Evaluation of Slope Stability and Countermeasures for Tailings Dam at Camachin Iron Mine, Philippines

Hayato Ota

Laboratory of Rock Engineering and Mining Machinery

Department of Cooperative Program for Resources Engineering

1. Introduction

Tailings dams are essential structures for storing large volumes of tailings generated during mining operations, and ensuring their long-term stability is indispensable. In particular, upstream tailings dams are widely adopted due to their economic efficiency and ease of construction; however, because the embankment is raised progressively on previously deposited tailings, a reduction in stability with increasing dam height is one of a major concern.

In this study, numerical analyses considering staged construction were conducted for an upstream tailings dam at the Camachin Iron Mine located in Bulacan Province, Philippines. The effectiveness of applying a rockfill berm to improve dam stability was investigated.

2. Analysis model

In this study, stability analyses considering staged dam construction were performed using the two-dimensional finite element analysis software RS2. The analytical model consisted of the ground, initial dam, embankment, tailings, and a rockfill berm as shown in Figure 1. The mechanical properties are shown in Table 1. Mohr–Coulomb failure criterion was applied to all materials. A rockfill berm was installed on the toe of slope to improve the overall stability of the dam.

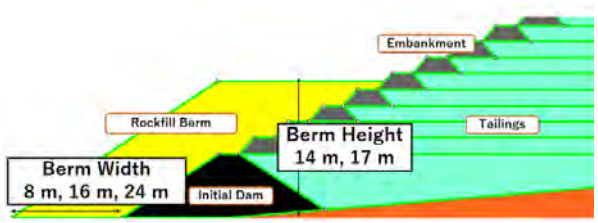


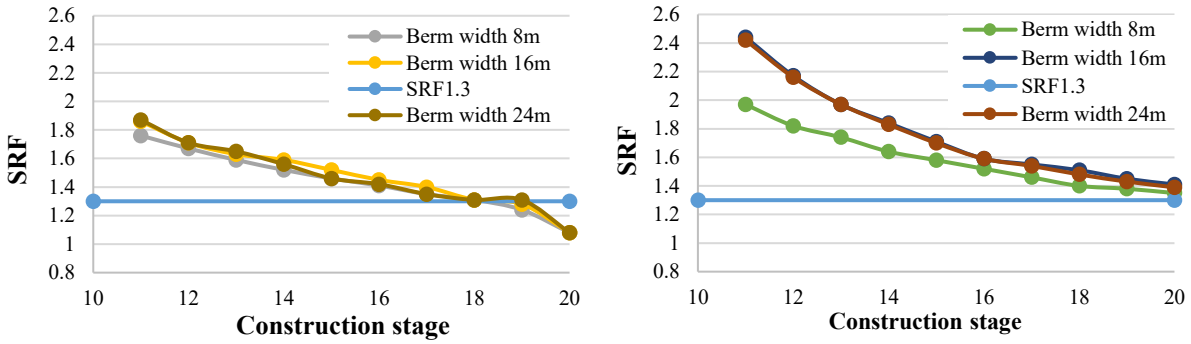
Figure 1. Analysis model

Table.1 Mechanical properties

	Unit weight (MN/m^3)	Poisson's ratio	Young's modulus (MPa)	Internal friction angle (degree)	Cohesion (MPa)	Permeability (m/s)
Ground	0.023	0.25	300	35	0.05	1.0×10^{-7}
Initial dam	0.021	0.25	100	35	0.05	5.0×10^{-8}
Embankment	0.02	0.3	50	30	0.01	1.0×10^{-6}
Tailings	0.0185	0.3	10	26	0.006	5.0×10^{-7}
Rock fill berm	0.019	0.3	40	42	0.001	1.0×10^{-1}

3. Results and Discussion

Figures 2(a) and (b) show the critical strength reduction factor (SRF) for berm heights of 14 m and 17 m, respectively. The SRF represents the numerical equivalent of the factor of safety. In this study, an SRF of 1.3 or higher was adopted as the criterion for evaluating slope stability. The results indicate that the SRF decreases as the construction stages progress, corresponding to an increase in the height of the tailings dam. When the berm height is 14 m, the SRF decreases to below 1.3 at construction stage 20 (the final stage, corresponding to a dam height of 48 m), regardless of berm width, suggesting a potential risk of slope failure. In contrast, the SRF remains above 1.3 even at the final construction stage when the berm height is 17 m and the berm width is larger than 8 m. This demonstrates that the rockfill berm significantly contributes to the enhancement of slope stability. Furthermore, although stability generally increases with increasing berm width, the improvement becomes less pronounced when the berm width exceeds 8 m. These results indicate that rockfill berms are effective in enhancing the stability of tailings dams and that berm height is a dominant factor governing slope stability.



(a) Berm height: 14 m (b) Berm height: 17 m

Figure 2. SRF at construction stage