

The Impact of a Debris Flow on Opposing Obstacles
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Annotation: Debris flows are one of the major negative factors affecting the ecological balance of the environment, and various types of measures are used for their regulation. The fluctuations in the transportability and energy characteristics of such anomalies are of such a scale that the ability to mitigate their impact does not align with the potential for maintaining a stable landscape infrastructure environment.

The aim of debris flow regulation in this study is to assess their dynamic impact on structures, evaluate the energy of critical equilibrium, and develop innovative models.

Based on the purpose of regulation, the operational means of both energy and transportability characteristics do not fully meet the high criteria for assessing their impact. Equally relevant is the accuracy of describing the obtained results—such as the flow's adherence to structures, elastic reception, and circumfluence capabilities—using operational means, as well as the complexity of developing innovative solutions. Consequently, refining existing methods of limit equilibrium, wave motion, and impact impulses to assess debris flow energetics and develop innovative flow behavior models through operational means is crucial. Additionally, evaluating the deformation characteristics caused by interactions with opposing obstacles plays a significant role in addressing the challenges of regulating natural anomalies.

Keywords: Debris flows, Ecology, Dynamic

impact Assessment, Critical equilibrium, Innovative models, Limit equilibrium, Wave motion, Shock impulses

Main Body

loods are one of the natural disasters in environmental sustainability issues, for which various forms of phytoremediation are used, as well as different regulatory engineering design solutions [1, 2, 3, 7, 11, 13].

The architecture of the proposed structures, structural solutions, and environmental protection objectives are related to the diverse existence of floods, whose transport capacity and energy differ significantly from one another [8, 9].

The scales of fluctuation in the transport capacity and energy characteristics of the presented anomaly are represented by such boundaries that the effect of freeing the environment from them often fails to meet the possibilities of ecological balance.

As determining criteria for the evaluation of energy, when dealing with deformation caused by tension-compression, the possibilities of limit equilibrium and wave motion are often used in engineering practice.

Since the impact of floods on the environment is linked to the complexities of flow-channel interactions, it is essential to consider both the morphometry of the riverbed and the specific characteristics of flow behavior and hydraulics. Due to their anomalous nature, the hydraulics of floods

differ significantly from those of water flows.

Accordingly, establishing a connection between their hydraulics and channel processes represents one of the key challenges in environmental protection [4, 5, 6, 7, 10].

When the channel bed is stable, its diameter varies along the flow direction. It is essential to assess ongoing channel processes and study the energy-defining characteristics of the flow in relation to the parameters determining deformability [12].

The impact of any flow on encountered obstacles depends on pressure changes within its body, disrupting the steadiness of the flow. A similar phenomenon occurs when a debris flow moves through a channel. Pressure changes cause not only the disruption of steadiness but also disturbances during interactions with encountered obstacles.

Due to the complexity of the phenomenon and the multitude of interdependent factors, the scale of deformability and disturbance must be analyzed in relation to elasticity-defining characteristics, while the assessment methodology used in material strength studies should serve as an operational tool.

The disruption of steadiness and the potential for disturbance in a water flow have been established through hydraulic flow observation studies, with a measured value of 0.33. However, this value has not yet been determined for debris flows based on current data, necessitating further research and the development of appropriate theories.

Based on existing statistics on the impact of debris flows on landscape infrastructure, the potential for pressure changes within its body can be represented through rheological principles. When a debris flow encounters obstacles, the formation of a disturbed zone alters its density along with its body.

The expansion of the debris flow body,

followed by its replenishment with the next wave within the increased pressure zone, leads to the division of the mass into two parts. The first region, where pressure-driven formation occurs, moves with a velocity V_w . The dynamic impact on velocity within the high-pressure area induces a counterflow movement, which is known as the disturbance velocity V_w .

The stability of debris flows formed in pockets and the potential for equilibrium disruption are associated with the interplay of cause-and-effect factors. Given the complexity of initiation and movement, particular attention must be paid to the proper adaptation of models to the process and the necessity of selecting appropriate geometric shapes for structural forms.

Based on the above, the regulation of such anomalies and the reliability of selecting regulatory measures remain a challenging and unpredictable task for ensuring the stability and decentralization of landscape infrastructure in almost every country. Regulatory measures adapted to incorrect phenomena and the applied operational means often fail to produce the necessary results. Consequently, this leads to cases of overflow in the shoreline zone of the flow, as well as the disruption of settlements, and it is known as a disaster that causes casualties among the residents.

The assessment of the impact potential of debris flows, the refinement of existing calculation models, and their innovative modification in the study are based on the theory of forces.

For the selection of a comprehensive and innovative calculation model and the development of operational computational tools, the following assumptions have been considered and applied:

- During the impact of the debris flow on opposing obstacles, it is assumed that the potential and kinetic energies are equal.

- The relationship between deformation and force is considered linear.
- At the initial stage of tension-compression, the proportionality limit somewhat exceeds that of the process in progress.
- By increasing the number of impact loads on the test sample, no additional deformation occurs.
- After a certain period, the deformation completely disappears, and the relationship between force and deformation becomes linear.
- The threshold for changes in the debris flow mass is a function of its physical and mechanical characteristics.
- When the magnitude of the force acting on the debris mass is equal to the mass's extension, the proportionality coefficient is one. Moreover, an increase in the linear extent of the deformation does not alter this coefficient.

The assessment of the impact of a debris flow on opposing obstacles can be studied based on the scheme presented in Fig. №1.

According to the calculation scheme, the dynamic impact of the linear elongation of the debris mass deformability at section I-I on the vertical axis is represented by Δ_{dyn} , while the static potential of internal friction is denoted by Δ_{st} .

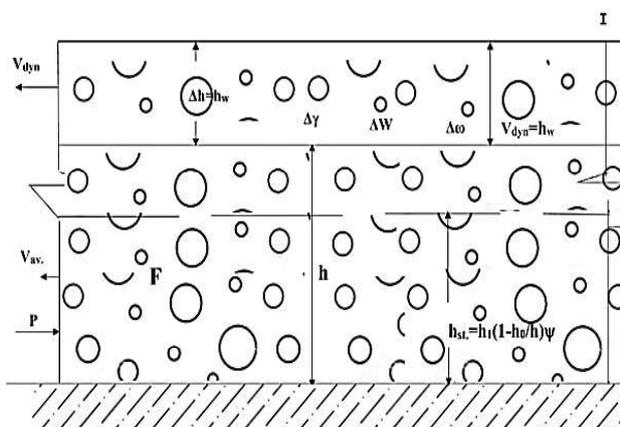


Fig. 1. Calculation scheme of debris flow deformations.

Based on linear deformations, the magnitude of kinetic energy in the case of debris flow mass deformability

$$T = Ph_1 = P(h + \Delta_{dyn}) \tag{1}$$

Based on the theory of tension-compression, within the limits of proportionality and considering the internal potential, in the case of a debris flow with a depth of h , taking into account the force magnitude $P = K\Delta_{st}$, the magnitude of kinetic energy is

$$T = K\Delta_{st}(h + \Delta_{st}) \tag{2}$$

The magnitude of the energy expended by external forces, according to the calculation scheme, i.e., the work performed, is

$$A = \frac{P\Delta_{dyn}}{2} = \frac{K}{2}\Delta_{dyn}^2 \tag{3}$$

Based on the energy equivalence and the conservation of a continuous medium:

$$\frac{K}{2}\Delta_{dyn}^2 = K\Delta_{st}(h + \Delta_{dyn}) \tag{4}$$

Equation 4 with respect to Δ_{dyn} is a quadratic equation, the solution of which is:

$$\Delta_{dyn} = \frac{2hg}{\Delta_{st}} \tag{5}$$

Based on the elastic-deformability of the debris flow, the linear elongation caused by deformation, when the modulus of elasticity is $E = \rho V_w^2 w$, represented by the density ρ and wave velocity V_w , is given by:

$$\Delta_{st} = \frac{Ph}{EF} = \frac{\gamma h^2}{2} \frac{(1 - \frac{h_0}{h})^2 \psi^2 h}{\rho V_w^2 h (1 - \frac{h_0}{h}) \psi} = h(1 - \frac{h_0}{h})\psi \tag{6}$$

The impact of debris flow on opposing obstacles, considering the deformability of its mass and the effect of the impact, gradually transitions from one established motion to another. The deformation of the debris flow body is characterized by a gradual change in discharge between cross-sections without dynamic effects, which could be caused by inertia and impulses. In this case, the phenomenon is considered quasi-stationary, and gravitational forces are balanced by resistance forces. Under such conditions,

within the limits of proportionality, deformability is stabilized by the gradual change in discharge. The motion parameters transition gradually, and the cross-sectional elements change without dynamic effects. The change in discharge is situated between the depths h and h_1 of a continuous wave. Accordingly, the computational model can be represented by the continuity equation:

$$Q - \omega V_w = Q + \Delta Q - V_w(\delta\omega + \omega) \quad (7)$$

In the case of wave generation, since the wave thickness is related to the discharge Q and the live cross-sectional area ω , we have: $V_w = \partial Q / \partial \omega$. For the initial discharge Q , this results in:

$$V_w = \frac{\partial(\omega V)}{\partial \omega} = \omega \frac{\partial V}{\partial \omega} + V \frac{\partial \omega}{\partial \omega} = V + \omega \frac{\partial V}{\partial \omega} \quad (8)$$

The average velocity of the flow ω with a live cross-section and discharge Q , when the specific discharge is $q = V_{st}h$, $f(\beta) = \frac{\beta}{2(\beta^2 - 1)} + 1/3(1 - \beta^2)$ and $\beta = h_0/h$, the average velocity is given by $V_{st} = h^2 v_t(\beta)$, and the wave propagation velocity is $V_w = 3V_{st}$.

In the 6th relation, when $h_0 = 0$ and $\Psi = 1$, $D_{st} = h$, and when $h_0 = h$ and $\Psi = 1$, $D_{st} = 0.1$.

Taking the 6th relation into account, in the 5th we obtain:

$$\Delta_{dyn} = h(1 - h_0/h)\psi \left(1 + \sqrt{1 + \frac{4}{(1-h_0/h)\Psi}} \right) \quad (9)$$

Based on the linear elongation model, the magnitudes of static and dynamic loads can be expressed by the following relationships:

$$P_{st} = K \Delta_{st} \\ P_{dyn} = K \Delta_{dyn} \quad (10)$$

From the magnitudes of the 10 th forces:

$$P_{dyn} = 4,5 \left(1 + \sqrt{1 + \frac{4}{(1-h_0/h)\psi}} \right) \frac{\alpha \omega V_{st}^2}{g} \quad (11)$$

In the 11th assumption, when $K = 4,5 \left(1 + \sqrt{1 + \frac{4}{(1-h_0/h)\psi}} \right)$, the magnitude of the dynamic force is $P_{dyn} = K^* \frac{\gamma \omega V_{st}^2}{g}$.

In order to easily determine the impact capacity of mudflows on buildings, the value of the K^* coefficient for various types of mudflows, namely, for the equivalent bond depth h_0 and the internal friction coefficient ψ , is given in the form of Table 1.

Design Values of the Coefficient K^*
Table N 1

$\Psi \backslash h_0/h$	0	0.2	0.4	0.6	0.8	10
0.1	33.2	30.77	28.90	27.44	26.17	25.09
0.2	25.09	23.32	22.05	20.97	20.09	19.40
0.4	19.4	23.03	17.24	16.56	15.97	15.48
0.6	16.95	15.97	14.89	14.70	14.20	13.82
0.8	15.48	11.47	14.11	13.62	13.32	12.84
1.0	14.50	13.81	13.32	12.92	12.54	12.25

Based on the data presented in the table, it is possible to select appropriate measures according to the magnitude of the corrective coefficient K^* , in relation to the characteristics of the mudflow

.Conclusion

Mudflows are among the most prominent natural disasters, characterized by their destructive impact. In order to manage and mitigate their effects, various types of structures have been employed, each designed to serve specific regulatory and protective functions. Taking into account both the transport capacity of mudflows and the diversity of structural types used for their regulation, predictive indicators have been established for potential disruption to landscape infrastructure stability. These indicators are based not only on the impact potential of the mudflows but also on the changes in their physical and mechanical properties.

The study proposes scenarios for the disruption of the limiting equilibrium stability of mudflows and their potential impact on encountered resistances.

The applicability limits of rapid assessment tools have been clarified, and innovative models for evaluating the energy behavior of the flow have been developed using the theories of limiting equilibrium, wave motion, and impact impulses.

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