdot \frac{\sin 90^\circ}{\sin(90^\circ + 3^\circ)} = 5.66 m$$

$$p''^3_{aF} = \gamma_3 \cdot (h''_{e2} + h''_3) \cdot k''_{a3} \cdot \frac{\sin\theta''_3}{\cos\delta''_3} =$$

$$20 \cdot (5.66 + 0.194) \cdot 0.4743 \cdot \frac{\sin 90^\circ}{\cos 6.73^\circ} = 55.92 kN/m^2$$

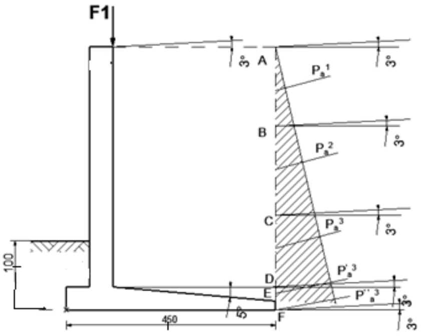

Figure 3 Distribution of lateral pressures

b) Active pressure resultants determination for layer S1 (Figure 3):

$$P_{a1} = \frac{1}{2}\cdot\gamma_1\cdot h_1^2\cdot k_{a1} = \frac{1}{2}\cdot 20.79\cdot 1.7^2\cdot 0.5259 = 15.8kN/m$$

For layer S2 (Figure 3):

$$P_{a2} = \frac{1}{2}\cdot\gamma_2\cdot h_2^2\cdot k_{a2}\cdot(1+\frac{2\cdot h_{e1}}{h_2}) =$$

$$\frac{1}{2}\cdot 20\cdot 2^2\cdot 0.5135\cdot(1+\frac{2\cdot 1.71}{2}) = 57.81kN/m$$

For layer S3 (Figure 3):

$$P_{a3} = \frac{1}{2}\cdot\gamma_3\cdot h_3^2\cdot k_{a3}\cdot(1+\frac{2\cdot h_{e2}}{h_3}) =$$

$$\frac{1}{2}\cdot 20\cdot 1.5^2\cdot 0.4743\cdot(1+\frac{2\cdot 3.85}{1.5}) = 65.45kN/m$$

$$k_F = tg^2\cdot(45^\circ - \frac{\varphi}{2}) = tg^2\cdot(45^\circ - \frac{20,2^\circ}{2}) = 0.487$$

$$P_F = \frac{1}{2}\cdot k_F\cdot\gamma_3\cdot {D_f}^2 = \frac{1}{2}\cdot 0.487\cdot 20\cdot 1^2 = 4.87kN/m$$

For layer S´3 (Figure 3):

$$P'_{a3} = \frac{1}{2}\cdot\gamma'_3\cdot h'^2_3\cdot k'_{a3}\cdot(1+\frac{2\cdot h'_{e2}}{h'_3}) =$$

$$\frac{1}{2}\cdot 20\cdot 0.306^2\cdot 0.5107\cdot(1+\frac{2\cdot 5.35}{0.306}) = 254.72kN/m$$

For layer S´´3 (Figure 3):

$$P''_{a3} = \frac{1}{2}\cdot\gamma''_3\cdot h''^2_3\cdot k''_{a3}\cdot(1+\frac{2\cdot h''_{e2}}{h''_3}) =$$

$$\frac{1}{2}\cdot 20\cdot 0.194^2\cdot 0.4743\cdot(1+\frac{2\cdot 5.66}{0.194}) = 10.59kN/m$$

c) Vertical and horizontal active pressure protections

$$P_{a1}{}^H = P_{a1}\cdot\cos(\beta+\delta_1) = 15.8\cdot\cos(3^\circ+5.87^\circ) = 15.61kN/m$$

$$P_{a1}{}^V = P_{a1}\cdot\sin(\beta+\delta_1) = 15.8\cdot\sin(3^\circ+5.87^\circ) = 2.44kN/m$$

$$P_{a2}{}^H = P_{a2}\cdot\cos(\beta+\delta_2) = 57.81\cdot\cos(3^\circ+6.07^\circ) = 57.09kN/m$$

$$P_{a2}{}^V = P_{a2}\cdot\sin(\beta+\delta_2) = 57.81\cdot\sin(3^\circ+6.07^\circ) = 9.11kN/m$$

$$P_{a3}{}^H = P_{a3}\cdot\cos(\beta+\delta_3) = 65.45\cdot\cos(3^\circ+6.73^\circ) = 64.51kN/m$$

$$P_{a3}{}^V = P_{a3}\cdot\sin(\beta+\delta_3) = 65.45\cdot\sin(3^\circ+6.73^\circ) = 11.06kN/m$$

$$P'_{a3}{}^H = P'_{a3}\cdot\cos(\beta+\delta'_3) = 254.72\cdot\cos(3^\circ+6.73^\circ) = 251.06kN/m$$

$$P'_{a3}{}^V = P'_{a3}\cdot\sin(\beta+\delta'_3) = 254.72\cdot\sin(3^\circ+6.73^\circ) = 43.05kN/m$$

$$P''_{a3}{}^H = P''_{a3}\cdot\cos(\beta+\delta''_3) = 10.59\cdot\cos(3^\circ+6.73^\circ) = 10.44kN/m$$

$$P''_{a3}{}^V = P''_{a3}\cdot\sin(\beta+\delta''_3) = 10.59\cdot\sin(3^\circ+6.73^\circ) = 1.79kN/m$$

$$P_F{}^H = P_F\cdot\cos(\beta+\delta_3) = 4.87\cdot\cos(0^\circ+6.73^\circ) = 4.83kN/m$$

$$P_F{}^V = P_F\cdot\sin(\beta+\delta_3) = 4.87\cdot\sin(0^\circ+6.73^\circ) = 0.57kN/m$$

Analytic examination of the abutment wall

The analytic examination of the abutment wall consists in the examination to tilting and sliding of the wall.

The determination of the weights of the abutment wall considering that $\gamma_{concrete} = 24.50$ kN/m^3 and it is made for a length of 1m.

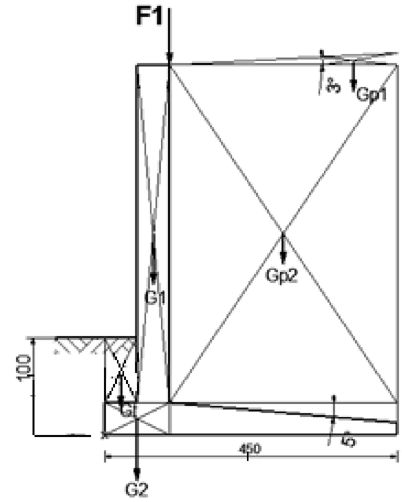

Figure 4 Determining the centre of gravity of the terrain

$$G_1 = A_1\cdot 1\cdot\gamma_b = 0.5\cdot 5.2\cdot 1\cdot 24.5 = 63.7kN$$

$$G_2 = A_2\cdot 1\cdot\gamma_b = 0.5\cdot 1\cdot 1\cdot 24.5 = 12.25kN$$

$$G_3 = A_3\cdot 1\cdot\gamma_b = 0.194\cdot 3.5\cdot 1\cdot 24.5 = 16.64kN$$

$$G_4 = A_4\cdot 1\cdot\gamma_b = \frac{0.306\cdot 3.5}{2}\cdot 1\cdot 24.5 = 13.12kN$$

$$G_t = A_t\cdot 1\cdot\gamma = 0.5\cdot 0.5\cdot 1\cdot 20 = 5kN$$

$$G_{p1} = A_{p1}\cdot 1\cdot\gamma = 0.18\cdot 3.5\cdot 1\cdot 20 = 12.84kN$$

$$G_{p2} = A_{P2}\cdot 1\cdot\gamma = 1.7\cdot 3.5\cdot 1\cdot 20.79 +$$
$$2\cdot 3.5\cdot 1\cdot 20.77 + 1.5\cdot 1\cdot 3.5\cdot 20 = 374.09kN$$

$$G_{p3} = A_{p3}\cdot 1\cdot\gamma = 0.5\cdot 0.306\cdot 3.5\cdot 1\cdot 20 = 10.71kN$$

Conclusions

a) The examination to tilt of the abutment wall is being made through the determination of the mentioned proportion F_{SR} of the stabilities and tilt to an inferior point of the foundation of the wall.

$$M_5 = G_1\cdot 0.75 + G_2\cdot 0.5 + G_3\cdot 2.75 + G_4\cdot 2.27 + G_t\cdot 0.25$$
$$+G_{p1}\cdot 3.33 + G_{p2}\cdot 2.75 + G_{p3}\cdot 3.33 + P^V{}_{a1}\cdot 1 + P^V{}_{a2}\cdot 1 + P^V{}_{a3}\cdot 1$$
$$+P''^V_{a3}\cdot 3.33 + P''^V_{a3}\cdot 4.5 = 63.7\cdot 0.75 + 12.25\cdot 0.5 + 16.64\cdot 2.75$$
$$+13.12\cdot 2.27 + 5\cdot 0.25 + 12.84\cdot 3.33 + 374.09\cdot 2.75 + 10.71\cdot 3.33$$
$$+2.44 + 9.11 + 11.06 + 43.05\cdot 3.33 + 1.79\cdot 4.5 = 1411.88kNm$$

$$M_r = P^H{}_{a1}\cdot 4.07 + P^H{}_{a2}\cdot 2.67 + P^H{}_{a3}\cdot 1 + P'^H_{a3}\cdot 0.298 + P''^H_{a3}\cdot 0.065$$
$$+P^H{}_F\cdot 0.67 = 15.61\cdot 4.07 + 57.09\cdot 2.67 + 64.51\cdot 1 + 251.06\cdot 0.298$$
$$+10.44\cdot 0.065 + 4.83\cdot 0.67 = 359.2kNm$$

$$F_{SR} = \frac{M_{stab}}{M_{rast}} = \frac{1411.88}{359.2} = 3.93\rangle 1.5$$

It results therefore that the wall does not tilt under the action of the forces exerted by the earth.

b) the examination to sliding of the wall is made through the determination of the mentioned ration F_{sl} of the sum of the vertical forces F^V as well as the horizontal ones F^H (for sandy clay considering a coefficient f = (0.3 … 0.5) taken from STAS 3300/2-85, with the condition:

$F_{sl} \geq (1.1 \ldots 1.5)$

$$\sum_{i=1}^{n} F_i^H = P^H{}_{a1} + P^H{}_{a2} + P^H{}_{a3} + P'^H_{a3} + P''^H_{a3} + P^H{}_F =$$

$$15.61 + 57.09 + 64.51 + 51.06 + 10.44 + 4.83 = 203.54kN$$

$$\sum_{i=1}^{n} F_i^V = P^V{}_{a1} + P^V{}_{a2} + P^V{}_{a3} + P'^V_{a3} + P''^V_{a3} + P^V{}_F + G_1 + G_2 + G_3 + G_4$$

$$+G_t + G_{p1} + G_{p2} + G_{p3} = 2.44 + 9.11 + 11.06 + 43.05 + 1.79 + 0.57$$

$$+63.7 + 12.25 + 16.64 + 13.12 + 5 + 12.84 + 374.09 + 10.71 = 576.37kN$$

$$F_{sl} = \frac{\sum_{i=1}^{n} F_i^V}{\sum_{i=1}^{n} F_i^H} \cdot f = \frac{576.37}{203.54} \cdot 0.5 = 1.41 \geq 1.1$$

The minimum value 1.1, imposed by coefficient F_{sl} is the bellow the result of the determination, respectively 1,41, resulting therefore that the abutment wall is examined to sliding.

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