Review of Rock Pile Type River Krib Stability Concept

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Abstract

An effective and sustainable solution to address the problem of riverbank erosion, protect the environment, and offer economic and operational benefits. In addition, this research also contributes to the development of science and technology in civil engineering and water resources management. The study's objectives were to formulate stability coefficients of rock-pile kribs and analyze how changes in each variable affect the overall stability of the kribs. The research methodology conducted was a literature review, theoretical analysis, and physical modeling. The expected results are to find the relationship between river flow parameters and the stability coefficient of rock piles, to see the flow pattern that affects the stability of rock piles in the krib, and to find the influence of the position of the krib on the stability of the rock pile krib. It is estimated that the weight of the rock pile krib building face layer (W) is influenced by the flow velocity (V), the specific gravity of the rock (γ_S), the stability coefficient (K_s), the slope of the structure ($Cot\alpha$), and the water depth (h). The use of natural materials in river management is effective in controlling erosion, directing water flow, creating new habitats, and protecting riparian infrastructure. Further research on the stability of rock-pile-type river Kribs experimentally under various river conditions, as well as innovations in rock design and materials, is relevant and important at this time.

1 Introduction

A river is defined as a body of water that varies in size, ranging from large rivers to small streams flowing through a watercourse. In addition, the term is sometimes applied to natural channels or drainage channels created by flowing water, whether filled with water or not. Stream stability is the condition of a waterway that does not change significantly from year to year, although it can change at

[*] Masterminded EasyChair and created the first stable version of this document

different times of the year due to changes in flow and sediment load (Malaysia - UNESCO Cooperation Program (MUCP), 2017). Stone piles are often used as supporting buildings, but often also as main buildings. For example, to support the construction of a Cofferdam. At the same time as the main building, for example: Groin, Breakwater, Jetty, rock shelter, stone fill dam. Rock piles are actually relatively stable, but their stability is reduced if they are submerged in water or exposed to runoff (P. S. Atmojo, 2008). From the above background, it is very interesting to study because it can provide an effective and sustainable solution to overcome the problem of riverbank erosion, protect the environment, and offer economic and operational benefits. In addition, this research also contributes to the development of science and technology in the field of civil engineering and water resources management. The main objective of the study was to formulate the stability coefficients of the rock-pile krib and analyze how changes in each variable affect the overall stability of the krib.

2 Research method

The research methodology undertaken was a literature review, and theoretical analysis, and physical modeling. The purpose of the literature review in this study is to provide a strong theoretical foundation on the stability of rock-pile type river cribs. The theoretical analysis in this study involves the development of a mathematical model that describes the relationship between various variables affecting the stability of rock-pile type river cribs. These variables include flow velocity, water level, conveyance time, rock weight, stability coefficient, and building slope. The physical modeling in this study will be carried out through laboratory experiments to test the stability of rock-pile-type cribs under various flow conditions.

2.1 River Flow Hydraulics.

Flow in open channels experiences very complex resistance because it is influenced by many variables, which depend on each other and their interactions cannot be known properly. The influence of other variables is still speculative, so observations are still being made, where the simplified form of the resistance equation is as follows:

$$\frac{S}{F_r^2} = f(Re, d_z/h) \tag{1}$$

Where: F_r is the Froude number, Re is the Reynolds number, d_z is the diameter of the channel bottom material (mm), h is the flow depth (m), f is the DarcyWeisbach friction factor. The Darcy-Weisbach friction factor uses the following equation:

$$f = 8f_s/F_r \tag{2}$$

Meanwhile, the following equation can be used to evaluate *resistance*:

$$S_f = \frac{V_*^2}{C_*^2.g.R} \tag{3}$$

and shear velocity the following equation is used:

$$v_* = \sqrt{\tau_0/\rho} \tag{4}$$

Where: τ_o is shear stress (kg/cm^2), $u*$ is shear velocity (m/s), ρ is water density (kg/m^3), R is hydraulic radius (m), $R = h$ for rectangular cross section, C is dimensionless Chezy coefficient, g is gravitational acceleration.

2.2 Empirical Equation of Flow Velocity.

The same shear stress dependence occurs in open channel flows with large Reynolds numbers, hence the empirical equation (Robert J. Kodoatie, 2013).

$$u^* = C\sqrt{RS_0} \tag{5}$$

where C is the Chezy coefficient, R is the hydraulic radius (m), S_o is the channel slope.

2.3 Rock Pile Stability.

Rock piles used in coastal safety structures such as breakwaters, groins and revetments are relatively stable, but this stability will be reduced when submerged in water or exposed to flowing water runoff. The review is carried out at one or more points, for example point A. The water velocity at the review point (V_a) will be able to move a stone of a certain diameter, if the velocity is greater than the critical velocity of the stone (U_{cr}) (P. S. Atmojo, 2008). Rock stability assessment uses commonly used formulas as well as several other formulas (P. S. Atmojo, 2008):

$$U_{cr} = \sqrt{\Delta.g.D}.(1{,}0).\log\frac{6.y_a}{D} \tag{6}$$

Another formula:

Isbash, 1935

$$U_{cr} = 1{,}07\sqrt{\Delta.g.D} \tag{7}$$

Goncharov, 1959

$$U_{cr} = 1{,}75.\log\frac{8{,}8.y}{\mathrm{D}}.\sqrt{\Delta.g.D} \tag{8}$$

Levi, 1959

$$U_{cr} = 1{,}4.\sqrt{\Delta.g.D} \times \left(\frac{h}{\mathrm{D}}\right)^{0{,}2} \tag{9}$$

Maynord, 1978

$$U_{cr} = 1{,}28.\sqrt{\Delta.g.D} \times \left(\frac{h}{\mathrm{D}}\right)^{1/6} \tag{10}$$

The water velocity (V_a) is calculated by the formula (P. S. Atmojo, 2008):

$$V_a = \sqrt{2.g.Z_a} \tag{11}$$

Where U_{cr} is the critical velocity of the rock (m/s), ρ_s is the density of the rock (2.65 tons/m^3), ρ_w is the density of seawater (1.03 tons/m^3), g is the Earth's gravity (9.81 m/s^2), D is the diameter of the rock (m), y_a is the water depth at point A/review point (meters), Z_a is the water level from point A (meters). A review of the stability of the rock against water runoff is shown in Figure 1.

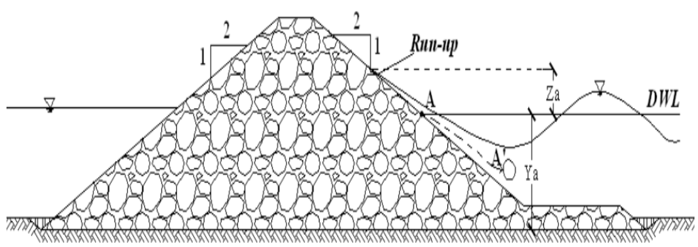


Figure 1: Overview of stone stability against water runoff.

2.4 Krib Building.

Krib building is one part of the handling of scour that occurs in river cliffs. Krib construction is classified into 3 (three) types of krib construction, namely: permeable type where river water can flow through the krib, impermeable type where river water cannot flow through the krib and semi-permeable type (combined of both the permeable type and the impermeable type). Based on its formation, kribs can be classified into 2 (two) types, namely transverse type and longitudinal type, krib construction and placement location are shown in Figure 2 (Triatmodjo, 1999).

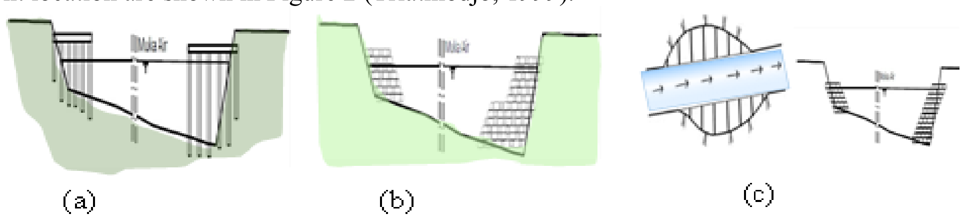


Figure 2: Permeable crib construction (a), semi-permeable crib construction (b), and impermeable crib location and construction (c).

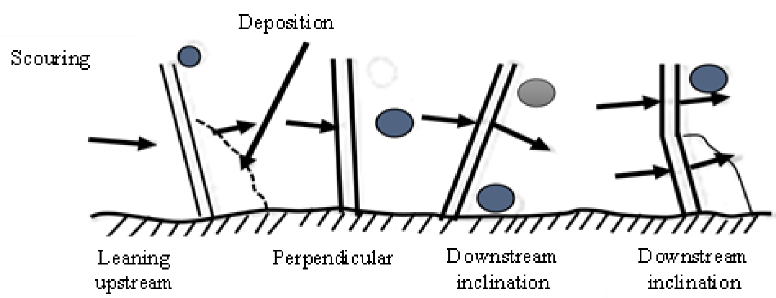
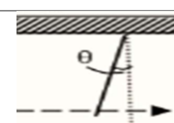


Figure 3: Krib formations and scouring-deposits on the riverbed.

Commonly used krib formations There are three kinds of krib formations that are commonly applied in building krib buildings, namely perpendicular to the current, inclined upstream and inclined downstream shown in Figure 3 and the relationship between the length and interval of the krib is shown in Table 1.

Table 1: Relationship between length and crib interval.

Location of cribs in the river	Flow direction and angle of crib growth θ	Sketch
Straight section	10^0 - 15^0	
Outside bend	5^0 - 15^0	
Inner turn	0^0 - 10^0	

The type of krib should be considered based on the hydraulics function of the krib from past experiences and examples of kribs constructed in the past. The process of determining the type of crib requires special attention to the following points: Low permeable cribs with consolidated foundations are usually adequate to protect riverbanks; Cribs are not suitable for rivers with narrow channels or for small rivers; Large gap permeable cribs, such as pile cribs; Impermeable cribs can reduce scour on the channel bed. To explain the river safety rubble mound debris material, it is necessary to adopt the theory of coastal protection rubble mound marine groin. This krib is included in the type of semi-permeable krib so that it can still penetrate water. Buildings with stone pile structures in determining the size of these stones are recommended to use the Hudson formula (Triatmodjo, 1999).

$$W = \frac{\gamma_r H^3}{K_s (S_r - 1)^3 Cot\theta} \tag{12}$$

$$K_s = \frac{\gamma_r H^3}{W (S_r - 1)^3 Cot\theta} \tag{13}$$

Where W is the grain weight of the protective stone (tonnes), γ_r is the specific gravity of the stone (tonnes/m), γ_a is the specific gravity of seawater (tonnes/m^3), H is the plan wave height (m), θ is the side slope angle, K_s is the stability coefficient of the protective stone shape. From Equation 10 applied to the rock pile structure for protection in the river, the variable $H = V$, V is the flow velocity. A sketch of the rock groin is shown in Figure 4.

$$K_s = \frac{\gamma_r V^3}{W (S_r - 1)^3 Cot\theta} \tag{14}$$

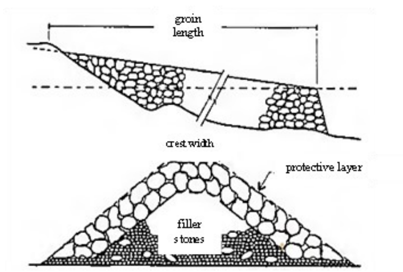


Figure 4: Groin of rock piles.

2.5 Physical Hydraulic Model Test.

The physical model created must have similarity or compatibility with the prototype. To achieve this, the physical model must be geometrically, kinematically, and dynamically congruent to the prototype (Yuwono, 1996).

2.6 Geometric Congruence.

Geometric congruence is also called shape congruence, which is the comparison between the size of the prototype analog and the model must be the same size. The comparisons used are length, area and volume.

$$n_l = \frac{magnitude\ in\ prototype}{bmagnitude\ in\ model} \tag{15}$$

All measurements at random points on the model and prototype should be to the same scale.

2.7 Kinematic Construct and Dynamic Construct.

Kinematically congruent is congruent movement. The comparisons used are time, speed and discharge. Dynamic congruence is the force of force that occurs when the motion is kinematically congruent, and the ratio of the moving mass and the force causing it is homologous in magnitude. If the relationship between scale and congruence has been fulfilled, then the level of accuracy needs to be considered in relation to the magnitude of the scale value used.

3 Results and discussion

The literature study will include a review of previous studies related to the stability of river kribs and boulder pile structures. An experimental study on the effect of boulder spacing on mean and turbulent flow characteristics. Explaining that the nature of the current flow at the bottom of the channel is very complex and changes increase with the retreat of the pebbles, additional information about the mechanism and purpose of sediment transport at the bottom of the channel was obtained (Golpira, et al, 2020). (Nguyen, 2018) stated that the results of mathematical models have uncertainty because different numerical schemes can be applied, therefore laboratory tests are needed for comparison and to verify numerical simulations.

Research on super-long rock socket fill piles emphasized critical loading factors affecting pile stability, including self-weight and skin friction, with small disturbances potentially causing instability (C. Araujo et al, 2023). Additionally, an updated stability analysis of a similar structure, the Old River Low Sill Structure, highlighted the importance of monitoring and investigating foundation conditions to prevent rubbing and undermining, ultimately improving the stability of the structure (Xu, C and Yao, W, 2021). The time-varying dynamics of river flow can be affected by structures such as stabilized bridge piers, causing new eddies and channels to form around them (Nenny et al, 2016). The shape of the pile groin affects the flow pattern by changing the flow velocity in different parts of the river, which in turn impacts the wetted cross-sectional area. A decrease in flow velocity on the outer side occurs due to a decrease in flow discharge caused by the placement of pile groins (A. S. Sukri and R. Karamma, 2018).By combining these findings and methods, riverbank stability can be effectively managed using rock piles and other structural enhancements.

This study uses several variables to fulfill the formulation and objectives of the study, the research variables are speed *(v)*, water level *(h)*, flow time (*T*), stone weight *(W)*, stability coefficient *(K_s),* building *slope (θ)*. A cutaway sketch of the research model of one stone seed and stone pile is shown as well as the stone displacement mechanism. shown in Figure 5 and a top view sketch of the research model of krib installation is shown in Figure 6.

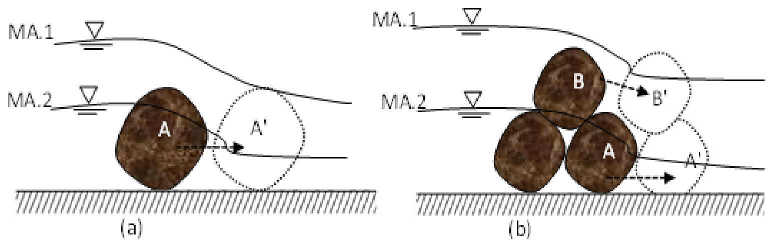


Figure 5: A cutaway sketch of the research model of a single stone seed (a) and a pile of stones (b), and the mechanism of stone displacement.

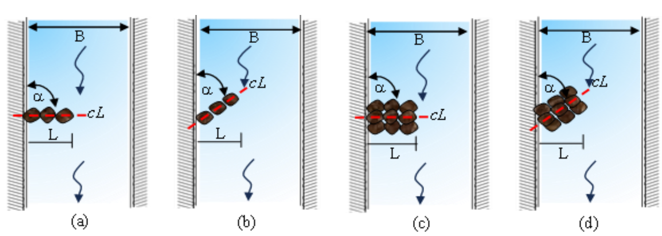


Figure 6: Top view of the research of single-row rock pile type krib installation model and rock piles T_{b1} = 90^0 (a and c) and T_{b2} = 45^0 (b and d), with variation of krib length (*L*) against river width (*B*) = 0.15B, 0.2B, and 0.25B.

3.1 Simulation Plan and Model Scale.

In the research of the stability concept of the rock pile type river krib, the research plan of the running process is shown and Table 2.

Table 2: Research simulation plan of the running process.

Krib model	River bend (θ)	Length of krib *(L)*	Discharge *(Q)*	Flow time (*t*)	Stability krib
T_{b1}	3 variations	3 variations	3 variations	3 variations	Observation
T_{b2}	3 variations	3 variations	3 variations	3 variations	Observation

The research hypothesis of the experimental review of the concept of stability of the rock pile type river krib is that the estimated weight of the stone layer of the rock pile krib building (*W*) is influenced by the flow velocity (*V*), the specific gravity of the stone (γ_s), the stability coefficient (K_s), the slope of the structure ($Cot\alpha$), and the water depth (*h*) or can be written $W = f\,(V, \gamma_s, K_s, Cot\alpha, h)$.

The hypothesis of this study states that the stability of rock-pile type river cribs is influenced by several key variables and how they interact in determining the weight of the crib face stones (*W*), i.e. the effect of high flow velocity (*V*) tends to increase the shear force on the crib face, which can lead to shifting of the stones and instability of the crib structure. Therefore, a larger stone weight is required to resist this force and maintain the stability of the krib. The effect of higher specific gravity of stone (γ_s) means that the stone is denser and heavier, which increases the stability of the krib by providing more mass to resist flow forces. Stones with higher specific gravity are more difficult to move by the flow of water. The effect of a higher stability coefficient (K_s) indicates that the krib structure is more resistant to the forces exerted by the water flow. This usually reflects an optimized design and arrangement of stones that improves overall stability. The effect of steeper slopes (lower $Cot\alpha$ values) tend to be more stable as they provide more resistance to horizontal forces from water flow. Conversely, steeper slopes (higher $Cot\alpha$ values) may be less stable and require heavier stones to compensate for these forces. The effect of greater water depth (*h*) increases the hydrostatic force on the crib, which may result in additional stress on the crib structure. Therefore, heavier stones may be required to maintain stability at greater depths.

Mathematically, the relationship between the weight of the krib building stone (*W*) and the variables affecting it. In this context, the function *f* represents the complex relationship between these variables, which can be a linear or non-linear relationship depending on the specific conditions of the flow and krib structure. Experimental testing and data analysis will help in determining the specific form of this function and make it possible to model and predict the required stone weight for various flow conditions. If we consider an increasing flow velocity (*V*), then we can predict that the stone weight (*W*) must increase to maintain the stability of the crib. Similarly, if the specific gravity of the stone (γ_s) increases, we may see a decrease in the required stone weight (*W*) as heavier stones provide more mass and resistance to flow.

Determining the exact relationship between these variables is key to designing effective and durable krib structures. An in-depth understanding of how each factor contributes to krib stability will make it possible to optimize krib design, reduce the risk of erosion and river bank failure, and ensure safer and more efficient river operations. This hypothesis reflects the understanding that the stability of rock pile-type kribs is the result of the interaction of several hydraulic and structural variables. The proposed experimental research will test this hypothesis by measuring and analyzing how changes in each variable affect the overall stability of the krib. The results of this research will provide important insights for better krib design and implementation in the future.

4 Conclusion

From the discussion of the conceptual review of the stability of the stone pile type river krib, it can be concluded and provide recommendations that the expected results are to get the relationship between river flow parameters and the stability coefficient of the stone pile, find the flow pattern that affects the stability of the stone pile on the krib, get the influence of the krib position on the stability of the stone pile krib. With the estimated weight of the stone layer in front of the stone pile krib building (W) is influenced by the flow velocity (V), the specific gravity of the stone (γ_S), the stability coefficient (K_s), the slope of the structure ($Cot\alpha$), and the water depth (h).

The review shows that the interrelationships between the concept reviews of the stability of rock-pile type kribs are interrelated. The use of natural materials in river management has been shown to be effective in controlling erosion, directing water flow, creating new habitats and protecting riparian infrastructure. Further research on the stability of rock-pile-type river kribs experimentally under various river conditions, as well as innovations in rock design and materials, is relevant and important at this time. The results of this study are expected to assist policy makers and stakeholders in designing more targeted and efficient interventions in maintaining river stability and ecological functions. By taking into account the results of this study, practical and implementable steps in addressing river problems can be realized, which in turn will support the welfare of communities that depend on the sustainability of river ecosystems.

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