The effect of horizontal drainage on sediment water content in the spoilbanks of Sengguruh reservoir, Brantas river, Indonesia

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Abstract. In the Brantas River System, Sengguruh is the first reservoir in the direction of the river flow. This reservoir functions to protect Sutami Reservoir from severe sedimentation. The effective storage capacity was about 24% of its initial storage. In order to restore the storage, dredging work at Sengguruh Reservoir must be carried out over the course of the year. To support the dredging, it is necessary to carry out technical work so that sediments in the temporary spoilbanks can be immediately hauled to another place and then are ready to be refilled. Hauling can be done optimally if the sediment condition in the spoilbanks is quite dry. Therefore, it is necessary to know how horizontal drainage can affect the sediment water content in the spoilbanks.

Keywords: sediment, spoilbank, water content, horizontal drainage.

1. Introduction
The Sengguruh Reservoir is located at the junction between Lesti River and Brantas River. It has a catchment area of approximately 1,659 km². Sengguruh is a multipurpose dam that serves to protect Sutami Reservoir from severe sedimentation and to generate electricity of 2 x 14.5 MW or equivalent to 91.02 x 106 kWh per year [¹]. The gross storage capacity of Sutami Reservoir had decreased to approximately 82 million m³ (32% from initial effective storage) over 4 years (1973-1977) before Sengguruh Reservoir was built [¹]. The reduction of the storage capacity rate after the Sengguruh Reservoir was built became slower compared to the previous period. Based on the results of the last study in 2015, the effective storage capacity of the Sutami Reservoir was 53.3% of the initial storage.

The existence of the Sengguruh Reservoir is very important to extend the lifetime of the Sutami Reservoir. For this purpose, Jasa Tirta Public Corporation (PJT I) as the reservoir manager continues to carry out reservoir dredging activities as a short-term corrective action. Dredging throughout the year requires large amount of temporary spoilbanks (temporary banks for dredged sediment). The availability of spoilbanks is a major problem in the Sengguruh reservoir dredging work since the capacity of spoilbanks are limited. The spoilbank area cannot be developed due to land availability and social problems.
In order to counter the problems above, it is important to schedule the filling of spoilbanks (by dredging) and the hauling of sediment from the temporary spoilbanks to another permanent spoilbank. All spoilbanks located near the reservoir (Figure 3) are temporary spoilbanks, which need to be emptied immediately after dredging. Another problem is that the sediment cannot be hauled from these temporary spoilbanks immediately after the dredging work, since it has a high water content. The dredged sediment require a longer time to dry naturally (without horizontal drainage), and thus technical efforts need to be taken to dry it quickly.

This paper discusses about the effect of horizontal drainage on the water content of dredged sediments.

2. Materials and Methods

2.1. Research Site

The location of this research is the Sengguruh Reservoir, which is in the region of Malang Regency, Province of East Java, Indonesia. The location map of the spoilbanks is shown in Figure 3 below.

![Figure 1. Sengguruh Dam location on Brantas River Basin Map](image1)

![Figure 2. Drone view of Sengguruh Reservoir](image2)

![Figure 3. Spoilbank Location Map of Sengguruh Reservoir](image3)
2.2. **Analysis Method**

The following are the steps of the study:

1. Two test pits were prepared with a width of 5.0 m, length of 5.0 m, and depth of 2.0 m. Test pit 1 was prepared without horizontal drainage and test pit 2 was prepared with horizontal drainage.
2. The test pits were filled with dredged sediment.
3. Soil core samples were taken at day 7 and day 39 after each test pit was filled.
4. Water content was tested for each taken sample as above (ASTM D-2216-98). The results of sediment water content between the test pits are compared.
5. Conclusions are drawn.

2.3. **Preparation of Test Pits**

![Figure 4.a. Test Pit A (without horizontal drainage)](image)

![Figure 4.b. Test Pit B (with horizontal drainage)](image)

The test pits have a size of 5.0 m x 5.0 m x 2.0 m. To prevent collapse, the walls of the test pits are lined with bamboo fences as shown in Figure 4.a and Figure 4.b above.

![Figure 5 Detail of Horizontal Drainage](image)

Horizontal drainage is illustrated in Figure 5. Horizontal drainage consisted of several layers from different materials (Figure 5a). HDPE pipes (perforated and corrugated) were used to drain water from the dredged sediment.
2.4. Test Pit Filling and Core Sampling

Core sampling at test pits was taken at 7 days and 39 days after filling with dredged sediment. Those samples were taken at depths of 0.5 m, 1.0 m and 1.5 m under the sediment surface. The points of core sampling (top view) are shown in Figure 7.

![Figure 6. Core Sampling of Test Pits](image)

Figure 6. Core Sampling of Test Pits

2.5. Water Content Testing
Water content testing was carried out in the laboratory by the ASTM standard (ASTM D-2216-98).

3. Results and Discussion

3.1. Grain Size Distribution

The grain size test at the laboratory showed that more than 50% of granules passed the number 200 sieve. It can be seen that the sediment is fine-grained (more than 35% passed sieve no. 200 for USDA and more than 50% for USCS). This is clearly shown in Figure 8. The grain size of the sediment in the spoilbank of Sengguruh Reservoir tends to be finer than other reservoirs in the Brantas River Basin (see Figure 9).
3.2. Soil Classification

| Depth (cm) | Sieve Number 200 Passage | LL (%) | PL (%) | PI (%) | AASHTO Classification | Explanation |
|------------|---------------------------|--------|--------|--------|------------------------|-------------|
| -50        | 76.53%                    | 49.60  | 27.53  | 22.07  | A7-6                   | Clay Soil   |
| -100       | 72.92%                    | 48.00  | 30.26  | 17.74  | A7-5                   | Clay Soil   |
| -150       | 70.64%                    | 48.00  | 32.83  | 15.17  | A7-5                   | Clay Soil   |

Table 1 shows that there are granules of clay in the sediment, which makes it difficult to reduce its water content. A smaller grain size will make it harder for it to dry, as the permeability coefficient will be smaller.

3.3. Water Content Testing

Figure 8. Grain Size Distribution of Sengguruh Reservoir

Figure 9. Sediment Grain Size Distribution of Brantas River Basin

Figure 10. Water Content vs Depth from Laboratory Testing

Figure 11. Water Content vs Depth from Previous Research [3]
Figure 10 shows the value of water content in each test pit at each depth. The sloped lines for the results of this research in Figure 10 are similar to the previous research as shown in Figure 11. Figure 11 resulted from laboratory experiments with clay soil samples of a length of 17 cm, width of 15 cm, and height of 20 cm using the siphon method and a suction pump. It can be said that the steeper line slope represents that soil water content at the bottom will decrease more slowly. Soil water content at the bottom of test pit B (with horizontal drainage) decreased faster than the top. It is shown that horizontal drainage can affect the water content of soil at the test pits.

4. Conclusion
Test pits without horizontal drainage resulted in steeper water content lines than with horizontal drainage. This shows that horizontal drainage can reduce the soil water content faster, especially for areas with a depth of 1.5 m (near the horizontal drainage). However, this study was conducted with limited time and number of taken samples, and thus further research is needed in order to understand the behaviour of soil water content of spoilbanks with horizontal drainage.

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