Design of Concrete Sheet Pile Revetment As A River Protector And Recreation Facilities

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Abstract. Revetment is a strengthening structure on river slopes from erosion. Erosion of river slopes can widen the wet cross section of the river and increasing scouring can endanger the surrounding buildings. The construction of the Demangan Water Gate in Surakarta City (Phase I) is planned at the mouth of the Pepe river downstream. The construction work will result in changes in river morphology, therefore it is necessary to protect the river slopes so that landslides do not occur. Apart from being a river slope protector, the Revetment design can also be a recreation area and an inspection road. The construction to be used is a concrete sheet pile revetment with reinforcement of the piles behind it as an anchor. Between the concrete sheet pile and the concrete pile, it is connected by a beam-slab structure so that it becomes a portal system. River slope stability analysis using GeoStudio2018 R2 software. River slope conditions that may occur are applied in several modeling, including: River slope conditions without Revetment reinforcement, River slope conditions with Revetment reinforcement, Conditions when changes in river water level elevation occur and river slope conditions when erosion occurs. Based on the results of modeling analysis on the original slope when the river water level increase then recedes has the smallest safe number (SF = 1,822). This is because on the back side of the Revetment, the active soil pressure is in a saturated condition, while the front side of the Revetment loses hydrostatic pressure as a counterweight. The highest safety number is in slope modeling with Revetment strengthening when the river water level increase (SF = 3.114), because the hydrostatic pressure on the back and front of the Revetment is balanced. Revetment construction on river slopes increases the safety rate by 30.64% - 43.70%. With the strengthening of the river slopes, it is hoped that it can provide sufficient security from the main function of protecting the river slopes and obtaining additional functions as a recreation area.

***Keywords**: Safe Number; Erosion; Recreation; Revetment; River Slopes; Sheet pile.*

1. Introduction

The floodgate is a building that functions to control the flow of river water for irrigation purposes and to prevent flooding. Construction work for Demangan Water Gate in Surakarta City (Phase I) near the mouth of the Pepe Hilir River. With the construction of this sluice gate, it is necessary to strengthen river slopes (revetment) at the upstream and downstream of the sluice structure. The reinforcement is intended to prevent slope damage due to changes in river morphology at that location. Revetment is a strengthening structure on river slopes from erosion. Erosion of river slopes can widen the wet cross section of the river and increasing scouring can endanger the surrounding buildings.

Figure 1. Site Map

Apart from being a river slope protector, the revetment design can also be a recreation area and an inspection road. The construction to be used is a concrete sheet revetment with reinforcement of the piles behind it as an anchor. Between the concrete sheet pile and the concrete pile, it is connected by a beam-slab structure so that it becomes a portal system. The location of the revetment construction work is in Sewu Village, Jebres District, Surakarta City. The location map is presented in Figure 1.

The existing field conditions at the revetment retrofitting location plan are as follows:

(a)

(b)

(c)

(d)

Figure 2. Site Condition, (a) Photo from Upstream; (b) the condition of the slope of the river on the left of the Kali Pepe estuary; (c) the condition of the riverbank of the Pepe River; (d) slope conditions downstream of the estuary of Kali Pepe.

2. Methods

2. 1. Slope Stability

Slope stability analysis is generally based on the concept of limit plastic equilibrium (limit plastic equilibrium). The purpose of the stability analysis is to determine the safety factor of a potential landslide field. The safety factor is defined as the value of the ratio between the holding force and the driving force. (Hardiyatmo, 2012)

$$SF = \frac{\tau}{\tau_d} \quad (1)$$

with :

SF = safety factor

τ = maximum shear resistance (kN/m^2)

τ_d = shear resistance occurs (kN/m^2)

SNI 8460-2017 recommends the following safe factor categories:

Tabel 1. Recommended slope SF value

Rock slope conditions	Recommended safety factor values
Permanent slope conditions	1.5
Temporary condition	1.3

Bowles (1984) recommend the following safe factor categories:

Tabel 2. Recommended slope SF value

SF	failure
SF<1.07	It happens
1.07<SF<1.25	It happened
SF>1.25	Rarely happening

The method of calculating the forces acting on the landslide plane has been developed by several researchers, including: Bishop's rigorous, Spencer's, Sarma's and Morgenstern-Price which provide a more complex way by taking into account the moment force balance. The forces acting on the landslide section are shown in Figure 2. As follows:

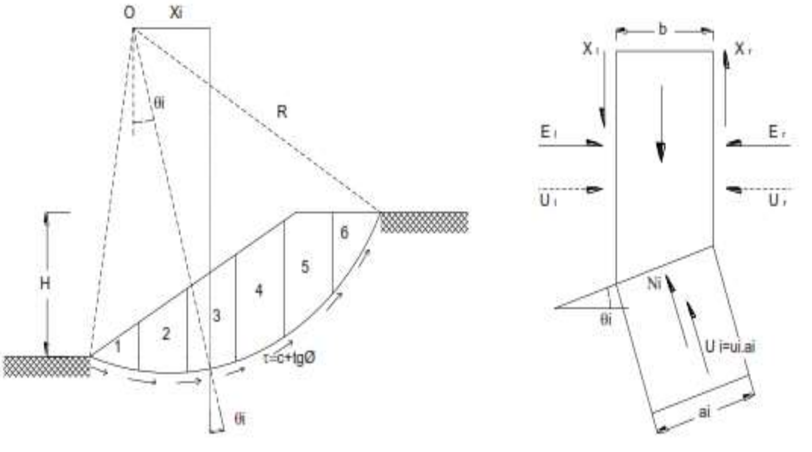

Figure 3. The force acting on the slice of the landslide plane

Soil shear strength parameters consist of cohesion (c) and internal friction angle (φ). According to Mohr-Coulumb (1776) in Hardiyatmo (2012) gives the following general equation:

$$\tau = c + \sigma tg\varphi \qquad (2)$$

with :

τ = soil shear streght (kN/m^2)
c = soil cohesion (kN/m^2)
φ = friction angle (º)
σ = normal stress at the failure surface (kN/m^2) (kN/m^2)

2. 2. Soil Properties

The data used are the results of core drilling as deep as 30 m. The summary of the soil layer is as follows:

Tabel 3. Type layer of soil

No	Layer of soil	Dept (m)	C (kPa)	Ø (º)	γ (kN/m³)
1	Stiff clay	0 - 2.5	32	12.87	1.69
2	Medium dense sand	2.5 – 7.5	12.7	18.31	1.68
3	Sand Stone	7.5 - 9	17.4	29.37	1.73
4	Very stiff clay	9 – 11.5	29.2	20.75	1.76
5	Very dense sand	11.5 - 12	35	30	1.8

2. 3. Sheet pile Properties

The sheet sheet used is FPC-320 500 with concrete quality fc '= 42 Mpa. Meanwhile, the pile used as the anchor is prestressed concrete 400x400 square pile with concrete quality fc '= 42 Mpa. While the slab and beam structure uses ready mix concrete with k-300 quality.

2. 4. Geometry of slope and Slope reinforcement system

The slope geometry data and the slope reinforcement system used are as follows:

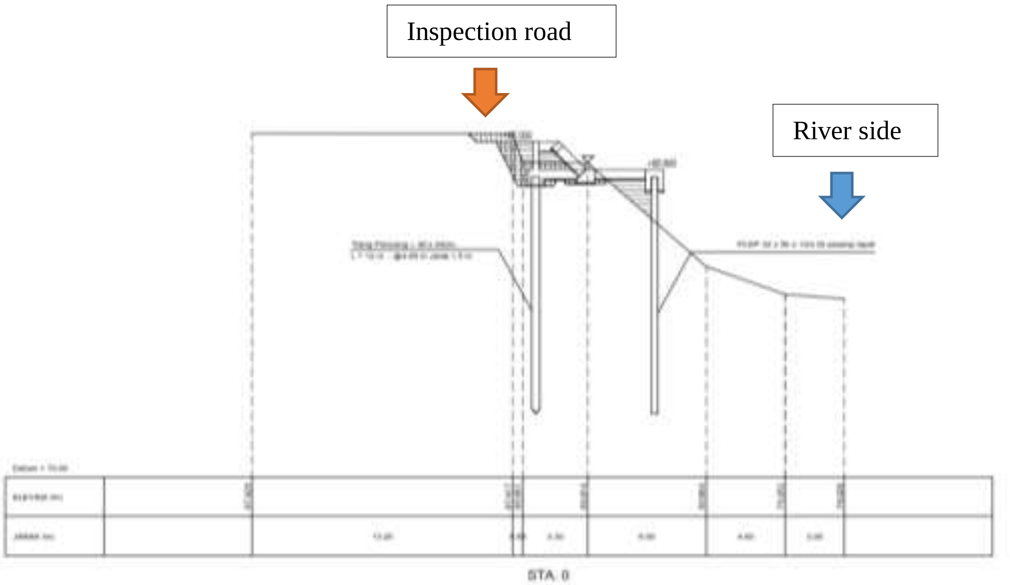

Figure 4. Slope reinforcement system

2. 5. Analysis

Slope stability analysis with Slope / W with input from the parameters of deep drill test results. This analysis will look at changes in the safety number of several models of slope conditions that are likely to occur.

3. Results and Discussion

3.1. Model 1: Original Slope

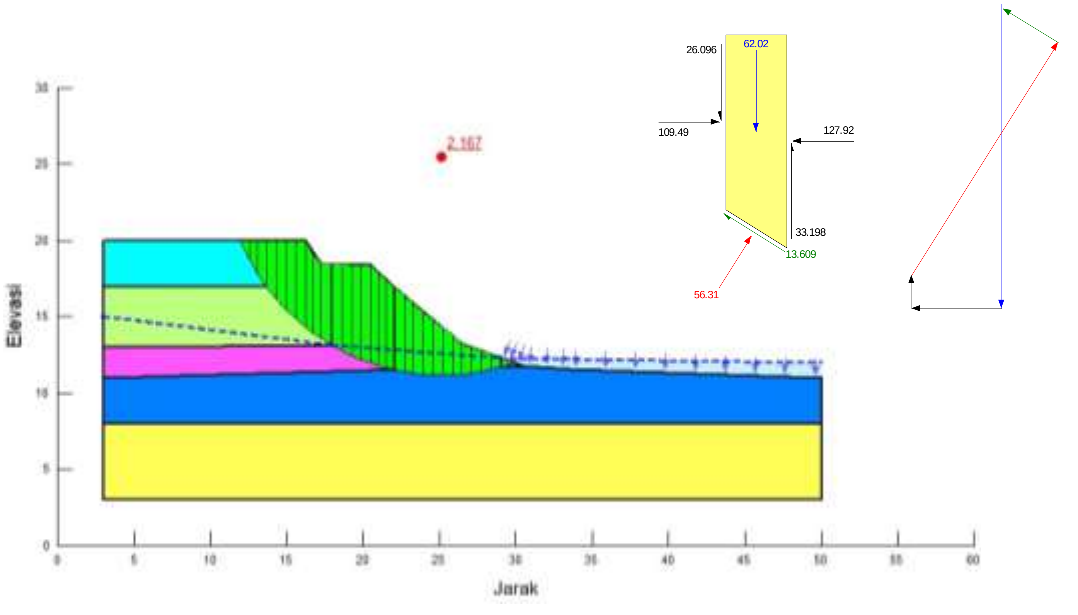

Figure 5. Model 1 analysis

Figure 5 is the original slope condition without reinforcement with low tide river water level and low water level. Indicates a safe number (SF) = 2.167

3.2. Model 2: Original slopes with revetment reinforcement

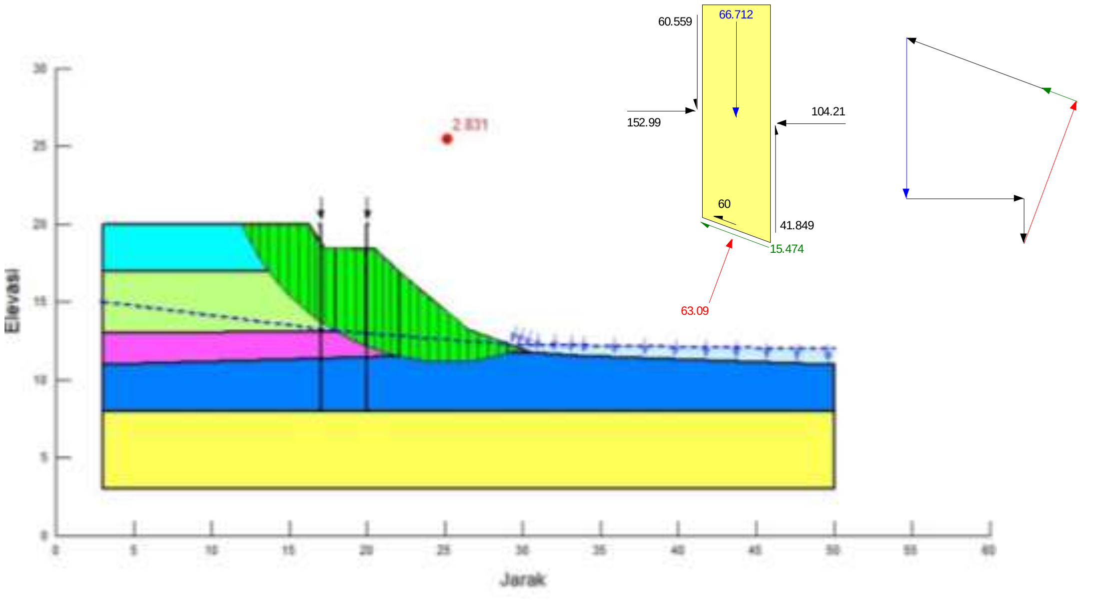

Figure 6. Model 2 analysis

Figure 6 shows the Original slope condition with revetment reinforcement at low tide. Indicates a safe number (SF) = 2.831. The safety number increases because the maximum resistance increases with the sheet plaster that intersects the landslide plane.

3.3. Model 3: Original slopes with revetment reinforcement, river water level increase

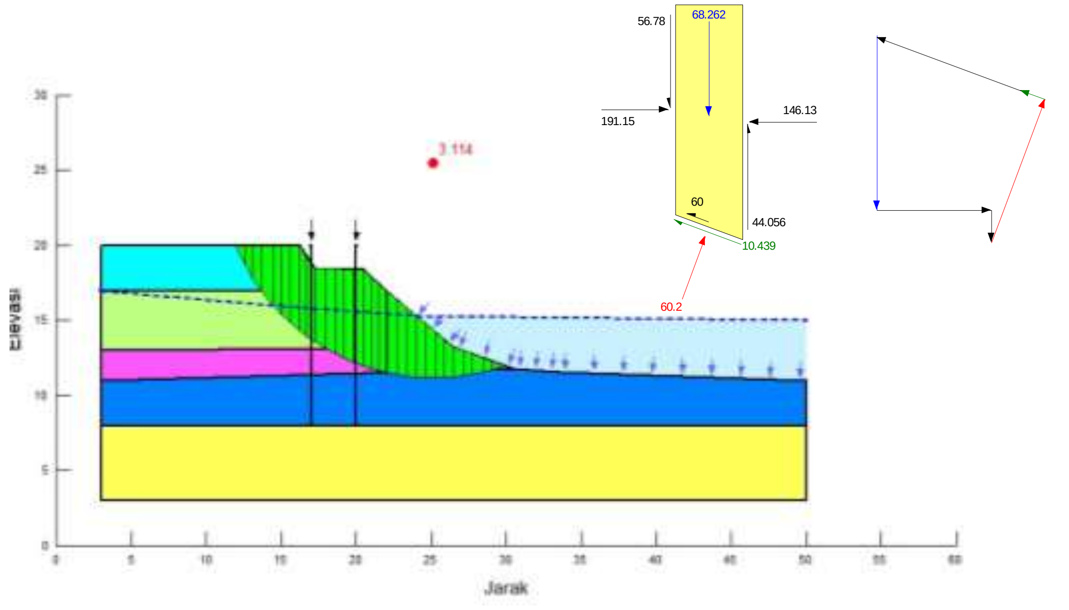

Figure 7. Model 3 analysis

Figure 7 Is the Original slope condition with revetment reinforcement when the river water level increase. Indicates a safe number (SF) = 3.114. The safety number increases because the maximum resistance is increased by the presence of sheet plaster which intersects the landslide area and the hydrostatic pressure of the river water.

3.4. Model 4: Original Slope with Revetment reinforcement, the river water level drops suddenly

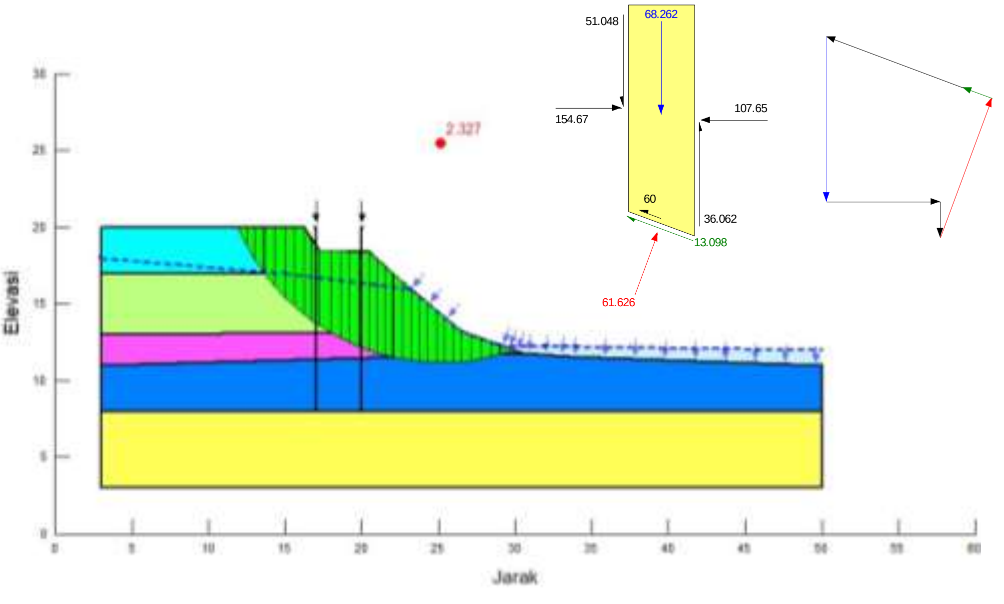

Figure 8. Model 4 analysis

Figure 8 Is the Original slope condition with the revetment reinforcement when the river water level drops suddenly. Indicates a safe number (SF) = 2.327. The safe rate decreases because the pressure resistance is reduced due to the loss of hydrostatic pressure from river water.

3.5. Model 5: Original slopes with revetment reinforcement, the river water level drops suddenly and erosion occurs

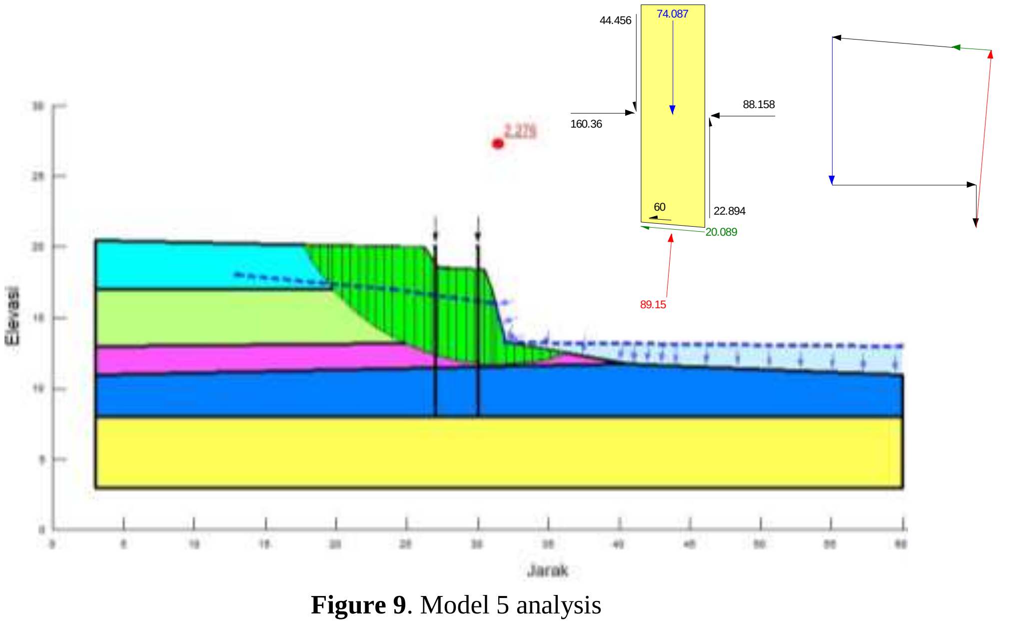

Figure 9. Model 5 analysis

Figure 9 is an extreme condition where the original slope with the revetment reinforcement when the river water level drops suddenly and erosion occurs simultaneously. Indicates a safe number (SF) = 2.276. The safe number decreases due to reduced passive soil pressure due to landslides and due to loss of hydrostatic pressure from river water. However, the safe number obtained is still within safe limits> 1.5.
To clarify the variation in the safe number values for several models or conditions, it can be seen in the following figure:

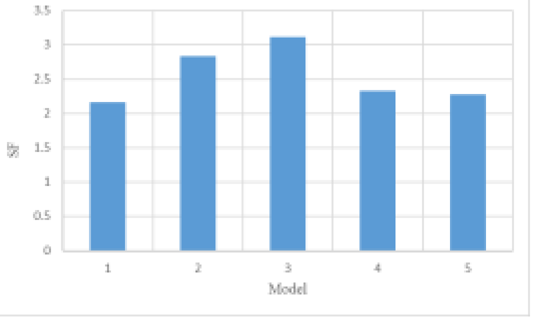

Figure 10. Models vs safety factor

The revetment structure design after review and analysis is typical as in Figure 10 as follows:

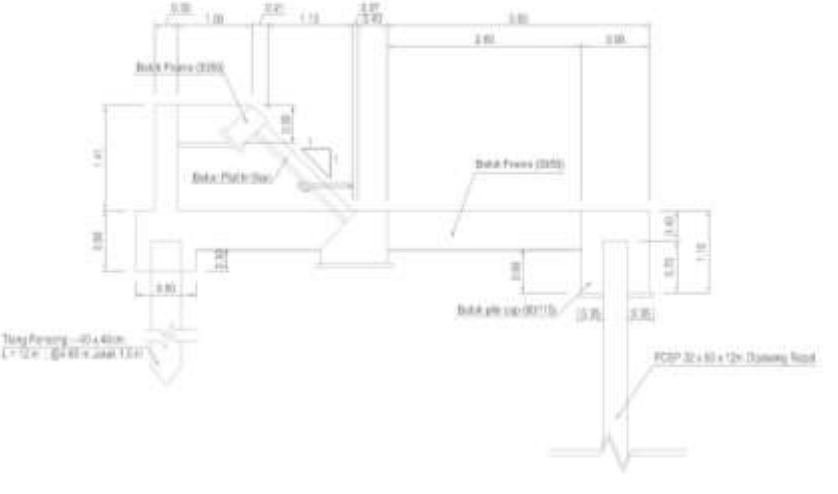

Figure 11. Typical Revetment Structure

The revetment structure that has been completed is shown in the following figure:

Figure 12. Revetment Structure

4. Conclusion and Recommendation

Revetments installed on river slopes can increase the safety rate by 30.64% - 43.70%, making it safe to use for river inspection and recreation activities. Extreme conditions occur when river water rises and erosion occurs but it is still within safe limits.

Tabel 1 Models Result

No	Type of model	Discription	Safety Factor	Result
1	Model 1	Original slope	2.167	Aman
2	Model 2	Original slopes with revetment reinforcement	2.831	Aman
3	Model 3	Original slopes with revetment reinforcement, river water level increase	3.114	Aman
4	Model 4	Original Slope with Revetment reinforcement, the river water level drops suddenly	2.327	Aman
5	Model 5	Original slopes with revetment reinforcement, the river water level drops suddenly and erosion occurs	2.276	Aman

Recommendation

For further research, the modeling can try adding the earthquake load and also the effect of rainfall. so that it can be seen the decrease in soil shear strength parameters due to the infiltration of rainwater into the soil.

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