Budownictwo o Zoptymalizowanym Potencjale Energetycznym Vol. 7, Nr 2/2018, s. 35-44
DOI: 10.17512/bozpe.2018.2.04

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EFFECTS OF COHESIVE MUDFLOW ON SEMI-CYLINDRICAL ANTI-MUD STRUCTURE

Counteracting the phenomenon of debris flow is implemented in various ways. As international practice has shown, hydrotechnical constructions occupy a special place among structures regulating debris flow. Despite the large variety of constructions, each of them has a strictly defined purpose. The specifics associated with the hazards of debris flow in a given area are taken into account when selecting such a construction. The work indicates the expediency of applying semi-cylindrical open-web constructions to regulate debris flow. The methodology of selecting the design elements is presented. A specific example of the construction calculation and graphic illustrations are presented.

Keywords: **debris flow, semi-cylindrical form, anti-debris flow measures**

INTRODUCTION

Retaining debris flow by engineering methods, their placement on sections of the flow transit and reliability issues are directly related to correct selection of construction parameters. The influence of rheological parameters on flows of this kind makes the possibilities of choosing the type of construction and design solution even more difficult.

PROPOSED CONSTRUCTION FOR DEBRIS FLOW

From the point of the difference in the impact on a cohesive debris flow and the originality of the structural solution, we proposed construction [1], whose innovation is expressed in the gradual transformation of its height in accordance with the flow. The construction is also characterized by high reliability and efficiency in order to protect the environment. This construction is represented in an arch stepped, which has a semi-cylindrical shape attached to each other in relation to the flow. In the direction of flow there is an increase in the semi-cylindrical construction surface. For a complete picture of the construction in Figure 1 an axonometric view of the anti-debris flow construction is given; Figure 2 shows the construction plan, and Figures 3 and 4 show construction sections A-A and B-B. The surface of the presented construction is created by a secondary resource, in particular, rails (1), which are fixed in a reinforced concrete foundation (2).

The construction height increases in the direction of the flow as the radii of the semi-cylindrical surface increase. The space of the open-web surface created by the rails is represented by rectangular gaps, the cross-sectional area of which does not vary in the height of the construction is constant [2-4]. The construction cross-section value itself depends on the debris flow strength and the hydraulic parameters in the transit section. During the debris flow passage, the force of the first impact is manifested on the first semi-cylindrical surface of the springboard, and the subsequent suppression of energy is effected by the cylindrical construction surface. The rectangular shape of the gaps of the surface makes it possible to provide an optimal energy attenuation effect. The construction can be applied in the case of repeated exposure of debris flow on it [5, 6].

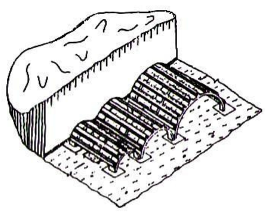


Fig. 1. View of open-web semi cylindrical construction

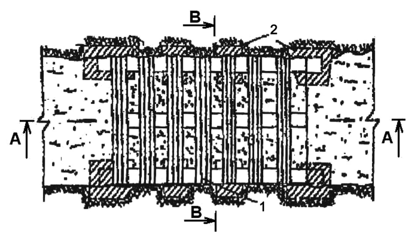


Fig. 2. Plan of anti-debris flow open-web construction

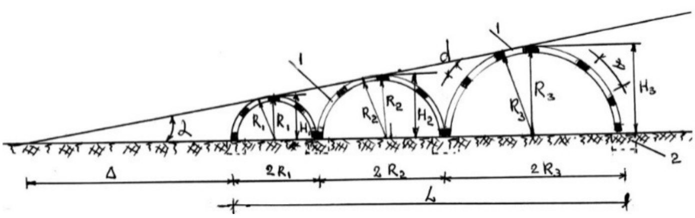


Fig. 3. Construction cross-section A-A

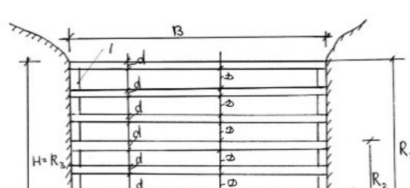


Fig. 4. Construction cross-section B-B

The advantage of the construction in comparison with a similar type of constructions is determined by its multiple reuse. The dimensions of the gaps and the frequency of them are determined by the maximum diameter of the stone transported by the flow. The design solution allows the flow to be distributed both along the height and length of the construction [7, 8].

When selecting the structural elements of the presented anti-debris flow construction, we give below the calculated ratios:

In the case of a circular arch, when the radius is R and the height H, the channel width is B. The radii of the semi-cylindrical surfaces (Fig. 1) are determined by the ratios:

$$R_1 = \Delta \frac{sin\alpha}{1 - sin\alpha} \tag{1}$$

$$R_2 = \Delta sin\alpha \frac{1 + sin\alpha}{1 - sin\alpha} \tag{2}$$

$$R_3 = \Delta sin\alpha \frac{1 + 3sin\alpha + 2sin^2\alpha}{1 - sin\alpha} \tag{3}$$

– The height of the construction H:

$$H = R_3 = \Delta sin\alpha \frac{1 + 3sin\alpha + 2sin^2\alpha}{1 - sin\alpha} \tag{4}$$

– The length of the construction:

$$L = 2R_1 + 2R_2 + 2R_3 = 2\Delta \tag{5}$$

– The change limits in the ratio of the height of the construction to its length are given by the formula:

$$\frac{1}{6} \leq \frac{H}{L} \leq \frac{5}{18} \tag{6}$$

– The angle of inclination of the construction surface to the base varies within 11÷13°.
– If the radii of the front semi-cylindrical surface are known, then the following can be determined from the formulas:

$$R_1 = \Delta \frac{sin\alpha}{1 - sin\alpha} \tag{7}$$

$$R_2 = R_1(1 + sin\alpha) \tag{8}$$

$$R_3 = R_2 \frac{1 + 3sin\alpha + 2sin^2\alpha}{1 + sin\alpha} \tag{9}$$

Height of the construction H, when d thickness of n pieces of beams located on its surface and the gap between beams D are known:

$$H = nd + (n-1)D \tag{10}$$

The number of beams

$$n = \frac{H+D}{d+D} \tag{11}$$

Thickness *h* of the not go through part

$$h = nd \tag{12}$$

The area of the open-web part of the construction

$$\omega_1 = B[n(d+D) - D - nd] = BD(n-1) \tag{13}$$

The coefficient of duty ratio *K*

$$K = \frac{\omega_1}{\omega} = \frac{1 - \frac{d}{H}}{1 + \frac{d}{D}} \tag{14}$$

The height of the construction when the angle of inclination to the base of the tangent passing through the open-web surface is known:

$$H = \frac{1}{2}\frac{1 + 3sin\alpha + 2sin^2\alpha}{1 - sin\alpha}L = K * L \tag{15}$$

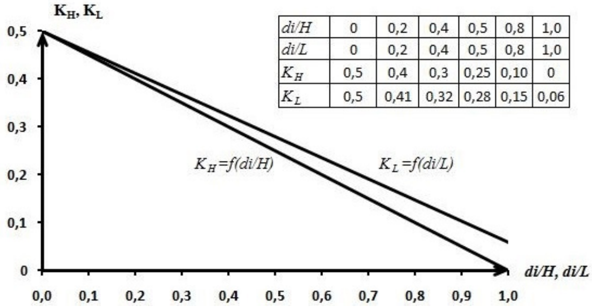
The relative value of the beam thickness to the maximum diameter *D*:

$$\frac{d}{D} = \frac{K * L}{2H - K * L} \tag{16}$$

The coefficient of the ratio in relation to the thickness of the beams and the height of the construction:

$$K = 0{,}5\left(1 - \frac{d}{H}\right) \tag{17}$$

For clarity, the possibility of changing the duty ratio is given in the form of a dependency graph (Fig. 5).



di/H	0	0,2	0,4	0,5	0,8	1,0
di/L	0	0,2	0,4	0,5	0,8	1,0
K_H	0,5	0,4	0,3	0,25	0,10	0
K_L	0,5	0,41	0,32	0,28	0,15	0,06

Fig. 5. Change of duty ratio coefficient in construction height and length

When $d = H$, the volumetric weight is γ, the area of the live section ω, the flow velocity V, the angle of inclination to the base α and the angle of internal friction φ, the equivalent depth of flow cohesiveness h_0 and flow height H, the P_2 force, acting on the construction in the case of a not go through construction will have the value:

$$P_2 = \frac{3{,}34\gamma\omega sin\alpha_1}{g} sin\alpha\left[cos\alpha_1 tg\varphi + \frac{h_0}{2H}\left(\sqrt{1+tg^2\varphi} - tg\varphi\right)\right] \tag{18}$$

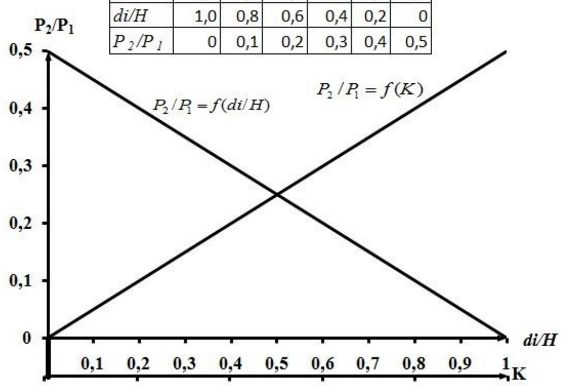
Similarly, the force acting on the open-web construction

$$P_2 = \frac{3{,}34\gamma\omega_1 sin\alpha}{g} sin\alpha\left[cos\alpha_1 tg\varphi + \frac{h_0}{2H}\left(\sqrt{1+tg^2\varphi} - tg\varphi\right)\right] \tag{19}$$

The duty ratio coefficient is

$$K = \frac{P_2}{P_1} = \frac{\omega_1}{\omega} \tag{20}$$

To estimate the magnitude of the shock force, we give the graphical attitude $\frac{P_2}{P_1} = f(K, di/H)$ (Fig. 6).



K	0,0	0,1	0,2	0,3	0,4	0,5
di/H	1,0	0,8	0,6	0,4	0,2	0
P_2/P_1	0	0,1	0,2	0,3	0,4	0,5

Fig. 6. Relative value dependence graph of forces acting on open-web and not go through constructions P_2/P_1 (relationship between duty ratio and ratio of beam width to construction height)

We evaluate the shock force on the presented construction on the basis of a specific assumption when the flow width is $B = 10$ m, the flow passage height through the channel is $H_{fl} = 5$ m, the flow velocity $V = 5$ m/s, the volumetric weight $\gamma = 2000$ kg/m^3, the angle of internal friction $\varphi = 30°$, the slope of the duct $i = 0.2$, flow streaming angle $\alpha = 30°$, maximum diameter of the transported stone $D_{max} = 0.4$ m $= D$, and beam thickness $d = 0.2$ m. In solving the problem, the calculation characteristics are determined by the sequence shown below. The value of the shock force on the construction is calculated by formula [9]:

$$P_1 = 3{,}34\frac{\gamma BHV^2}{g}\left[\cos\alpha tg\varphi + \frac{h}{2H}\frac{1-\sin\varphi}{\cos\varphi}\right] = \frac{3{,}34\cdot 2000\cdot 10\cdot 5\cdot 5^2}{9{,}81}\times 0{,}978\cdot 0{,}577 + \frac{4}{2{,}5}\frac{1-0{,}5}{0{,}866} = 6773{,}8$$

In the case of a cylindrical construction, we take the height of the construction $H = 5$ m.

The duty ratio coefficient is:

$$K = 0{,}5\left(1 - \frac{0{,}2}{5{,}0}\right) = 0{,}48$$

$$R_3 = H = 5\,\text{m}$$

$$R_2 = \frac{R_3(i + \sin\alpha)}{1 + 3\sin\alpha + 2\sin^2\alpha} = \frac{5(1+0{,}22)}{1 + 3\cdot 0{,}22 + (0{,}22)^2\cdot 2} = \frac{6{,}10}{1{,}70} = 3{,}58\ \text{m}$$

$$R_1 = \frac{R_2}{1+\sin\alpha} = \frac{3{,}58}{1+0{,}22} = 2{,}93\ \text{m}$$

$$\Delta = \frac{R_1(1-\sin\alpha)}{\sin\alpha} = \frac{2{,}93\cdot(1-0{,}22)}{0{,}22} = 10{,}38\ \text{m}$$

The construction length

$$L = 2R_1 + 2R_2 + 2R_3 = 2\cdot 5 + 2\cdot 3{,}88 + 2\cdot 2{,}93 = 2(5 + 3{,}58 + 2{,}93) = 23{,}0\ \text{m}$$

The number of beams on the semi-cylinder, when radius $R_3 = H$

$$n_1 = \frac{H+D}{d+D} = \frac{5+0{,}4}{0{,}6} = 9\ \text{pieces}$$

The total number of beams is

$$N_1 = (n-1)\cdot 2 + 1 = 17\ \text{pieces}$$

The number of beams on the second semi-cylinder is when $H = R_2$

$$n_2 = \frac{R_2+D}{d+D} = \frac{3{,}58+0{,}4}{0{,}6} = 6{,}63 = 7{,}0\ \text{pieces}$$

$$N_2 = (7-1)\cdot 2 + 1 = 13\ \text{pieces}$$

When $H = R_1$, number of beams n_3 on the first semi-cylinder is

$$n_3 = \frac{R_1+D}{d+D} = \frac{2{,}93+0{,}4}{0{,}2+0{,}4} = 5{,}55 \approx 6\ \text{pieces}$$

Respectively

$$N_3 = (6-1)\cdot 2 + 1 = 11 \text{ pieces}$$

The total number of beams in the construction is

$$N = N_1 + N_2 + N_3 = 17 + 13 + 11 = 41 \text{ pieces}$$

The force applied to the open-web construction is

$$P_2 = KP_1 = 0{,}48 \cdot 6773{,}8 = 3251{,}42 \text{ kN}$$

An estimate of the shock force variation along the construction length in the flow direction is a function of the ratio of the construction beam thickness to its height. The shock force value on a not go through construction when the thickness of its beam varies with respect to the total height will be:

$$\frac{di}{H} = 0,\ K = 0{,}5,\ Pi = P_1 \cdot 0{,}5 = 6773{,}8 \cdot 05 = 3386{,}9 \text{ kN } \frac{Pi}{P_1} = 0{,}5$$

$$\frac{di}{H} = 0{,}2,\ K = 0{,}4,\ Pi = P \cdot 0{,}6 = 0{,}6 \cdot 3773{,}8 = 4064{,}8,\ \frac{Pi}{P_1} = 0{,}6$$

$$\frac{di}{H} = 0{,}4,\ K = 0{,}3,\ Pi = 0{,}7 \cdot 6773{,}8 = 4741{,}6,\ \frac{Pi}{P_1} = 0{,}7$$

$$\frac{di}{H} = 0{,}6,\ K = 0{,}2,\ Pi = 0{,}8 \cdot 6773{,}8 = 5419{,}8,\ \frac{Pi}{P_1} = 0{,}8$$

$$\frac{di}{H} = 0{,}8,\ K = 0{,}1,\ Pi = 0{,}9 \cdot 6773{,}8 = 6076{,}4,\ \frac{Pi}{P_1} = 0{,}9$$

$$\frac{di}{H} = 1{,}0,\ K = 0,\ Pi = 1 \cdot 6773{,}8 = 6773{,}8,\ \frac{Pi}{P_1} = 1{,}0$$

The shock force distribution on the construction height in relative units is shown in the form of a graph (Fig. 7).

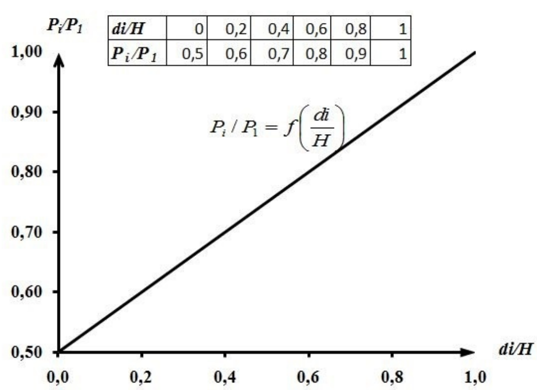


Fig. 7. Graph of shock force variation with variation of construction not go through part in relative units $P_i / P_1 = f(di / H)$

To determine the necessary number of constructions, special emphasis is given to the possibility of neutralizing the impact force thanks to the construction. Proceeding from this, the graph of the deterrent force P variation with respect to the construction height has the form:

$$\frac{di}{H} = 0,\ \ di = 0,\ \ P_0 = P_{\text{deaf}} - 3386{,}9 = 3386{,}9\ \text{kN}$$

$$\frac{di}{H} = 0{,}2,\ \ di = 1{,}0,\ \ P_0 = 6773{,}8 - 4064{,}8 = 2709{,}0\ \text{kN}$$

$$\frac{di}{H} = 0{,}4,\ \ di = 2{,}0,\ \ P_0 = 6773{,}8 - 4741{,}6 = 2032{,}2\ \text{kN}$$

$$\frac{di}{H} = 0{,}6,\ \ di = 3{,}0,\ \ P_0 = 6773{,}8 - 5419{,}8 = 1354{,}0\ \text{kN}$$

$$\frac{di}{H} = 0{,}8,\ \ di = 4{,}0,\ \ P_0 = 6773{,}8 - 6076{,}4 = 697{,}4,\ \ P_0 = 697{,}4\ \text{kN}$$

$$\frac{di}{H} = 1{,}0,\ \ di = 5{,}0,\ \ P_0 = 6773{,}8 - 6773{,}8 = 0,\ \ P_0 = 0\ \text{kN}$$

On the basis of the above calculation, special importance is given to neutralization of the force acting on the construction (Fig. 8) in selecting the protected constructions amount.

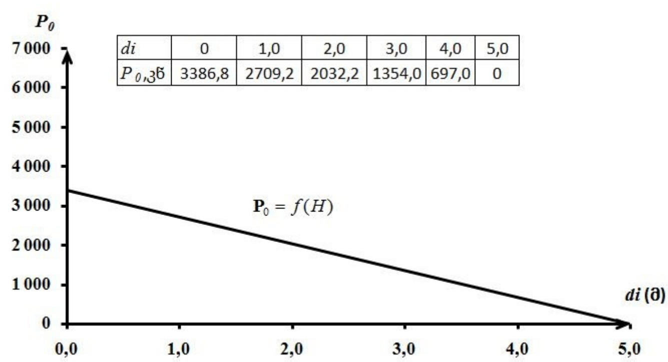


Fig. 8. Regularity of residual shear along construction height

On the basis of the acting force obtained from the calculation, when the duty ratio is K, and the deafness coefficient is K_1, the number of constructions is determined by the formula:

$$N = \frac{P}{P - P_{deaf.}} = \frac{1}{1 - K_1} \qquad (21)$$

In general, based on the change in not go through, the number of constructions is given in the form of a graph in Figure 9.

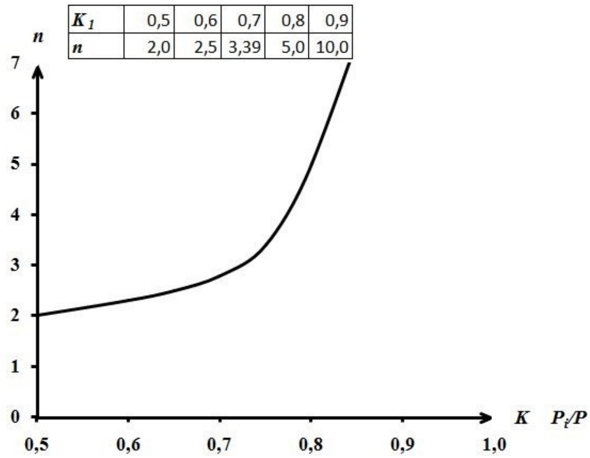


Fig. 9. Dependence of number of constructions on not go through ratio

With the help of the graph in Figure 9, when off-duty ratio K = 0.48, and the number of constructions is 1.8, we take 2 constructions, i.e., in the case of 2 constructions, the deafness ratio should decrease to 0.5. i.e., when not go through ratio K = 0.50, the number of constructions is N = 2.0; and as to the rod thickness, due to its reduction, the off-duty ratio increases, and the structural dimensions of the remaining construction elements remain unchanged.

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EFEKTY ZWARTEGO PRZEPŁYWU GRUZOWEGO PRZEZ PÓŁCYLINDRYCZNĄ KONSTRUKCJĘ ANTYOSUWISKOWĄ

Przeciwdziałanie zjawisku przepływu gruzowego jest realizowane na różne sposoby. Jak pokazała praktyka międzynarodowa, konstrukcje hydrotechniczne zajmują szczególne miejsce wśród struktur regulujących przepływy gruzowe. Mimo dużej różnorodności konstrukcji każda z nich ma ściśle określony cel. Specyfika związana z niebezpieczeństwem przepływu gruzowego w danym obszarze jest brana pod uwagę przy ich doborze. W pracy wskazano celowość zastosowania półcylindrycznych konstrukcji w otwartych kanałach stosowanych w celu regulowania przepływu gruzowego. Przedstawiono metodologię doboru elementów konstrukcyjnych. Przytoczono konkretny przykład obliczeń konstrukcyjnych oraz ilustracje graficzne.

Słowa kluczowe: przepływ gruzowy, forma półcylindryczna, przeciwdziałanie przepływom osuwiskowym