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Counter measures Energy on Debris Flow Event by Open-Type Sabo Dam Model

Haeruddin C. Maddi[1], Muhammad Saleh Pallu[2], M. Arsyad Thaha[3] and Rita Lopa[4]

[1]Doctoral Student of Civil Engineering, Email: her45pu@yahoo.com
[2]Profesor of Civil Engineering, Email: salehpallu@gmail.com
[3]Associate Profesor of Civil Engineering, Email: arsyad999@gmail.com
[4]Associate Profesor of Civil Engineering, Email: ritalopa04@yahoo.com

[1,2,3,4] Hasanuddin University Makassar,
Poros Malino Km.6, Kab. Gowa, South of Sulawesi, Indonesia.

Abstract

Sabo dam has the main function as one of sediment control structure, the other functions is to reduce flow energy velocity,during debris flow event. This study examines the use of open-type Sabo-dam by analyzing the debris deposit in front of sabo dam during debris flow event. By knowing the number of energy to be controlled, it is expected to be useful in choosing the type and the amonut of sabo dam structures series along the river. The reduction of energy ultimately affects the stability of the structure at the bottom such as reducing local scouring and reducing damage to the peak (crest) of sabo dam (abrasion). This research was conducted to investigate and analyze the relationship of variables such as sediment thickness (T), sediment porosity (ε), water discharge (Q), sediment diameter (d_{50}) and uniformity coefficient (C_u), to independent variables of flow thickness (h_1/h_0), flow velocity (v_1/v_0)) and relative energy (E_1/E_0). To facilitate the observation and retrieval of data, a 1:50 scale model of physical modeling on a prototype in the field. Validation, verification and calibration model is very important before the data is collected. This is a series of research methodology conducted at the Hasanuddin University Hydraulics Laboratory. The results showed that the sediment thickness (T), porosity (ε), water discharge (Q), diameter (d_{50}) and uniformity coefficient (C_u) had an effect on changes in flow thickness (h_1/h_0), flow velocity(v_1/v_0) and relative energy reduction (E_1/E_0), this is shown from the analysis of the relationship between variables and the Non-Dimensional Parameter (NDP) analysis, the relationship between dependent variables (T, Q, C_u, **ε**, and d_{50}) against the independent variables (v, h and E) studied and observed in this study based on the results of distributed patterns grouping that have been shown, then obtained a new formula that can determine the magnitude of relative energy changes to each parameter used with the value of linear equations of Y=1.8669X-0.158, with the value of variables relationship observed R=0,5869.

Keywords: Mount Bawakaraeng, open-type sabo-dam, relativeflow energy, Jeneberang River, local scouring.

INTRODUCTION

Sedimentation processes occur along rivers, weirs, and dams are the main problems that can be found in almost all rivers in Indonesia, especially rivers with typical debris since almost all catchment areas in Indonesia are experiencing these problems due to the intensification of utilization and land use changing patterns. These problems will have an impact on the sedimentation process, which ultimately leads to a decrease in water quality, often giving even worse effects such as uncontrolled flow patterns in the form of mass flow, not only affecting water quality but also can threaten stability of the structures along the river[1].

Under certain conditions, a process that begins with saturated soil with a pattern of land cover at low-density levels at heavy rain with high intensity and lasts long enough to trigger landslide or movement of soil with a large sediment movement (landslide). [2] argues that the occurrence of land movement, in this case, is the most determining factor and regulating the stability of the slope and causing mass movement is determined by five (5) factors, as follows; (1) the location and slope of the soil; (2) sediment characteristics; (3) sediment structure and variation; (4) hydrological conditions; and (5) the sensitivity of the area where the landslide occurs. The accumulation of the movement or soil movement in large numbers, generally preceded by various processes such as the occurrence of small cracks due to the soil structure effect, the closure pattern and slope angle, so that the fractures from time to time increased, so that whenheavy rain with high intensity often triggers the occurrence of landslides or sedimentmovement in large enough quantities. In addition to the high rainfall as a factor triggering the soil movement, also caused a lot by the earthquake. This process took place in a very fast and the process of sedimentation flowing into the river and eventually triggered a massive flood that brought material mud, rocks, and wood pieces (Woody Debris Flow). This condition is significant if it occurs in the river because with the drainage media will increase the potential flow of debris that occurs.

Furthermore, [3] suggested that landslide is a very complex natural phenomenon that is very difficult to model or simulate. Predicting very dangerous conditions such as landslide is very difficult because there is no experimental activity that can measure the initial events, the selection of ways, and the outcome of the event. Based on the results of field and laboratory investigations on the behavior of the debris flow which is a mixture of wood, sediment and water particles can be obtained that most of the wood material in the debris flow is concentrated in the front and trapped by open checks. Trapped wood traps form a mutually conspicuous formation on checks of the dam causing sediments to settle behind, especially in debris flow conditions [4].

Based on the above descriptions and previous studies, a study is required to examine the reduction of the flow energy by debris flow deposits retained by open-type sabo-dam after the occurrence of debris floods. So that besides the main purpose of sabo dam development is to control the sediment, especially the boulder, also has other objectives to reduce and decrease the flow energy causing damage to the downstream structure such as abrasion on the crest of sabo dam, and causing the local scoring on downstream of sabo dam .

SEDIMENTATION PROBLEMS

The main problem commonly found in sabostructure is the local scoring down the main structure or sub-dam structure. This condition occurs when the sabo dam is fully loaded with debris, so if there is a drainage process both during debris and post debris flooding, the flow pattern is concentrated at a certain point in the top (crest of sabo dam)that can generate flow energy that can threaten the stability of the sub-dam downstream. This will affect the structure and stability of the sediment control structure as a whole because it can threaten the stability of the main building or the body of the sabo dam as shown in Figure 1. So that it is necessary to conduct anengineeringanalysis to break the flow so that it is not centered on a certain place. One of the engineering calculations performed in this research is by applying open typesabo dam, which can decrease the flow cress level and decrease the flow energy, because it does not flow on the tip of the sabo cress and the flow is not centered but spreads in the sediment gap that is held in front of the sabo dam[5].

Local scoring occurs at one flow velocity where the sediment is transported larger than the sediment supply. Sediment transport increases with increasing sedimentary shear stress, scouring occurs when changes in flow conditions cause increased shear stress at the flow base. Therefore, it can be said that scour is an erosion of the base and cliffs of alluvial channels[6]. The Erosion and sedimentation process is a complex problem, which is strongly influenced by the flow conditions, and the condition of the river sediment material itself [7].

[8] defines the scouring of a stream accompanied by the transfer of material through the action of a fluid motion. Local scouring occurs at a flow velocity in which the transported sediment is larger than the supplied sediment. The velocity of building stability after full sediment loads, with the flow velocity,is very affectedbythe local scouring process, the faster the structure is filled with sediment and reaches its stability level, the faster the structure reaches the stability and is safe from local scouring.

Figure1. The process of local scoring on the downstream of sabo dam structures.

Although the concept of sediment control has been achieved, especially in terms of controlling the flow of debris and mud flow [9];[10], some problems are still common in the field as well as the ability of sabo buildings to survive in a long time. The problems that we often encounter such as the occurrence of scouring on top cress sabo dam (abrasion) due to grain scattering that lasted for a long time, this flow actually occurs at the time of post debris flow. Many special treatments have been applied to suppress the scour rate as is the case with Selective Stone Material which is choosing local stone with certain qualities through testing especially with the average characteristic range of K-600, another method applied is steel coating on top (crest) of sabo, and both methods are able to survive 2-5 years, theywill begin to be eroded by swift scours that lasted for a long time. Figure 2 shows the condition of scouring on top cress Sabo dam even though it has been applied several methods to suppress the rate of scouring, this shows the number of flow energy that occurs in the event of debris flow and posts flow debris[11];[12];[13].

Figure. 2. The process of abrasion on downstream of Sabo dam structure.

The analysis is emphasized on the hydrological behaviour of the sedimentary stream, in this case, post debris flow on the open-type sabo dam and draft on the planned segment by analysing the relationship of variables such as sediment;

thickness (T), porosity (ε), water discharge (Q), diameter (d_{50}) and uniformity coefficient (C_u), to free variables; the flow thickness (h_1/h_0), velocity of water (v_1/v_0) and relative energy (E_1/E_0). The problem of flow energy is the greatest effect on the destruction of Sabo dam in the river, so the researchers want to see a large absorption of the flow energy by applying the treatment to the Sabo dam with slit type through physical modelling in the hydraulics laboratory.

METHODOLOGY

This study represents the location on the upper of the Jeneberang River precisely in the upstream of sabo dam existing series designed with athree-dimensional model with a 1:50 model scale. This research is expected to answer the phenomenon of problems during this happening in the field and other rivers with a fairly high debris, due to the high flow energy that is still difficult to control both during debris flow and post debris flow event. The modeling of thethree-dimensional physical model is intended to facilitate the implementation of research and data retrieval. It is expected that between the physical models in the laboratory have in common with prototype conditions in the field. River modelling can be done with Fixed Bed Model or a Moveble Bed Model. In this modelling is used with Fixed Bed Model.

The next step is the observation and data collection. Model verification and validation are critical in the development of a simulation model[14].The validation, verification and calibration of the modelwere conducted before data collection. This research is a series of research methodology conducted at Hasanuddin University Hydaulics Laboratory. System runningtest was performed 27 times for each thickness of T_1=50 mm, T_2=100 mm, and T_3=150 mm, with water discharge variation Q_1=2,8 l/sec,Q_2=4,3 l/sec, and Q_3=5.8 l/sec; uniformity coefficient Cu_1=1.9 mm, Cu_2=1.8 mm, Cu_3=1.6 mm, and Cu_4=1.0 mm; sediment porosity ε_1=0.596%, ε_2=0,536%, ε_3=0,552%, ε_4=0,565%, ε_5=0,574% and ε_6=0,596%; and diameter of sediment respectively d_{501}=37,5 mm, d_{502}=26,5 mm, d_{50}=25.0 mm, d_{504}=22.0 mm, d_{505}=19.2, and d_{506}=19.0. Figure 3 shows the physical modelling performed at the Laboratory.

In this research, tested and analyzedconducted to examine the relationship of variables such as sediment; thickness (T), porosity (ε), water discharge (Q), diameter (d_{50}) and uniformity coefficient (C_u), to analyzed independent variables; flow thickness(h_1/h_0), velocity of water (v_1/v_0)) and relative energy (E_1/E_0).

Fig. 3 below shows the complete modeling sequence carried out in the hydraulics laboratoryHasanuddin University, from the shelter to the two-dimensional model and the three-dimensional model in which the experiment is carried out. before the data is collected, the first we need to calibration model is done to ensure that the model have the sama to the field conditions.

$$E_o = \frac{V_o^2}{2(g)} \quad (1)$$

$$E_1 = \frac{V_1^2}{2(g)} \quad (2)$$

Where:

E_0 = Energy without sediment

E_1 = Energywithsediment

V_0 = Velocity withoutsediment

V_1 = Velocity withsediment

g = Gravity

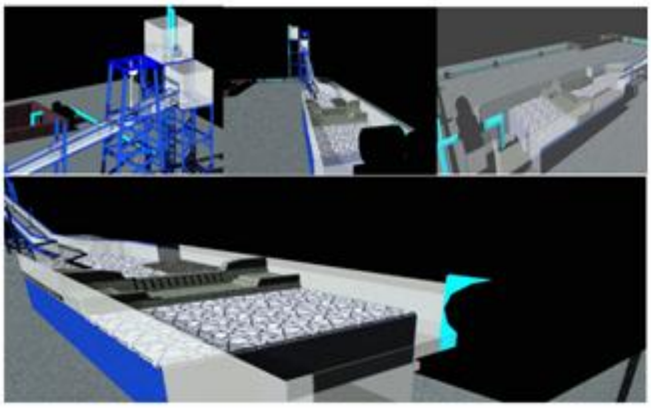

Figure 3. Physical modeling in laboratory

RESULT AND DISCUSSION

Calculation of Model Scale

The results of model scale as shown in Table 1.Based on thecalculation, it can be seen that the relative error value of the model with a 1:50 scale is 16.06% and the model's accuracy is 83.94%. This value is considered to be good, given the field conditions with debris occurrence involves many parameters that cannot be measured properly. Until the modelling with debris flow is still having trouble.

Based on Table 1, it can be seen that relative error values occur in the model, so what has been achieved so far through physical modeling in the laboratory is a step forward for approaches by studying the behavior of the river, especially at peak debit during debris flood, as well as river characteristics including sediment characteristics and flow patterns that tend to change in the event of debris flow.

Analysis of change velocity of water (v_1/v_0) and flow thickness (h_1/h_0)

In Fig.4 below, there is shown an example of a sediment thickness treatment in front of an open-type sabo dam and representing a thickness (T) of 50 mm, 100 mm and 150 mm, with variations in water discharge treatment Q_1=2.8 l/sec, Q_2=4,3 l/sec, and Q_3=5.8 l/sec, uniformity coefficientC_{u1}=1.9 mm, C_{u2}=1.8 mm, C_{u3}=1.6 mm, and C_{u4}=1.0 mm, sediment porosity ε_1=0.596%, ε_2=0.536%,ε_3=0.552%, ε_4=0.565%, ε_5=0.574% and ε_6=0.596%, and the sediment diameters of each d_{501}=37.5 mm, d_{502}=26,5 mm, d_{503}=25.0 mm.

Table 1. Results of model scale calculations used in the model

Errorpermittedin the model (%)	Accuracy physical modelhydraulic (%)	Assumptionof losthigh pressin the model (mm)	Calculation trial & error (mm)	TermsMinimum heightwaterabovein the modelH (mm)	Highwater in the riverQ $_{2Th}$ (m)	Ratio of model scale	Model scale
1.00	99.00	3.6584	0.990	547.834	1.680	0.3261	3.07
2.00	98.00	3.6584	0.980	273.456	1.680	0.1628	6.14
3.00	97.00	3.6584	0.970	181.995	1.680	0.1083	9.23
4.00	96.00	3.6584	0.960	136.263	1.680	0.0811	12.33
5.00	95.00	3.6584	0.950	108.823	1.680	0.0648	15.44
6.00	94.00	3.6584	0.940	90.529	1.680	0.0539	18.56
7.00	93.00	3.6584	0.930	77.460	1.680	0.0461	21.69
8.00	92.00	3.6584	0.920	67.659	1.680	0.0403	24.83
9.00	91.00	3.6584	0.910	60.034	1.680	0.0357	27.98
10.00	90.00	3.6584	0.900	53.934	1.680	0.0321	31.15
16.06	83.94	3.6584	0.839	33.204	1.680	0.0200	50.00

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Figure 4. One example of thickness treatment on coefficient and different diameter

The analysis of sediment thickness, flow rate, porosity, coefficient of uniformity and middle diameter of sediments (T, Q, C_u, ε, d_{50}) to each effect of relative velocity of water (v_1/v_0) of flow thickness (h_1/h_0) and relative energy (E_1/E_0), the test is performed on all parameters used in this study.

One of the calculations presented in the calculation of porosity at 50 mm thickness of sediment in Table 2 below. Giventhe results of this calculation is enough,however researchers only present one example of the calculation results by taking the example of one parameter that is porosity. Both the thicknesses of 50 mm, 100 mm and 150 mm show nearly the same effect on changes in flow velocity (v_1/v_0) and flow thickness (h_1/h_0) at the downstream of slite-typesabo dam.

Based on the test results shown in Table 3, it can be seen the effect of porosity to depth in 50 mm sediment thickness. The debit of 2.8 l/sec on the porosity of 0.536% of the flow thickness is at a depth of 0.820 mm, until the porosity of 0.574% of the flow thickness rises to 1.174 mm, whereas in the porosity 0.596% the depth decreases to 1.052 mm and for the 4.3 l/sec at 0.536% to 0.574% porosity seen elevation of water level increased from 1,028 mm to 1,239 mm and at porosity 0,596% water level decrease to 0,985 mm, for debit 5,8 l/sec experiencing the same condition at porosity 0,536 % up to 0.574% had an increase in flow thickness from 1.016mm to 1,680 mm and decreased in 0.596% porosity to 0.912%.

Table 2 also shows the effect of porosity on the velocity at 50 mm thickness, where at 2.8 l/sec with 0.514% porosity the flow velocity reaches 0.772 m/sec and up to 0.574% porosity the flow velocity decreases to 0.827m/sec while 0.596% porosity increases to 0.894 m/sec. At water discharge4.3 l/sec the porosity of 0.514% to 0.574% also decreased relative flow velocity from 0.860 m/sec to 0.830m/sec and at 0.596% porosity the velocity increased to 0.950 m/sec. The same is true for debit of 5.8 l/sec, porosity 0.514% to 0.574%,velocity decreased from 0.941 m/secto 0.836 m/sec and at 0.596% porosity, flow velocity increased to 0.998 m/sec. The relationship of porosity to depth and velocity at 50 mm sediment thickness can be seen in Fig.5.

Table 2.The effect of porosity (ε) on flow thickness (h_1/h_0) and flow velocity (v_1/v_0) atthickness (t) 50mm

C_u	Porosity (ε)	Sediment Thickness, (mm)	Q (litre/second)	h_1/h_o	v_1/v_0
1.0	0.596	50	2.8	1.052	0.894
1.9	0.574	50	2.8	1.174	0.827
1.8	0.565	50	2.8	1.142	0.839
1.0	0.552	50	2.8	1.058	0.846
1.6	0.536	50	2.8	0.820	1.001
1.0	0.514	50	2.8	1.081	0.772
1.0	0.596	50	4.3	0.985	0.950
1.9	0.574	50	4.3	1.239	0.834
1.8	0.565	50	4.3	1.224	0.841
1.0	0.552	50	4.3	1.017	0.869
1.6	0.536	50	4.3	1.003	0.932
1.0	0.514	50	4.3	1.028	0.860
1.0	0.596	50	5.8	0.912	0.998
1.9	0.574	50	5.8	1.680	0.836
1.8	0.565	50	5.8	1.401	0.849
1.0	0.552	50	5.8	0.983	0.957
1.6	0.536	50	5.8	1.344	0.888
1.0	0.514	50	5.8	1.016	0.941

Thepatternofthe point of dispersion relation between the depth and the relative velocity to porosity at 50 mm, 100 mm and 150 mm sediment thickness shown in Fig.5, the effect of porosity ondepth indicates that the larger porosity the relative water level will belarger , the effect of porosity on velocity indicates that the larger the porosity the relative velocity will be smaller. Fig. 5 below takes one example of a relationship graph on the inside 150 mm where the relationship pattern will tend to experience the same pattern of relationship between porosity to thethickness and sediment velocity.

Fig.5 shows the relationship pattern between variables on the 50 mm high sediment test, indicating that the treatment gives effect of sediment; thickness, water discharge, porosity, uniform coefficient, and middle diameter of sediment (T, Q, C_u, ε, d_{50}) shows the effect on relative velocity of water (v_1/v_0), flow thickness (h_1/h_0), there is a tendency, the greater the sediment; thickness, diameter, porosity and coefficient of uniformity, then the relative velocity decreases, and the flow height increases. While the water discharge tends to be positively correlated, the greater the flow rate at certain coefficient.

Table 3. Effect of uniformity coefficient (C_u) on energy (E_1/E_0) at 150 mm sediment thickness

C_u	Sediment Thickness, T (mm)	Q (litre/second)	E_1/E_0
1.9	150	2.8	0.347
1.8	150	2.8	0.535
1.6	150	2.8	0.567
1.9	150	4.3	0.435
1.8	150	4.3	0.539
1.6	150	4.3	0.639
1.9	150	5.8	0.454
1.8	150	5.8	0.553
1.6	150	5.8	0.646

The relationship between porosity (ε) and relative energy change (E_1/E_0) at 50 mm sediment thickness tested with water discharge of 2.8 l/sec, 4.3 l/sec and 5.8 l/sec, the effect of porosity on the energy produced by discharget variation can be seen the pattern of spreading. This pattern looks the same in all thickness of the sediment either 50 mm thickness, 100 mm or 150 mm. The formation of porosity is strongly affected by the sediment diameter and the uniformity coefficient. The larger the sediment diameter, the pores formed will be greater,and the coefficient of uniformity determines the number of pores that are formed. The pore size formed greatly mounds the flow mechanism as it passes through the sediment stack in front of the sabo dam, and directly affects the reduction of the flow energy.

sediment thickness, the flow velocity, and flow thickness tend to be greater.

Analysis of Energy Decrease (E_1/E_0)

Table 3 shows the same behavior regarding energy changes to the variation of uniformity coefficient (C_u). Based on the uniformity coefficient it is seen that the magnitude of energy always occurs in the smallest uniformity coefficient than the largest uniformity coefficient. It can be seen that the energy generated at 5.8 l/sec debit is greater than 4.3 l/sec and 2.8 l/sec debit at 150 mm sediment thickness.

In this study, the test of sediments with different uniformity coefficients are 1.6%, 1.8%, and 1.9% to analyze the magnitude of the energy changes to the variation. This test is also done on various sediment thicknesses that are 50 mm, 100 mm and 150 mm. In Figure 6 shows the pattern of relationship between the uniformity coefficient and the energy in 50 mm sedimentation.This shows the effect of theuniform

This indicates that the effect of porosity on the decrease of debris flow energy is very large, this is the same effect on the sediment thickness of 100 mm and 150 mm, meaning that the higher the sediment deposition in front of the sabo dam, the amount of space to pass through the sediment, generated will tend to be small and decrease.Based on the test that has been described in the results of this study that will be done dimension analysis on the variables that affect the variables are repeated in this study, then from the analysis obtained the equation of Non-Dimensional Parameter (NDP), with the equation as follows:

$$\frac{T^2\sqrt{gd_{50}}}{Q} \tag{3}$$

Where is

T = Sediment thixkness

Q = Velocity of sediment flow

d_{50} = Mean diameter of sediment

g = Gravity

The equation will be used to obtain the final equation of the parameters which most affect the relative energy of debris flow. Furthermore, data are performed to find the pattern of energy distribution spread over the overall NDP combined (T, g, $d_{50,}$ and Q) before being affected by porosity (ε) and uniformity coefficient (C_u). The pattern of distribution is presented in Figure 5. While the dispersion pattern showing the relationship between the combined NDP values without the effect of coefficient uniformity is presented in Figure 5.

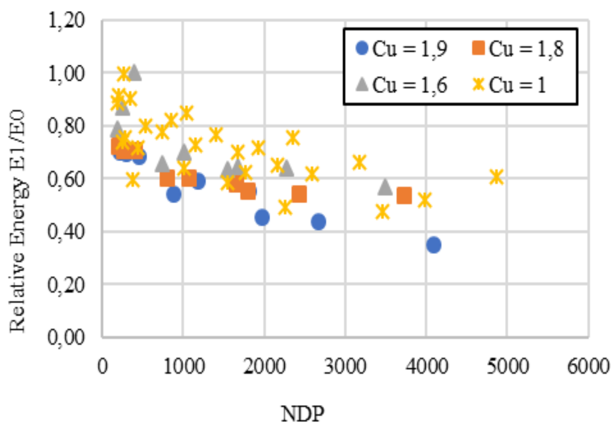

Figure 5. Relative energy changes (E_1/E_0) to NDP on each uniformity coefficient (C_u).

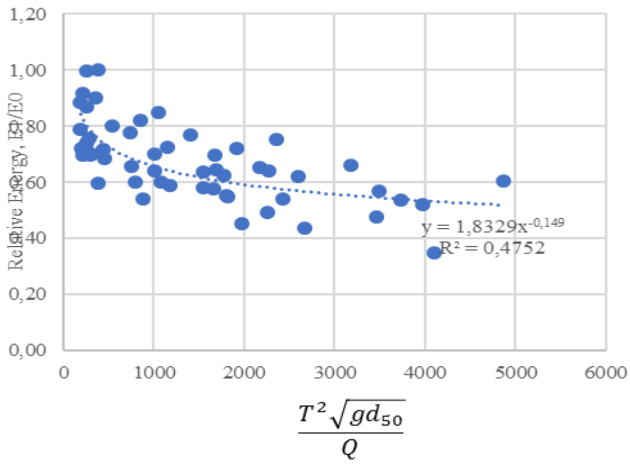

Figure 6. Relative energy changes (E_1/E_0) to NDP (T, g, d_{50}, and Q) without porosity (ε) and uniformity coefficient (C_u).

The next data plotting is done to see the pattern of the distribution of energy effect on the overall NDP combined (T, g, d_{50}, Q, and ε) before it is affected by the uniformity coefficient (C_u) where the initial equation used becomes:

$$\frac{T^2\varepsilon\sqrt{gd_{50}}}{Q} \tag{4}$$

Where is

T = Sediment thixkness

Q = Velocity of sediment flow

ε = Porosity

d_{50} = Mean diameter of sediment

g = Gravity

While the dispersion pattern showing the relationship between the combined NDP values without the effect of coefficient uniform is presented in Figure 7.

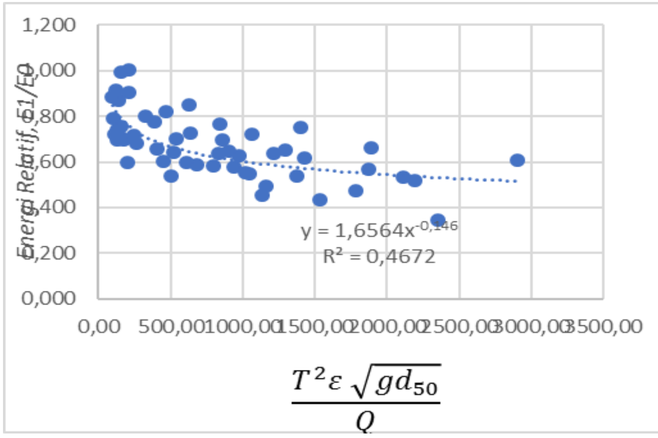

Figure 7. Relative energy changes (E_1/E_0) to NDP (T, g, d_{50}, Q, and ε) without the uniformity coefficient (C_u)

Furthermore, after the non-dimensional parameters (NDP) has been combined as a whole (T, g, d_{50}, Q, ε, and C_u) then the data grouping is performed to find the last pattern of distribution graphically as shown in Figure 8, with the equation as follows:

$$\frac{T^2C_u\varepsilon\sqrt{gd_{50}}}{Q} \tag{5}$$

Where is

T = Sediment thixkness

Q = Velocity of sediment flow

C_u = Coefficient of uniformity

ε = Porosity

d_{50} = Mean diameter of sediment

g = Gravity

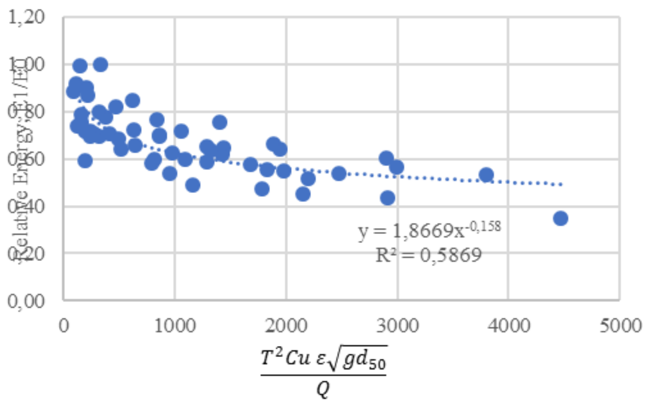

Figure 8. Relative energy changes (E_1/E_0) to the overall NDP (T, g, d_{50}, Q, and C_u).

Based on the result of grouping distribution patterns which have been shown, then got a new equation which can determine the amount of relative energy change to each parameter used. The equation is obtained:

$Y=1.8669X^{0.158}$(6)

based on the above equation, it will find the formula of Relative Energy equation to be:

$$\frac{g_o}{g_1} = n\tau^m \qquad (7)$$

Where is

E_1 = Energy with sediment

E_o = Energy without sediment

n = Constanta, 1.86669

m = Constanta, 0.1580

$$\tau = \frac{T^2 C_u \epsilon \sqrt{g d_{50}}}{Q}$$

Then obtained the final equation that is generated to determine the relative energy scale as follows:

$$\frac{E_1}{E_o} = n\left[\frac{T^2 C_u \varepsilon \sqrt{g d_{50}}}{Q}\right]^m \qquad (8)$$

Where is

E_1 = Energy with sediment

E_o = Energy without sediment

C_u = Coefficient of uniformity

ε = Porosity

d_{50} = Mean diameter of sediment

g = Gravity

n = Constanta, 1.86669

m = Constanta, 0.1580

Many study of debris flow also about sabo dam have been made, but almost study to analyzed the characteristic of debris flow and the function of sabo dam for countermeasures sediment during debris flow event. This research is expected to answer the phenomenon of problems during this happening in the field and other rivers with a fairly high debris, due to the high flow energy that is still difficult to control both during debris flow and post debris flow.This study especially to understanding about countermeasures flow energy depend of deposition and condition sediment by open-type sabo dam during debris flow event.

one of the studies that analyzed the energy with the title of kinetic energy model with two phases of debris flow has been implemented by[15] with the assumption that a numerical model for two-phase debris flow is develop on the basic of the understanding of the physical features. An equation of the kinetic energy of gravel particles in unit volume in debris flow is established in this equation the potential energy of the particles, energy from the liquid phase, energy consumption due to inner friction-collision between the particle, energy dispersion through collisions between particle, energy for inertia force, energy consumption due to the friction the rough bed and energy consumption at the debris front are considered.

CONCLUSIONS

1. Sediment discharge treatment (Q) shows a significant effect on velocity of water change (v_1/v_0), flow thickness (h_1/h_0) and relative energy (E_1/E_0) on slit type open sabo dam. The larger the debitflowing, the flow velocity, flow thickness and relative energy will be larger.
2. Uniformity coefficient treatment (C_u) and diameter (d_{50}) shows significant effect on velocity of water change (v_1/v_0), flow thickness (h_1/h_0) and relative energy (E_1/E_0) on slit type open sabo dam. The larger grains size diameter with a small uniformity coefficient will decrease the flow velocity, flow thickness and relative energy, as well as on small diameter grains with large uniformity coefficient, tending to increase flow velocity, flow thickness and relative energy.
3. Sediment thicknesstreatment (T) showed significanteffect on velocity of water change (v_1/v_0), flow thickness (h_1/h_0) and relative energy (E_1/E_0) on slit type open sabo dam. The thicker the sediment formed in front of the sabo dam, the flow velocity, flow thickness and relative energy will tend to decrease.
4. The treatment of porosity (ε) shows significant effects on changes in flow velocity (v_1/v_0), flow thickness (h_1/h_0) and relative energy (E_1/E_0) on slit type open sabo dam. The larger the pores are formed, the flow velocity, flow height and relative energy will decrease. Vice versa on the small porosity.
5. The relationship between the independent variables (T, Q, C_u, ε, and d_{50}) on the dependent variables (v, h and E) observed in this study, based on the results of distributed patterns grouping that have been shown, determine the number of energy changes relative to each parameter used. The equation obtained is Y=1.8669X-0.158, with the formula of relative energy equation becomes:

$$\frac{E_1}{E_o} = n\left[\frac{T^2 C_u \varepsilon \sqrt{g d_{50}}}{Q}\right]^m$$

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