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THE EFFECT OF POROUS CONCRETE HANDLING ON EROSION REDUCTION IN SLOPED SOIL AND SANDY CLAY CONDITIONS

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ABSTRACT

Erosion is the process of eroding the surface of the topsoil caused by the intensity of the rainfall that occurs and causing splashes due to the working kinetic energy (J/m2), coupled with runoff due to the slope factor, which is influenced by soil type and land cover. The characteristics of soil type and topography cause damage to the topsoil and push the sedimentation volume to increase from time to time. Therefore Road safety infrastructure buildings, such as cliff protection on a slope, irrigation building walls, and so on, require good security to avoid collapse or loss of slope stability. Reducing the occurrence of kinetic energy in the topsoil surface layer and reducing erosion can be done by making a surface layer with a porous concrete pavement structure. However, first, it necessary to analyze the amount of kinetic energy acting on the soil surface. The positive effects of porous concrete layers on slope stability are discussed using: i) geo-mechanical effects, namely soil reinforcement with shaft concrete; ii) soil hydrological effects, namely the suction regime of the soil, which is influenced by the absorption of water flowing through the concrete shaft. A one-dimensional vertical groundwater dynamics model is assumed to simulate the soil suction regime, representing soil covered with shaft concrete on slopes with various gradients. It was found that in various soil types and different slopes, in the case of sandy loam soils, geo-mechanical effects tend to be more relevant than soil hydrological effects during the rainy season.

Keywords: porous concrete, kinetic energy, geo-mechanical, rain intensity, slope

INTRODUCTION

In the development of human civilization, the decline in the socio-economic conditions of society is primarily due to the unwise exploitation of environmental resources [1].

In the development of the industry to date, human activity can be said to be an essential agent in ecological change. According to a 2005 study by Wilkinson, human activity is the most critical agent of geomorphic change, compared to natural processes that gradually work on the land surface.

Furthermore, Price, Ford, Cooper, and Neal [2] stated that the annual change in sediment caused by human activities exceeds that carried by river flows. In the treatment process carried out by humans in mining activities, many topographic trimmings with a reasonably extreme slope have caused many topographic changes, resulting in an erosion process in the area [3]. Likewise, in infrastructure development such as roads, dams, and so on [4], much topography is trimmed to increase erosion in the area, which will increase the incidence of sedimentation. On this basis, it is essential to reduce the increase in ecological damage in infrastructure development such as roads, built areas, and dams. Therefore, it is necessary to engineer a layering of the basic soil structure with special treatment, to minimize the stripping of the soil layer due to erosion caused by water flow

The topographical modelling approach for erosion and deposition is illustrated using the upstream Lematang Sub-watershed, South Sumatra Province, Indonesia. Geographically, the research area is located at 2º 45 '- 4º 20' South Latitude and 103º 05 '- 104º 20' East Longitude. The upper Lematang watershed consists of steep undulating hills, with slope angles of between 30% - 50%. To meet the irrigation water needs for the Lematang Irrigation Area in center Dempo District Pagar Alam City, South Sumatra Province, the Lematang Weir has been built, which is located in the hilly area of the upstream Lematang sub-watershed. Meanwhile, the hillsides that tilt towards the river flow in some places form steep slopes (the angle is almost 50%), such as the pedestal hill to the left of the weir, while the right pedestal hill is formed gentler slopes [5].

The most important thing in looking at the study of weir construction in the hill area is the need to calibrate the characteristics of the river in the watershed (DAS) of the study area. This is very important considering that the shape and magnitude of the flood hydrograph are highly dependent on the characteristics of the watershed. The watershed features become the basis for reducing the scour rate at the bottom of the channel [6].

In a study conducted by Sulaeman et al [4], the numerical analysis uses 3D Delft to predict patterns, flow velocity, and morphological changes upstream and downstream of the weir. The results showed a trend of change at the bottom of the river, namely degradation of the outer bend channel upstream of the weir and a decrease in the left side of the riverbed, while sedimentation occurred on the right downstream of the riverbed the weir.

METHOD

The approach used is first to compare the distribution of sediment transport values, erosion, and soil deposition with different parameters: a) only paying attention to topographic factors, b) topography and soil erosion, and c) topography, water seepage, and layering experiments. Second, a general assessment of watershed stability in terms of the mutual interaction between erosion and deposition is carried out by comparing the contribution of sediment from the Upper Lematang watershed.

RESULTS

Figure 1 presents the distribution of erosion and deposition in the Upper Lematang sub-watershed for four different combinations of factors using the USPED decline and deposition model [7]. Initially, the analysis was carried out only paying attention to topographical factors, then combined with soil erosion factors and land cover factors. They were analyzed simultaneously. Thus, there are three factors used in conducting analysis using the erosion mechanism of the runoff model for comparison purposes. Overall (see Table 1), the classification of the magnitude of the erosion distribution is minus (0 -100) tons/ha/year, spreading over an area of approximately 1,331.35 Km^2 in a room with a land slope of around 17^o – 34^o [8].

Fig. 1 The upper Lematang sub-watershed and the location of the Lematang Dam

Meanwhile, the amount of deposition is between +(0-100) tons/Ha/Year spreads over an area of approximately 1,278.41 Km^2, with a land slope of around 0^o-17^o. Meanwhile, sheet erosion of more than 500 tons/ha/year occurs on an area of approximately 71.26 Km^2. This magnitude of the erosion and deposition processes with high intensity is relatively low. The distribution also changes with the addition of topographic factors into the model. With a topographic slope of more than 34o, the amount of erosion is more than 500 tons/ha/year, occurring on an area of 33.54 Km^2. If the vegetation factor is removed, the erosion rate will increase significantly up to 0.5% [9].

River Channel Change Analysis

Based on speed distribution

Changes in the river bed upstream and downstream of the Lematang weir can occur due to the high flow velocity during drainage, of 2.3 m/s at a 5-year return period discharge downstream of the weir with an average river bed material around the downstream of the weir of 2 mm [5]. Based on the Hjulstorm graph, namely the relationship between the diameter of the material grains and the flow velocity (Figure 2), the tendency for scour to occur results in a decrease in the riverbed (blue line).

Table 1 Erosion classification and deposition of erosion rates in the upper Lematang sub-watershed

Classification (Ton/Ha/Year)	Area (Ha)	Area (Km2)	%
< - (2500)	273.75	2.74	0.09
-(2500-1000)	1,576.31	15.76	0.50
-(1000 – 500)	3,354.00	33.54	1.07
-(500 – 250)	7,125.50	71.26	2.28
-(250 –100)	15,693.13	156.93	5.02
(100 - 0)	133,134.75	1,331.35	42.62
(0 – 100)	127,840.88	1,278.41	40.93
(100-250)	13,411.19	134.11	4.29
(250-500)	5,599.94	56.00	1.79
> 500	4,364.25	43.64	1.40
Total		2,123.74	100.00

With the shape of the river that bends sharply upstream and downstream of the weir, it is possible for scouring to occur at the foot of the outer river bank. When depicted on the Hjulstorm graph, with a 5-year return period discharge and a flow velocity of 0.9 m/s, the grain size of the D50 material is 0.8 mm. At the upstream of the weir (red line), with a speed of 1.4m/s, at the downstream bend with a material diameter of D50 (2 mm), it is predicted that riverbed scour (green line) will occur (Figure 2).

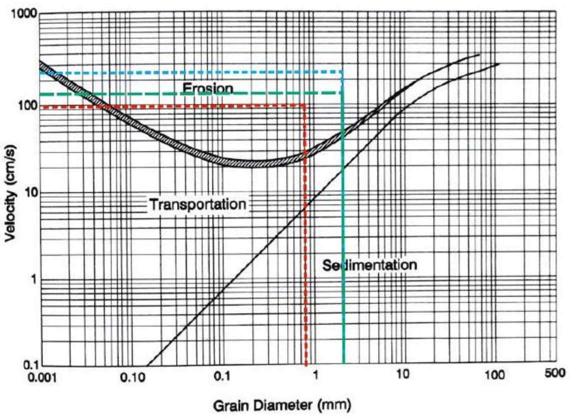

Fig. 2 Graph of the relationship between flow velocity and the grain diameter of the river bed material (0.8 mm)

Based on the flow shear stress

One of the parameters to predict scouring is the flow shear stress parameter (τo). By comparing the flow shear stress (τo), that occurs and the critical grain shear stress (τcr), the prediction of scouring or deposition will occur. From the results of plotting the flow shear stress on the graph of the relationship between the diameter of the sediment material and the shear stress in Figure 3, it is found that the shear force that occurs at the five-year return discharge, in the position after leaving the stilling pond, to the right of the downstream channel of the weir, has a shear force value of 43 N/m2 with a material diameter of 2 mm D50 (red line). This explains that with a 5-year return period, discharge of 26.3 m3/s can erode the riverbed downstream of the weir.

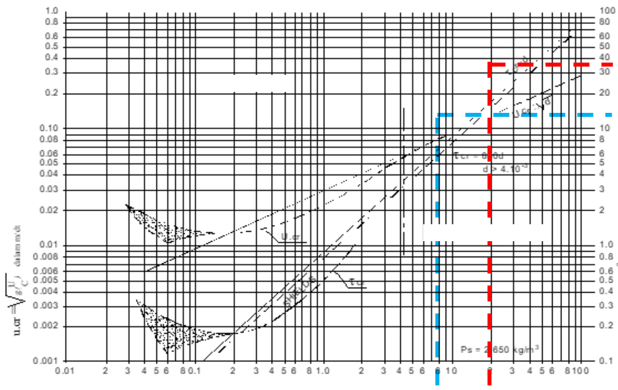

Fig. 3 Graph of critical shear stress relationship with riverbed grain diameter (2mm)

Similarly, upstream of the dam, the water flow from the left upstream hitting the cliff to the right upstream has a shear force value of 15 N/m2 with a material diameter of D50 is 0.8 mm shown in the blue line. This explains that the 5-year return discharge of 26, 3 m3/s can erode the riverbed upstream of the weir. The sheer force of the flow increases with the increase in release at the return period, and it will also increase the potential for greater scouring of the riverbed [5]

Discussion

Sediment transport rate and spatial distribution of erosion and sediment affected by topographical functions

In reducing the sediment transport capacity for the upstream Lematang sub-watershed, terrain geometry plays the most critical role. In addition, there is a fixed pattern underlying the sediment transport capacity, which is controlled by topographical conditions. When modified by vegetation cover conditions and soil type distribution, topographical geometrical properties (slope) determine the spatial distribution of sediment transport capacity in the sub-watershed [10]. Sheet flow is usually characteristic of areas with good vegetation cover. However, it can occur in very compacted soils, where soil detachment and the formation of natural flow can be prevented by compaction. The increasing contribution to the slope area, combined with high local slope values, is indicated by high levels of sediment transport. Areas with high sediment transport rates associated with concave slope profiles and valleys will accelerate convergent sediment transport rates. Comparing sediment transport rates between sheet erosion and natural erosion shows that the actual flow is turbulent. As a result, it can carry sediment further in the flow and be more concentrated along the valley and in the concave part of the hillside than if the flow was dispersed by vegetation in sheet flow.

Sediment transport rate divergence (qs) can be identified in areas where the sediment transport rate increases in the direction of flow (leading to erosion), decreases (leads to deposition), or remains constant (no corrosion or deposit). It is essential to emphasize the difference between the quantities calculated using the Erosivity Index (E) and Transport Capacity (T) equations, i.e., sediment transport rates and erosion and deposition rates: which can detect areas of high mass-carrying capacity. While the second allows the detection of erosion and deposition patterns determined by the distribution of incoming sediment supply to local transport capacity [11].

The resulting erosion/deposition map (based on topography only) shows that the estimated high-risk erosion areas are located at the top of the hillside, in basins and valley centers with concentrated flows. The depositional area usually occurs in the lower part of the hillside and the concave portion of the valley. This situation is consistent with previous results showing that the highest erosion rates correlate with divergent elements and deposition with convergent avalanche elements [12]. Maximum soil loss occurs on slopes with a slope degree of more than 34^o, and total soil erosion occurs on both sides of the traversed pitch.

Sediment transport rate and spatial distribution of erosion and sediment as a function of topography and soil erosion

Overall, by including the K-factor in the analysis, the spatial pattern of sediment transport shows the influence of areas with high erosion. However, because the distribution of soil types is highly correlated with topography, the design is strongly dominated by topography. Thus sediment flows will have lower values over a more prominent location across the landscape than they would have very high values concentrated in high-sloping sunken areas[13].

The inclusion of soil erosion patterns also modified the spatial distribution of erosion and deposition. This will increase the area of the area that is at greater risk of decline. Although the percentage of sites with erosion/deposition values is less than or equal to the case where the topography is the only triggering factor (42.62%). It should be noted the distribution of erosion and deposition values for both. Erosion and deposition cases were analyzed by taking into account the soil erosion factor, and the erosion percentage ranged from 5.02% to 4.29%. At the same time, the topographic factor has a much more significant influence on erosion (40.93 to 42.62) %. The corresponding erosion range from (-0 to 100) covered 9.92% of the study area (Table 1). Regions with maximum erosion risk are concentrated along steep slopes (42.62%), which also have large soil erosion values, while deposition occurs in areas with lower pitches and occurs along valleys [8].

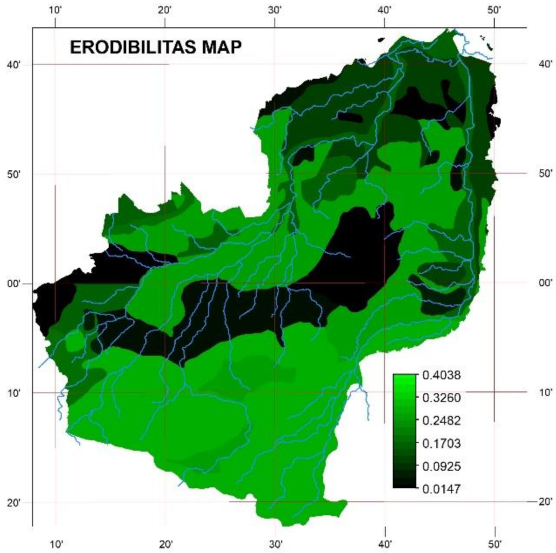

Fig. 4 Erosion and Sedimentation as a function of topography and soil erodibility

Reducing the effect of water seepage, which can reduce the amount of erosion

Experiment using a pond in a different case to test water seepage in a watercourse [14][15]. Six ponds with a capacity of 100 m3 observed the rate of seepage during the rainy season and after the rainy season. During the rainy season, surface water is kept at the pond's bottom, limiting the vertical flow of water and sometimes damaging seepage. One of the ponds was coated with a low-density polyethylene film to see the effect of the absence of seepage. The result provides the lowest level of seepage compared to pools lined with broken brick material or pools lined with a mixture of soil and cement.

Meanwhile, Wang et al conducted a study on seepage loss in channels with various coating materials [16]. The seepage loss analyzed by the Inflow-Outflow method varies from 0.225 to 0.315 ft3/ft2/hour. At the same time, the process of observing the water level in the pond obtained results ranging from 0.1954 ft3/ft2/hour to 0.2584ft3/ft2/hour. The rate of constant seepage loss over 200 ft in the earth channel was found to vary from 12 to 18 percent of the inflow to the outlet, i.e., 0.23 to 0.41 ft3/ft2/hr [17].

By conducting a semi-field trial using the following composition, [18] : (1) Cement-gravel-sand-gravel concrete (0.58 : 0.15 :5:10); (2) Cement – fly ash-sand-gravel concrete (0.8: 0.2: 5: 10); (3) A layer of sand – asphalt – cement on the soil base (0.85: 0.1: 0.05); (4) Sand-bitumen – cement layer on the cement mortar base (0.85: 075: 0.075) and (5) without treatment. The results obtained are that the maximum seepage occurs in the uncoated channel, which is 45 m3 per 1000 m2. While the minimum seepage in treatment No. 2 is 2.76 m3 per 1000 m2.

On this basis, to reduce water seepage due to the flow process in areas that significantly influence slopes and high erosion potential due to cliff erosion, it is necessary to design using coatings. It is recommended that infrastructure development, which can lose water or reduce surface erosion in general, should be equipped with a layer in all future projects.

Zhang et al [19] experimented on seepage loss through experiments with field conditions coated with different coating materials. The seepage of various coating specifications varies from almost nil to 0.3 m3/Mm2 in a double layer tile layer with a layer of 1:3 cement sand plaster on the slope side and single layer bricks on the base 6.8 cm thick asphalt concrete on the side—each layer. The seepage loss through the precast beams of single-layer cement mortar 1:3 bricks ranged from 0.04 to 0.16 m3/Mm2.

Preliminary laboratory tests have been carried out on a layer of asphalt concrete consisting of pea jelly, quarry dust, fine aggregate, rock dust (20: 40: 25: 10), and 60/70 asphalt 9 percent by weight and cement concrete 1:4:8 with 13 percent bentonite. Furthermore, it concluded that the asphalt concrete layer could function as a suitable coating material.

Experimentally Mclaughlin et al [20] proved that emulsified asphalt mixed with soil had shown promise as a coating material, reducing the level of erosiveness in a topsoil layer.

Worstell [21] conducted tests on various coating materials to study the seepage loss and found the range of seepage loss through different coating materials as below : (1) Concrete (0.009-0.29) m/day); (2) Compacted soil (0.003 to 0.29 m/day); (3) Asphalt cement (0.003 to 0.92 m/day; (4) Soil cement (100 : 5) with (0.009 to 0.06 m/day; (5) Chemical Sealant (0.1-2.53 m/day); (6) Sediment Seal (0.12 to 0.40 m/day); (7) Unlined (0.003 to 5.37 m/day).

The Maharashtra Engineering Research Institute Nasik [22] develop an inexpensive channel coating material in mortar-stabilized soil tile and fly ash concrete. It has been observed that flash has uniform properties except for its fineness, although the coal used has very variable properties.

It was observed that cement could be replaced by fly ash up to 10 percent for 1:3 and 1:5 mortars, and sand could be replaced by fly ash up to 20 percent for 1:3 and 1:5 mixtures. The study was made based on the strength criteria, and it was found that if 90 days is a strength criterion, then 20 percent of cement will be replaced for significant works such as dams, and if 28 days is a strength criterion, 15 percent of glue can be replaced with fly ash. Fly ash has been used in stable soils as support for tiles. This technique has been adopted in the Jaikwadi and Girna Command Areas.

CONCLUSIONS

1. Comparison of USLE, LS and topographic factors and the erosion/deposition index shows that a water-based destructive power approach is more appropriate for erosion modelling on a landscape scale. Especially when the location of both regions is at risk of erosion and with potential deposition, it is very likely to occur
2. With this analysis has improved the approach based on water damaging power units by increasing DEM calculations using smaller pixel sizes and by perfecting the flow direction using vector-grid algorithm
3. Retaining walls to hold the soil on the cliff from scouring due to flow patterns and flow velocity as well as natural collapse caused by water scouring and slope slope
4. It is recommended that infrastructure development, which can lose water or reduce surface erosion in general, should be equipped with a layer in all future projects.

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