http://journal.uir.ac.id/index.php/JGEET

E-ISSN : 2541-5794
P-ISSN : 2503-216X

Journal of Geoscience,
Engineering, Environment, and Technology
Vol 10 No 2 2025

RESEARCH ARTICLE

Geotechnical Analysis in the Case of Recovery Failure of West Out Pit Dump PT. Mifa Bersaudara

Danu Mirza Rezky[1*], Andi Ronald Khomeini[2], Kiagus Farobi Balyani[3]

[1] *Geotechnical Engineer, Technical Service Engineering Department, PT. Mifa Bersaudara, Aceh Barat, 23615, Indonesia*
[2] *Short Term Plan Engineer, Technical Service Engineering Department, PT. Mifa Bersaudara, Aceh Barat, 23615, Indonesia*
[3] *Long Term Plan Engineer, Technical Service Engineering Department, PT. Mifa Bersaudara, Aceh Barat, 23615, Indonesia*

* Corresponding author : danu.mirza@mifacoal.co.id
Tel.:+62-82313422602
Received: Jan 31, 2024; Accepted: May 31, 2025.
DOI: 10.25299/jgeet.2025.10.02.21232

Abstract

The formation of waste dump with heterogeneity of constituent materials and muddy Base conditions as the foundation of the waste dump is a challenge for practitioners and academics so that stable embankments as a place to dispose of overburden material can be formed. Case studies that occurred at PT. Mifa Bersaudara, namely the Failure of West Out Pit Dump (OPD) Elevation +30 to elevation +15 which caused the Water Monitoring Point (WMP 24) to be damaged and potentially damage the IUP boundary road. This incident occurred through Prism monitoring and the loss of the progressive movement category which caused the disposal of elevation +30 to be sterilized from dumping operations before recovery disposal was carried out. The Back Analysis Approach, Laboratory Testing, and tracing of dumping history were carried out to obtain accurate material model and property analysis. Geotechnical recommendations start from the reconstruction of the Water Monitoring Point by re-filling the failure area at elevation +20 and the compartment embankment at elevation +23. After that, it was continued with the reconstruction of the disposal leg (counterweight) elevation +25, as well as adjusting the geometry of the disposal elevations +30, +40, and +50 so that the failure area could be re-filled. The final results obtained from this case study are that the IUP boundary road and Water Monitoring Point were successfully constructed, Optimization of disposal in the failure area can be done by adding a volume of 1.3 million bcm, and the recovery area for the failure of disposal can be used as a reclamation area with an area of 4 Ha. The update of the Safety Factor value after the work stated that the disposal was in a Safe condition. Description of Recommendations, Staging Plan, and future research development will be explained further in this Paper.

Keywords: Out Pit Dump, Failure, Optimization, Reclamation.

1. Introduction

The development of proper Disposal Construction (Outpit dump and Inpit dump) has become an important topic that is often discussed by mining academics and practitioners. With the increasing adoption of open pit coal mining methods, issues related to waste dump slope instability that may affect the safety of personnel, mining equipment, reserve conservation, or environmental hazards have become significant issues of concern for mine planning and geotechnical practitioners (Kainthola et al, 2011; Wei Wang and Griffith, 2018).

Reduction in disposal strength that causes failure occurs due to several varying factors such as geological conditions, groundwater as internal factors (Beyabanaki, 2022; Devy and Hutayan, 2021; Setyananda et al, 2024) and the influence of weather and weathering as external factors (Chakufola et al, 2017; Damares et al, 2024; Miscevic and Vlastelica, 2014). In other cases, the cause of failure in disposal is a weak waste dump foundation which causes the disposal floor heave, which is then followed by further failure on a larger scale (Poulsen et al, 2013).

The results of the investigation of one of the failures in pit dump due to the presence of a layer of soft material (montmorillonite) on the floor disposal. where this layer becomes a sliding plane for landslides when there is an additional overburden load above it (Ang and Wenli, 2020; Rahmad et al, 2020; Hoy et al, 2024)

The case study that occurred at PT. Mifa Bersaudara, namely the Failure at the Out Pit Dump Elevation +30 on March 2, 2024, which resulted in damage to the planned Water Monitoring Point (WMP 24) compartment which is below the disposal at elevation +15. The historical base area of the dumping is a swamp area, which then became a slip plane due to the uncontrolled dumping of overburden material above it (Rezky and Zulkarnaen, 2023). Further explanation of the identification of the causes of failure is presented in the fishbone diagram (Fig. 1).

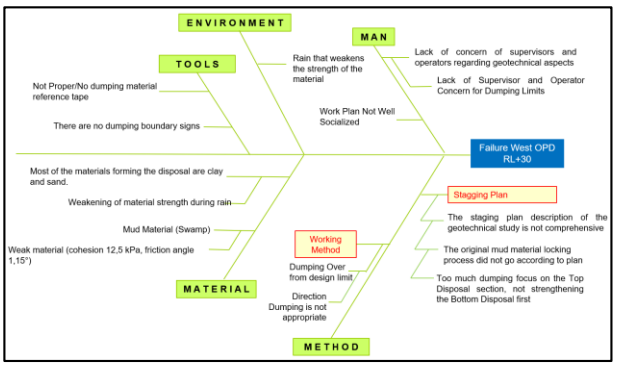


Fig 1. West Out Pit Dump fishbone analysis failure.

Crown crack at elevation+30 and Toe Failure (Heaving) at elevation+15 with a total failure distance from crown to toe of 120 m (Fig. 2).

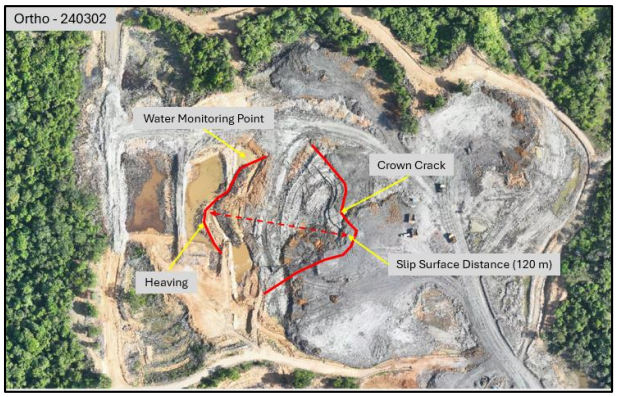


Fig 2. West Out Pit Dump Failure Scheme Elevation+30

Monitoring tools at the disposal are also installed to determine the actual movement of the waste dump (Panpan et al, 2018; Singh et al, 2017) which is used as a reference to determine follow-up actions on disposal activities so as not to endanger operational activities (Mohamed, 2021). The results of monitoring in the failure area show a progressive pattern (landslide) as presented in (Fig. 3). This paper will further elaborate on emerging issues and challenges, action plans, recovery, and disposal development opportunities to meet annual disposal needs.

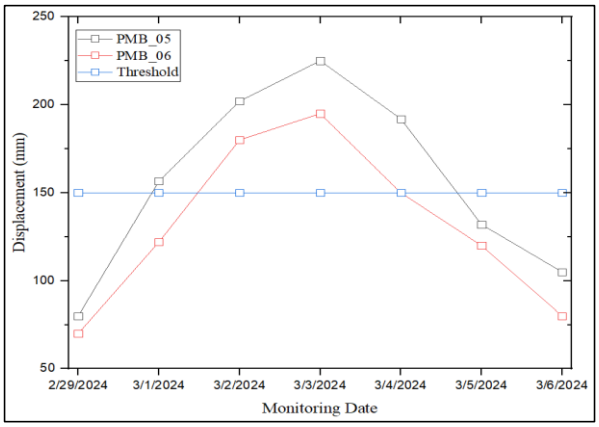


Fig 3. Report monitoring area failure

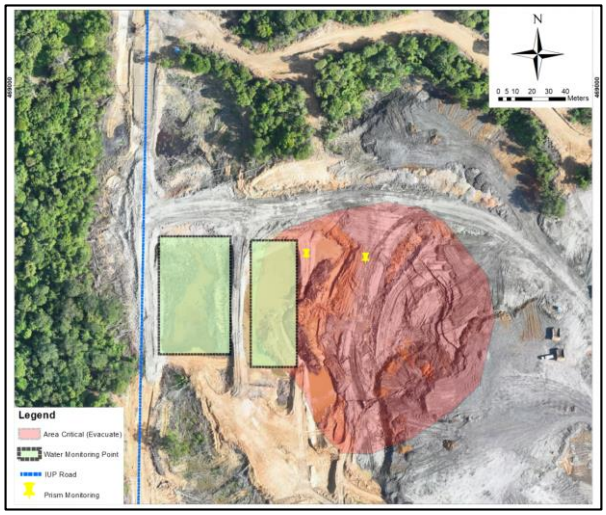


Fig 4. Research Location (West Out Pit Dump)

2. Research Method

2.1. Research Location

The research location is in West Out Pit Dump elevation +30 which is the original swamp area, at this location there are 3 projects that will be implemented, namely the construction of the iup boundary road, Water Monitoring Point (WMP 24), and the development of the disposal presented in (Fig. 4).

2.2. Failure Mechanism

The West Out Pit Dump failure occurred due to uncontrolled dumping of mud material placement (Ali Ahmad et al, 2017; Ding et al, 2024; Sasaoka et al, 2015) at the base disposal with a thickness of 4-5 m based on the survey situation so that the load of the overburden pile at elevation+30 pushed the mud (weak material) and overburden material above it through and damaged the Water Monitoring Point (WMP 24) compartment. The imbalance of the restraining and driving forces caused the landslide, justifying the circular failure type in the residual material (Mukhopadhyay et al, 2017; Wyle and Mah, 2004) The failure forms a ring along the slip surface line. An illustration of the failure mechanism of West Out Pit Dump elevation +30 is presented in (Fig. 5).

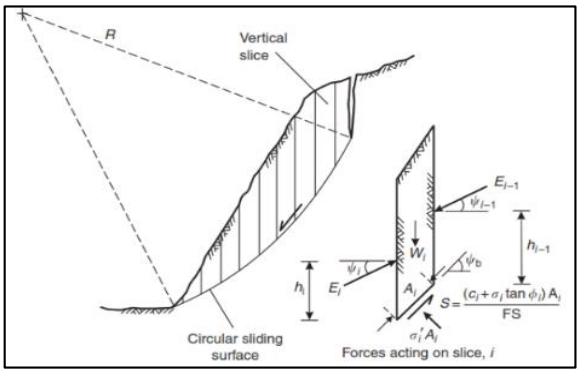


Fig 5. Failure Mechanism (Wyle and Mah, 2004)

The calculation of the safety factor is presented in the following formula:

$$FS = \frac{shear\ strength\ available\ to\ resist\ sliding\ (c+\sigma_n \tan\theta)}{shear\ stress} \quad (1)$$

Where c is cohesion (kPa), σ_n is normal stress, and θ is the inner shear angle. The FK used as a reference is 1.2 for the interramp slope bench and 1.3 for the overall slope bench (Adriansyah et al, 2021; Simatupang et al, 2024; Sirait et al, 2021).

Fig 6. Analysis Cross Section A-A'

Another approach to determine the failure mechanism is conducting a back analysis (Brown et al, 2016; Mandal et

al, 2017; Nejan and Timothy, 2008) by correcting the existing model to match the actual conditions at the time of failure. The cross-section incision map and Back Analysis are presented in (Fig. 6 and 7).

2.3. Material Properties

The value of material strength properties obtained from the results of the geotechnical laboratory (Irwan and Wiati, 2023; Ishak and Zaini, 2017; Kusnad, 2017) testing of PT Mifa Bersaudara and the approach of the results of back analysis, as well as the recapitulation of material properties, is presented in (Table 1).

2.4. Research Flow Chart

The systematic flow of research related to the elevation +30 West Out Pit Dump Failure is described in more detail in (Fig. 8).

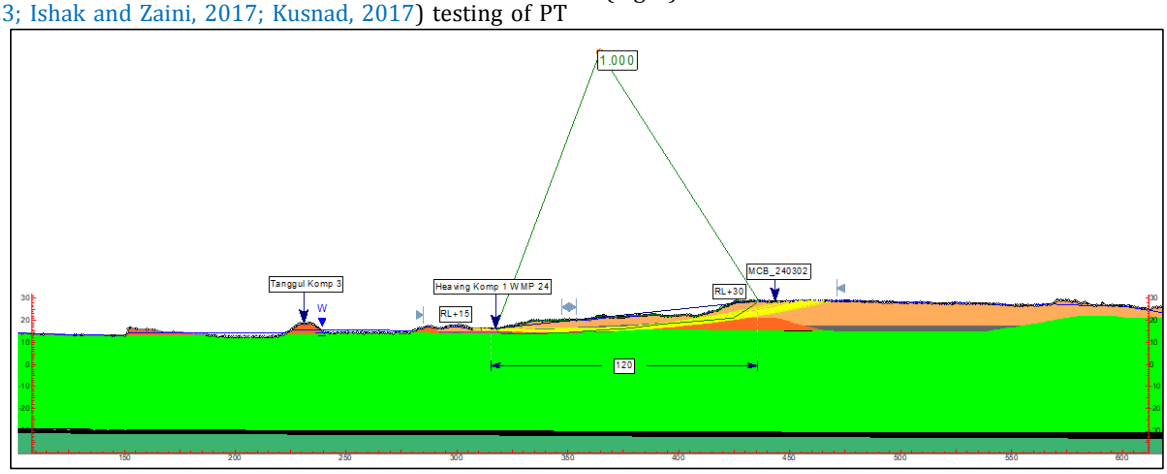


Fig 7. Failure Analysis of West Out Pit Dump Back FK (Section A-A')

Table 1. Material Properties Failure Analysis of West Out Pit Dump

Material	Parameter					
	Unit Weight (kN/m³)	Colour	Cohesion (kPa)	Phi (°)	UCS (kPa)	Strength Type
OPD Barat Existing	19		30	10		MC
Subsoil	19		4	14		MC
Mudstone Top	20		-		750	GHB
Mudstone	20		-		1000	GHB
Mud	17		12.25	1.12		MC
Mud Base	17		12.4	1.1		UN
Coal	14		-		5000	GHB
OPD Barat	20		50	10		MC
Sandstone	21				400	GHB

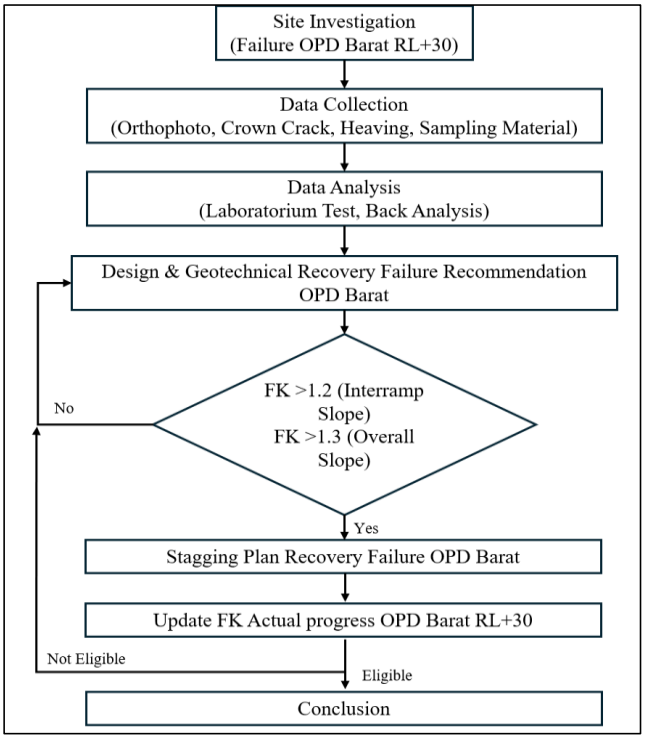


Fig 8. Research Flow chart

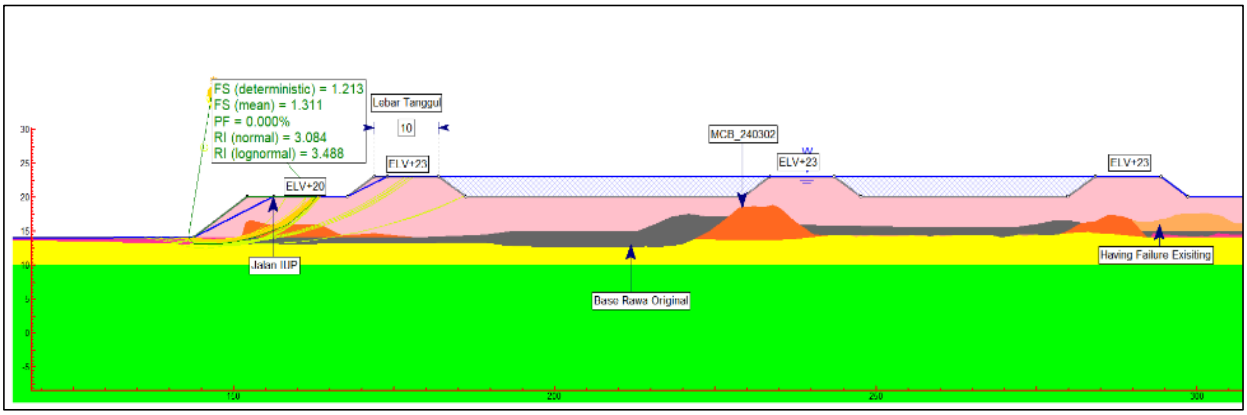
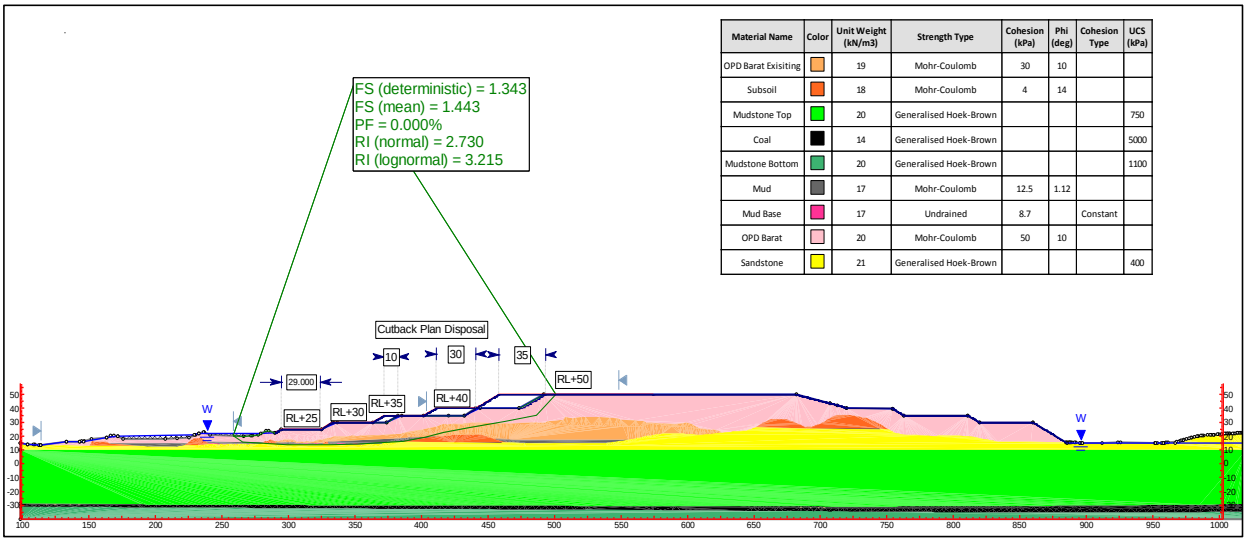


Fig 9. Geotechnical Analysis of Water Monitoring Point Reconstruction (WMP 24)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Cohesion Type	UCS (kPa)
OPD Barat Exisiting		19	Mohr-Coulomb	30	10		
Subsoil		18	Mohr-Coulomb	4	14		
Mudstone Top		20	Generalised Hoek-Brown				750
Coal		14	Generalised Hoek-Brown				5000
Mudstone Bottom		20	Generalised Hoek-Brown				1100
Mud		17	Mohr-Coulomb	12.5	1.12		
Mud Base		17	Undrained	8.7		Constant	
OPD Barat		20	Mohr-Coulomb	50	10		
Sandstone		21	Generalised Hoek-Brown				400

Fig 10. West Out Pit Dump Disposal Optimization Recommendation

3. Result and Discussion

3.1. West Out Pit Dump Geotechnical Recovery Recommendation Elevation +30

The West Out Pit Dump recovery begins with the rearrangement of the Water Monitoring Point, the recommendations given are as follows:

- Reconstruct compartment 2.3 by filling a flat pond at elevation +20, and forming a compartment embankment at elevation +23, the direction of discharge from west to east. Compartment 1 will be filled and will be a balance for the recovery of the West Out Pit Dump discharge.
- Moving 1 compartment to the north side, so that a total of 3 compartments with a planned storage volume according to regulations and the needs of the environmental team can be filled. The results of the analysis are presented in (Fig. 9).

After WMP 24 is completed in construction, the opportunity of West Out Pit Dump as a disposal site for OB material will be maximized in accordance with the geotechnical study based on the annual disposal plan design from the Mine Plan Team and design input parameters from the results of the Laboratory Test. The results of the analysis are presented in (Fig. 10).

The analysis results of Section A-A' states FK 1.34 and PF 0%, which means that the disposal is in a Safe condition with the following geometry changes.

Cut back plan disposal elevation +50 (35 m)
Cut back plan disposal elevation +40 (30 m)
Cut back plan disposal elevation +35 (10 m)

3.2. Stagging Plan West Out Pit Dump Recovery Failure

The stages of the West OPD recovery are as follows:

1. Release water at Base elevation +25 to WMP 24. Bench formation starts from the bottom bench of elevation +25 (both sides of WMP 24 and IUP Boundary Road) to strengthen the disposal foot and reduce the potential for heaving into compartment 1 and IUP Boundary Road. The formation was done gradually from the bottom. The dumping direction was from west to east (Fig. 11).

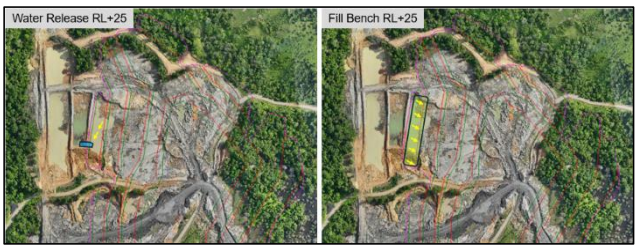


Fig 11. (a) Water Release Base elevation +25 (b) Fill Bench elevation +25

2. Prism monitoring in compartment 1 of WMP 24 will be installed to monitor the dumping progress. The geotechnical team will assess the location to see signs of

shifting compartment 1 during the dumping process (Fig. 12).

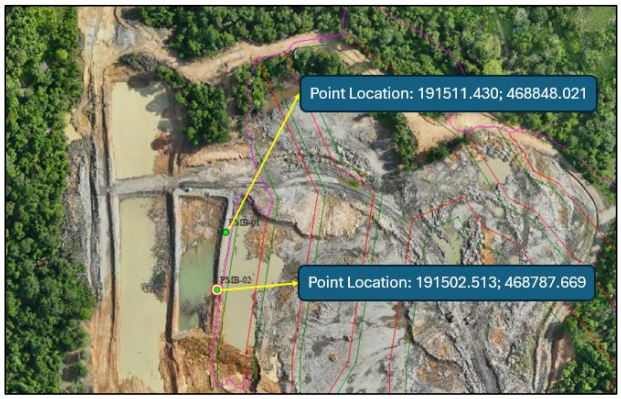


Fig 12. Prism Monitoring Installation

3.3. Result of Recovery Failure OPD West

The implementation of the West Out Pit Dump elevation +30 recovery failure work in accordance with geotechnical recommendations has a positive impact, namely the Water Monitoring Point (WMP 24) for 3 compartments can be constructed according to the design along with the IUP ring road, and the addition of disposal capacity which was previously held at elevation +30, can then be optimized to elevation +50. So that the sequence of both stripping overburden and coal getting can run according to plan to achieve the company's annual target. Changes in the condition of the West Out Pit Dump before and after recovery are presented in (Fig. 13).

Work on the West Out Pit Dump Recovery according to the stagging plan also has a positive effect on the addition of disposal capacity and additional reclamation areas, actual update of the situation in August 2024, there is a surplus of additional disposal progress volume in the ex-failure area of 1.3 million bcm which has a good impact on Overburden stripping and Coal Getting activities in the West Pit area. As well as an additional reclamation area of 4 Ha (Fig. 14).

Fig 13. Orthophoto *Recovery* West Out Pit Dump

Fig 14. West Out Pit Dump Optimization Results and Opportunity reclamation area

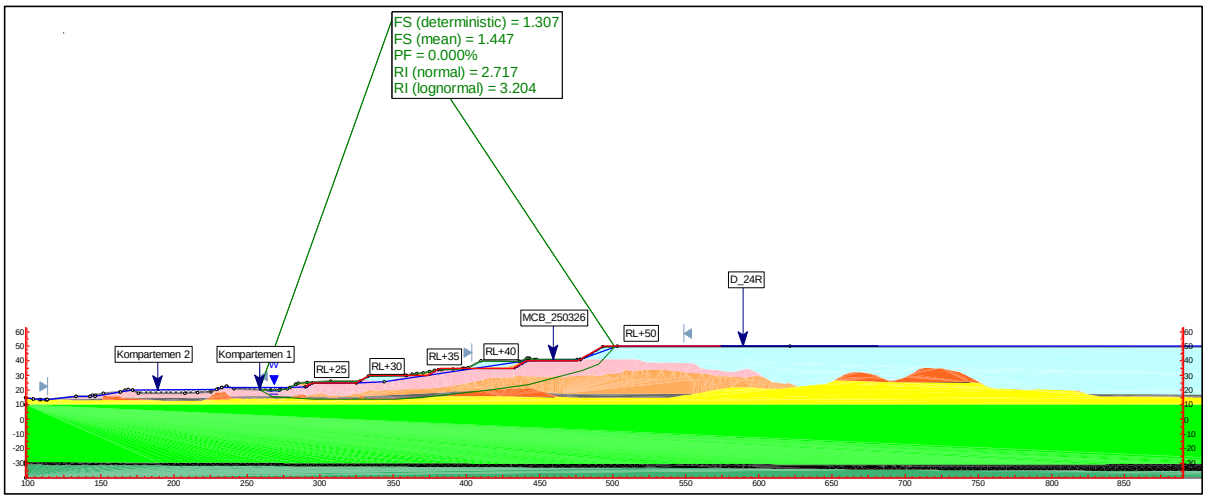


Fig 15. West Out Pit Dump Actual FK Update (August 2024)

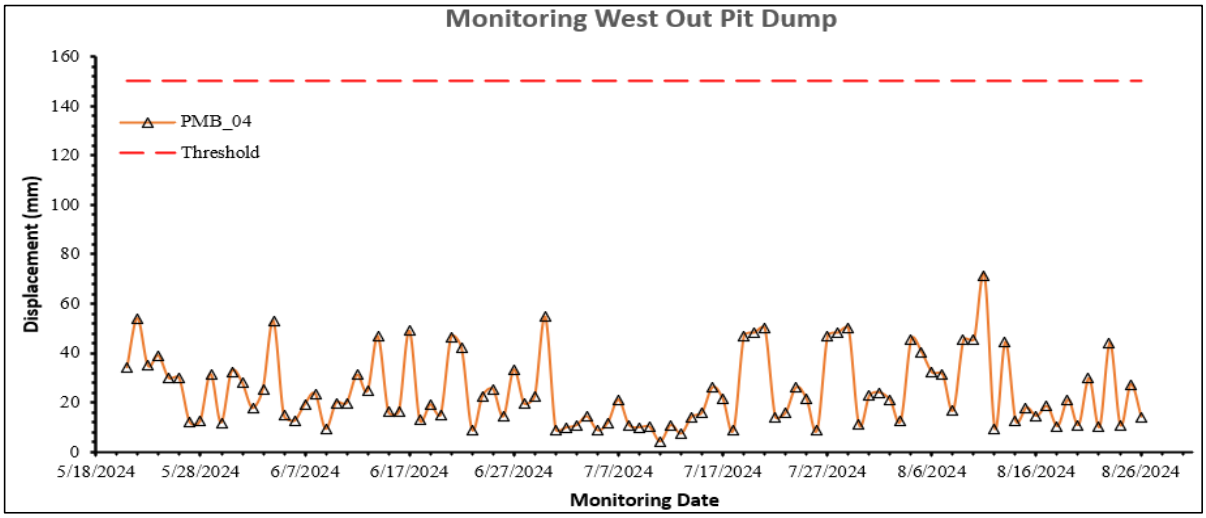


Fig 16. Report monitoring West Out Pit Dump

3.4. Results of the Implementation of the West Out Pit Dump Geotechnical Recommendations

Actual Safety Factors of the disposal development progress are analyzed to determine the suitability of recommendations with actual conditions in the field. Updates on the actual disposal slope stability with reference to the situation on March 26, 2025 are presented in (Fig. 15).

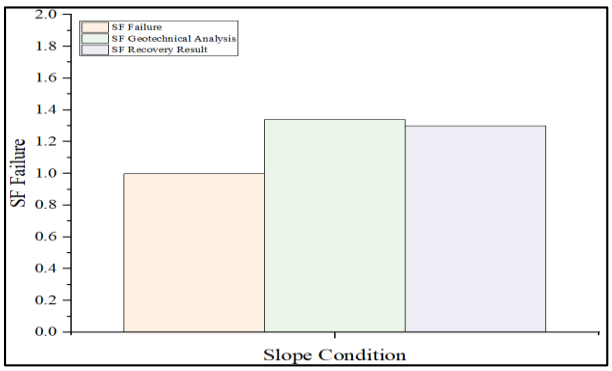


Fig 17. Safety Factors for various slope conditions

The results of the West Out Pit Dump slope stability analysis stated that the slope is in a Safe condition with FK 1.30, which means that the disposal is on track according to the planned elevation of +50. Progress monitoring of the West Out Pit Dump area is also presented in (Fig. 16) to find out the development of the disposal movement during the recovery progress.The results of prism monitoring stated that during the reconstruction, the resulting movement was still in the normal stage (Linear) with an average displacement of 50 mm. so it was concluded that both FK Progress and monitoring reports stated that the disposal slope was still safe. Changes in the Safety Factor during a failure, recommendations for geotechnical analysis, and actual recovery results are presented in (Fig. 17) to prove that the geotechnical analysis made is appropriate and can be implemented in the field.

From (Fig. 17) it can be concluded that the recovery was successful, the slope is in a safe condition and in accordance with the results of the analysis made and is within the threshold value of the safety factor set, namely 1.3.

Conclusion

The West Out Pit Dump failure recovery phase begins with closing the existing pond at elevation +20 and reconstructing the compartment embankment at elevation +23.

The West Out Pit Dump Disposal Optimization recommendation is to cut back the disposal optimization design plan at elevation +50, +40, and +35.

Stagging Plan for the recommendation work starts from releasing water in the base disposal plan and the dumping direction is set from west - east.

FK Update of the West Out Pit Dump recovery work is still in a safe condition (>1.3) which means that the disposal can still lift up according to the annual design plan.

The West Out Pit Dump failure repair work provides appropriate results, where WMP 24 can be re-formed, the IUP Ring Road is completed, the disposal capacity can increase, and additional reclamation areas on benches elevation +25, +30, +35 and +40 can be obtained.

The development of future research directions is to make and analyze the comparison of material balance to disposal stability, considering that in West Out Pit Dump there is a lot of mud in the original base, so the placement and arrangement of material balance needs to be further elaborated to facilitate the operational team when executing in the field and staying within technical guidelines according to geotechnical principles.

Acknowledgment

The author would like to thank the Technical Service & Engineering Team of PT Mifa Bersaudara for helping support data during the research and PT Antareja Mahada Makmur site Mifa Bersaudara as the Contractor who has helped implement the results of this research in the field.

References

Achmad, A., Aryoseno., Ardhiwisesa, P. 2017. Kejadian Longsoran Out Pit Dump (OPD) 01 Pama: Pengaruh serta Hubungan Dasar Timbunan terhadap Kestabilan Lerengnya. TPT XXVI Perhapi 2017.

Adriansyah, Y., Saprana, R.D., Sophian, I., & Khoirullah, N. 2021. The Application of Failure Method Probability for Analyzing in Pit Dump Stability at West Block "X" Pit PT. Berau Coal - East Kalimantan. Indonesian Mining Journal, 24(2), 71-83.

Ang, L., & Wenli, L. 2020. Influence Research of Weak Layer on Slope Sliding mode and Stability. IOP Conference Series: Material Science and Engineering, 914.

Beyabanaki, S.A.R. 2022. Impact of Groundwater Table Fluctuation on Stability of Jointed Rock Slopes and Landslides. Geotechnics, 2, 335-347.

Brown, I.R., Wood, P.J., & Elmouttie, M.K. 2016. Estimation of Insitu Strength from Back-Analysis of Pit Slope Failure. Australian Centre for Geomechanics, ISBN 978-0-992-4810-5-6.

Chakufola, S., Chileshe, P.R.K., Samuel, E.B. 2017. Weathering and its Potential Effect on Mine Slope Factor of Safety. IOSR Journal of Applied Geology adn Geophysics, 5(3), 21-33.

Damares, T.O., Ramdahan, F.I., Kai, L.o., & Diallo, C. 2024. Slope Stability Analysis using the Rock Structure Rating (RSR) Method and Atterberg Limit at Riau - West Sumatera Cross Road KM 165 Harau Subdistrict, Lima Puluh Kota Regency, West Sumatera Province. Journal of Geosicence, Engineering, Enviromental & Technology, 9(2).

Devy. S., & Hutayan, P.P. 2021. Groundwater Effect on Slope Stability in Open Pit Mining: A Case of West Kutai Regency, East Kalimantan, Indonesia. Journal of Geoscience, Engineering, Enviromental & Technology, 6(4).

Ding, H., Sun, S., Li, Q., Hu, J., Gong, R., & Zang, B. 2024. Comparative Test on Failure Characteristics and Mechanisms of Mine Waste Dump with Different Material Layouts. Sustainability, 16(7977).

Hoy, M., Doan, C.B., Horpibulsuk, S., Suddeepong, A., Udomchai, A., Buritatum, A., Chaiwan, A., Doncommul, P., & Arulrajah, A. 2024. Investigation of a Large-Scale Waste Dump Failure at the Mae Moh Mine in Thailand. Engineering Geology, 329.

Ishak, M.F., & Zaini, M.S.I. 2017. Physical Analysis Work for Slope Stability at Shah Alam, Selangor. Journal of Physics: Conference Series, 995.

Irwan, A.G., Wiati, I.T. 2023. Reconstruction of Natural Slope Stability by Limit Equilibrium Methods and Finite Element Methods. Dinamika Teknik Sipil: Majalah Ilmiah Teknik Sipil, 16(2), 43-49.

Kainthola, A., Verma, D., Gupte, S.S., & Singh, T.N. 2011. A Coal Mine Dump Stability Analysis - A Case Study. Geomaterials, 1-13.

Kusnad, S. 2017. Slope Stability Analysis Base on Type, Physical and Mechanical Properties Rock in Teluk Pandan District, East Kutai Regency, East Kalimantan Province. Journal of Geoscience, Engineering, Environment, and Technology, 2(4), 272-277.

Mandal, J., Narwal, S., & Gupte, S.S. 2017. Back Analysis of Failed Slope - A Case Study. International Journal of Engineering Research & Technology (IJERT), 6(5), 1070-1078.

Miscevic, P., & Vlastelica, G. 2014. Impact of Weathering on Slope Stability in Soft Rock Mass. Journal of Rock Mechanics & Geotechnical Engineering, 6, 240-250.

Mohammed, M.M. 2021. A Review on Slope Monitoring and Application Methods in Open Pit Mining Activities. International Journal of Scientific & Technology Research, 10(2), 181-186.

Mukhopadhyay, M., & Sen, P. 2017. Circular Failure Analysis for Slope mad up for Homogeneous Material - A Review. Journal of Mine, Metal, & Fuels.

Poulsen, B., Khanal, M., Rao, A.M., Adhikary, D., & Balusu, R. 2013. Mine Overburden Dump Failure: A Case Study. Geotechnical & Geological Engineering, Springer, DOI 10.1007/5 10706-013-9714-7.

Rahmad, L., Aryanda, D., & Daroji, M. 2020. Back Analysis of In Pit Dump Slope Failure and Remediation Result at Bara Anugrah Sejahtera Open Pit Coal Mine, Indonesia. Australian Center for Geomechanics, Perth, ISBN 970-0-9876389-7-7.

Sarihan, N.H., & Stark, T.D. 2008. Back Analyses of Landfill Slope Failure. International Conference on Case Histories in Geotechnical Engineering, 2, 34.

Sasaoka, T., Karian, T., Amarsaikhan, T., Hamanaka, A., Shimada, H., & Matsui, K. 2015. Study on Improvement of Dumping Site Stability in Weak Geological Condition by Using Compactd Layer. Open Journal of Geology, 5, 144-155.

Setyananda, A., Hartami, P.N., Maulana, Y., Tuheteru, E.J., Herdyanti, M.K., & Putra, D. 2024. Analysis of the Influence of Groundwater Level on Slope Stability at Highwall PT. X, South Kalimantan, IOP Conference Series: Earth and Enviromental Science, 1339.

Simatupang, I.D., Kausarian, H., & Elizar. 2024. Geotechnical Insight into Andesite Quarry Slope Stability : A Case Study from Desa Usul, Indragiri Hulu, Riau, Indonesia. Journal of Geoscience, Engineering, Environment, and Technology, 9(4), 591-599.

Singh, V.K., Masood, M.M., & Verma, T. 2024. Slope Monitoring Techniques in Open Cast Mines: A Review of Recent Advances. Journal of Mine, Metal, and Fuels, 72(1), 83-92.

Sirait, B., & Zulfahmi. 2021. Slope Stability and Bearing Capacity Analysis of Disposal in Open Pit Coal Mining.

International Seminar on Mineral and Coal Technology, IOP 882.
Rezky, D.M., & Zulkarnaen, B.P. 2023. Kajian Geoteknik Mudcell sebagai Tampungan Lumpur pada Disposal Tambang Batubara. Prosiding Temu Profesi Tahunan Perhapi (TPT XXXII), 303-313.
Wang, W., & Griffith, D.V. 2019. Case Study of Slope Failure during Construction of a Open Pit mine in Indonesia. Canadian Geotech Journal, 56, 636-648.
Wyllie, D.C. & Mah, C. 2004. Rock Slope Engineering. Ed 4. London. CRC Press
Yang, P., Wang, N., Jiang, Z., Yang, Y., & Yang, H. 2018. Overview of Slope Monitoring Technology. Material Science and Engineering, IOP 472.