Tailings Dam Failure Modes; Recognition, Prevention and Case Studies

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Abstract

Over the last decades, the failure of tailings dams has become a significant concern for public and engineers. Failure of tailings damsare often followed by releasing a large amount of tailings, whichleads to loss of lives, irreversible environmental damages, and large economic losses. Despite the improved techniques for designing, construction and operation, failure of tailings dams still occurs. Therefore, there might be apparent deficiencies that are repeated. This study provided an overview of failure modes associated with tailings dams, up-to-date monitoring and prevention techniques, and recent tailings dam failures. The frequency, severity,key factors, and recent examples of each failure mode is statically discussed.

Keywords: Tailings Dam, Failure Modes, Monitoring, Tailings Dam Safety, Failure Factors

1. INTRODUCTION

Tailings dams are supposed to retain tailings permanently, but many failures of these dams have been reported during the last century. As a result of the recorded failures of 283 tailing dams since 1915, approximately 2300 loss of lives, and more than 187 cubic meters of tailings release have been reported [1]. In countries with many mining activities, risk impacts of existing tailings dams is becoming a public concern since recent incidents occurred: Tailing failures at Cobriza (a copper mine) in Peru, Jade mine in Myanmar, Hindalco tailings in India, Machadinho tailings and Córrego de Feijão mine in Brazil are recently reported tailings failures throughout the world in 2019 [3]. All these preventable tragedies compel engineers to emphasis on prevention than reacting after the disaster. By considering the potential risks, miner lives can be saved, environmental damages can be minimized and costs can be optimized. A number of studies have been conducted on tailings dam failures. U.S. Committee on Large Dams (1994) conducted a research on 185 tailings dam incidents [4]. In addition, one of the most comprehensive learned lessons from tailing dams (221 tailing dam incidents) was compiled by ICOLD (2001). The rate of tailings dam failure in the past 100 years for 18,000 mines throughout the world is reported approximately 1.2%; however, the failure rate of water retention dams is estimated at 0.01%[5]. M. Rico et al. (2008) provided an investigation of worldwide historical tailing dam failures database. The data have been collected from newspapers, scientific papers, and technical reports. A preliminary analysis was conducted in order to evaluate the causes of failure, geographic and geometries distribution of incidents [6].Silveira et al. (2019) discussed that ensuring geotechnical stability is not merely sufficient; multiple geotechnical tests have been verified the performance ofCórrego de Feijão dam, just weeks prior to its collapse. Failure to properly manage the tailings results in cascading significant human and environmental legacies [7]. Lyu et al. (2019) stated that the tailings dam failure is significantly related to the economy state of the country where it is located. [8]. Despite the tailings failure reports, there are a series of researches on safety of tailings dams. Clarkson and Williams (2019) established a framework for the improvement of monitoring strategies for the geotechnical stability of the tailings dam[9].Xin et al. (2019) evaluated an index system for hazard sources of tailings impoundment.Their analysis results indicate that the safety of tailings pond indexes include the dam height, total capacity, flood discharge, safety degree and seismic intensity [10]. In this study, a detailed re-evaluation of the known tailing dam failure modes with statistical evaluationsis followed by their related case studies. In addition, available developed techniques for site monitoring is discussed. The main objective of this study is to enhance the understanding of tailings dam safety approaches.

2. TAILINGS DAM FAILURE MODES

The term failure mode in this study refers to the mechanism by which a tailings dam ultimately failed. The ICOLD (2001) categorized recognized causes of failuresin 8 modes which are (1) slope instability (SI), (2) Seepage (SE), (3) Foundation failure (FN), (4) overtopping (OT), (5) Structural inadequacies (ST), (6) earthquakes (EQ), (7) Mine subsidence (MN), and (8) Erosion (E). The frequency of reported tailings dam failure modes (current as of march 1, 2019) are presented in Figure 1. Many of tailings dam failures were not sufficiently documented which assigned 27% of all reported failures. The majority of tailings dam failure modes attributed to overtopping, slope instability and earthquake, which in total included about 50% of all reported failures. Seepage, foundation failure and structural inadequacies each consists 7% of all reported failures and erosion and mine subsidence are the least reported failure modes from 1915 to 2019.In the following, all mentioned failure modes are discussed with related recent failures.

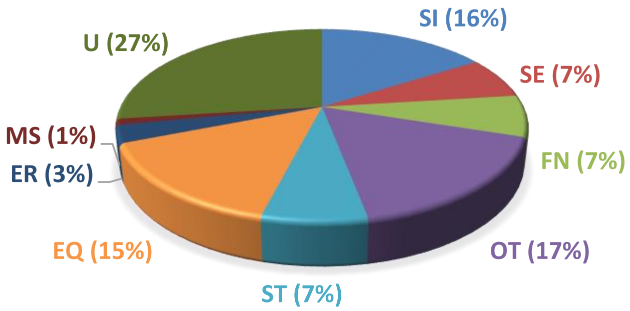


Figure 1. Frequency of reported tailings dam failure modes(N=342)

2.1 Slope instability:

In this failure mode, a constant load causes deformation to a point at which the tailings dam partially or completely fails. Mostly caused by partial saturation of areas designed for a dry condition. Even in the absence of high excess pore water pressure to initiate liquefaction, the dynamic stresses may result in slope instabilities. Slope instability of tailings dam may occur by the following factors: (1) Slopes at their reposed natural angle and consist of substantial saturated zones (2) Variation of phreatic level position as a consequence of intense rains, inadequate functioning or nonexistent of the drainage system, increasing the saturation rate by insufficient operation, or poor management of decant ponds (3) Presence of a weak layer in retaining dyke (4) Insufficient geometry of retaining dyke (Freeboard height, slopes, and width of the crest), or shear strength decrease of foundation soil. The timeline of the reported slope instability failure of active/inactive tailings damsis illustrated in figure 2. Many researchers believed that geotechnical structures as tailings dams become more stable over time especially designed slopes, thus, it can be seen from figure 2 that a few inactive dam failures are reported due to slope instability in comparison with active dams. The reported data shows an increasing slope instability failure trend from 1910s to 1970s followed by a decreasing trend to present. Five tailings dam failures due to slope instability are reported in 2010s to present throughout the world, which the most recent failures are provided in table 1.

Table 1- Recent reported tailings dam failures due to slope instability

Name	Year	Location	Ore type	Active/Inactive
Newcrest Mine	2018	Australia	Au, Cu	Active
Hernic Platinum	2017	South Africa	Pl	Active
LouyangXiangjian	2016	China	Al	Active

2.2 Seepage (Seepage and internal erosions)

Erosion of tailings dam material due to water passing through the dam that are designed for dry condition is called seepage. The stability of tailings dam is significantly influenced by the seepage due to its permeability potential. The seepage phreatic line of tailings pond is also called "lifeline".

Due to the inaccuracy of the boundary conditions and complicated geological conditions of the tailings impoundment, finding an exact theoretical solution of the seepage field in tailing impoundment is difficult.The tailings beneath the phreatic line show a reduction rate of consolidation, and the saturated tailings, reduce the effective stress and shear strengthof the dam, and increasing its weight.Further, floods, inadequacy of drainage facilities and rainstorms often induce phreatic line to rise in the tailings dam, which in turn cause seepage damage. In tailings dam, piping effect occurs due to deformation conditions induced by osmosis. After the piping effect occurrence, the properties of tailings change, resulting in a decrease in modulus of deformation and shear strength of the tailings, and enhanced permeability, which eventually lead to the tailings dam break and the tailings pond collapse.The timeline of the reported seepage failure of active/inactive tailings dams is illustrated in figure 3.Just one data is found for seepage failure in inactive dams which shows this failure mostly occur in active dams. The most recent seepage failures of tailings dam are presented in table 2.

Table 2- Recent reported tailings dam failures due to seepage

Name	Year	Location	Ore type	Active/Inactive
Talvivaara	2012	Finland	Ni	Active
Hudson Bay	2012	Canada	Pb, Zn	Inactive
MAL Magyar	2010	Hungary	Al	Active

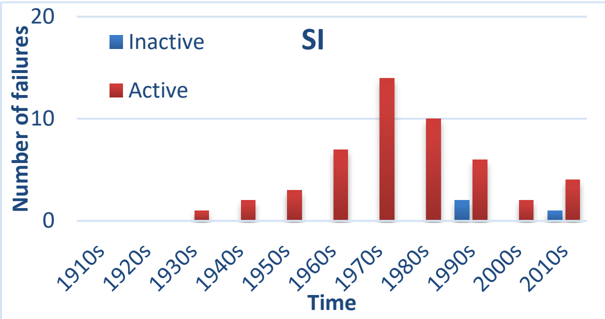


Figure 2. Timeline illustrating reported slope instability failure of tailings dams

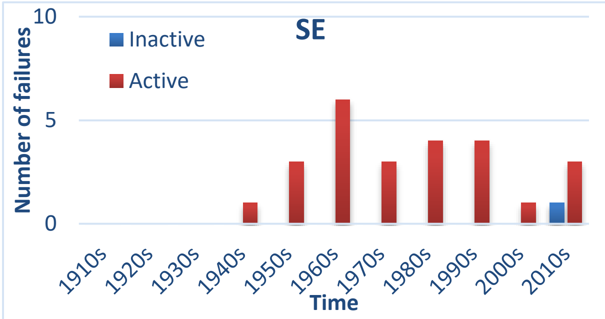


Figure 3. Timeline illustrating reported seepage failure of tailings dams

2.3 Foundation failure (Structural and foundation conditions, foundations with insufficient investigations):

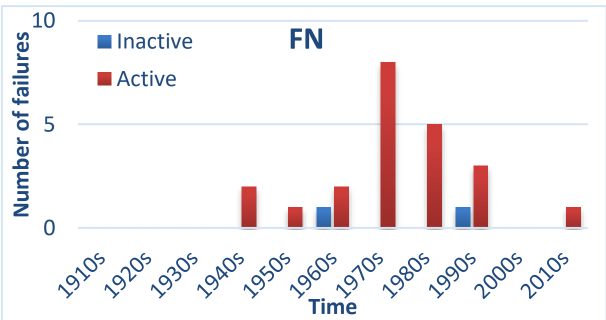
The foundation failure is a failure related toconstruction of dam on a surface, whichdoes not provide adequate support for the dam's weight.Chronology of tailings dam failure show that the foundation failure is a prevalent cause of tailings impoundments failure. The foundation permeability plays a key role in the stability of dam structure. Low permeable materials cause an increase in shear strength and pore pressure on the foundation [11]. The inappropriate geological surveys and design errors is a common cause for the instability of the tailings dam foundation. Geological detailed data for corresponding ground treatment can prevent instability of tailings dam foundation. The timeline of the reported foundation failure of active/inactive tailings dams is illustrated in figure 4. Although the frequency of this failure mode is less, the severity of the failures is mostly very serious (Figure9). The most recent seepage failures of tailings dam are presented in table 3.

Table 3- Recent reported tailings dam failures due to foundation failure

Name	Year	Location	Ore type	Active/Inactive
Imperial Metals	2014	Canada	Cu, Au	Active
Boliden	1998	Spain	Pb, Zn	Active
Coeur d'Alène	1995	New Zealand	Au	Active

2.4 Overtopping:

Overtopping is water passing over the top of the tailings dam. Mostly tailings dam are made up of highly erodible materials. A large number of tailings dam are located on a mountainous area. During heavy rainfalls, the water level of the tailing impoundment rises dramatically in a short period. Further, if the dam permeability is low, rainwater is discharged at a very slow rate, which results in the overtopping phenomenon and instability of the dam. Overtopping mostly occur due to mismanagements resulting from ignorance of soil mechanics principles, negligence, poor training of staff, and a measure of dishonesty. Two overtopping failures of tailings dam in South Africa are examples of poor managements. [16] The timeline of the reported overtopping failure of active/inactive tailings dams is illustrated in figure 5. As shown in this figure many overtopping failures of inactive damshas been reported which may refer to mismanagement of drainage facilities of inactive dams. Although, many overtopping failures are reported, the severity of most of its failures are minor (Figure 9). The most recent seepage failures of tailings dam are presented in table 3.



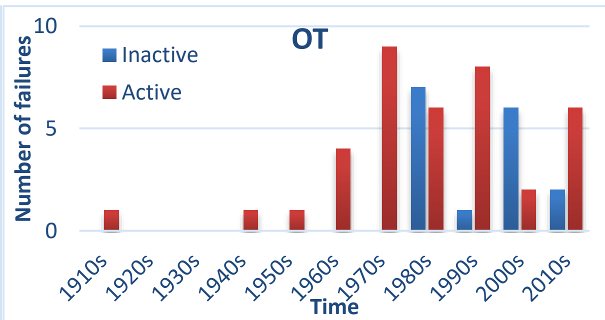


Table 4- Recent reported tailings dam failures due to overtopping

Name	Year	Location	Ore type	Active/Inactive
Duke Energy	2018	USA	Coal	Active
Alunorte	2018	Brazil	Bauxite	Active
Duke Energy	2016	USA	Coal	Inactive

2.5 Structural (Structural inadequacies, inadequate or failed decants)

Structural failures of tailings dam can be largely attributed to failures of engineering design or construction. Conservative design and construction practices by adopting larger safety margins in the designs, seems to be necessary to tackle these problems. In addition, the failures related to natural hazards, are mostly followed by structur … tural failure … in figure 6 … ned 7% of all … ve dams w … which is not … in recent years. The most recent structural failures of tailings dam are presented in table 5.

Figure 4. Timeline illustrating reported foundation failure of tailings dams

Figure 5. Timeline illustrating reported overtopping failure of tailings dams

Table 5- Recent reported tailings dam failures due to structural inadequacies

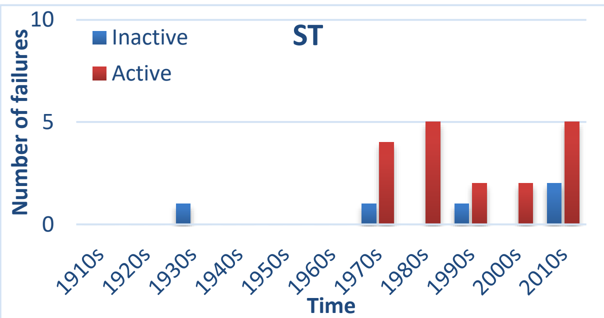
Name	Year	Location	Ore type	Active/Inactive
Kokoya	2017	Liberia	Au	Active
Benguet	2016	Philippines	Au	Inactive
Mariana	2015	Brazil	Fe	Active

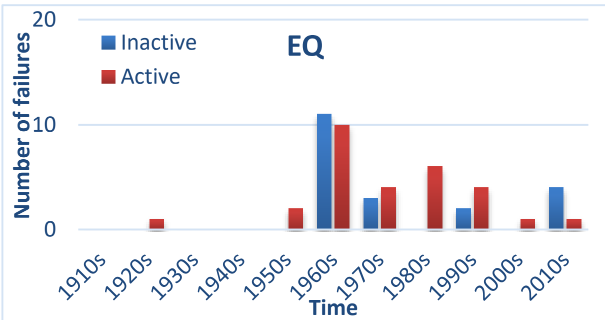
2.6 Earthquake (Seismic instability):

Earthquake causes the tailings pond to break the dam. The mechanism of earthquake induced breakage in tailing reservoir is commonly caused by liquefaction of the tailings sand triggered by earthquakes which weaken the tailings material strength, destabilized the tailings dam and causing large deformations [12] The key factors affecting the tailings liquefaction are the size, shape, compression, arrangement, gradation, depth of the wetting line, compactness, and seismic intensity. In comparison with similar earth/rock dams, the understanding and research on the failure mechanism and seismic response of tailings dams are few. After the earthquake, in order to understand the potential damage risks of the tailings dam, the post-earthquake stability analysis of the tailings dam is increasingly incorporated in the evaluation and design process. The tailings dam seismic performance should include seismic stability analysis, seismic liquefaction analysis, and seismic deformation analysis. In addition, the main cause of high tailings dam failure is liquefaction. Seismic inertial force has a secondary effect on the seismic stability of high dams.Common features of tailings dam failure by seismic action are: (1) the presence of a large pond that may encroach on outer impoundment dyke. (2) The outer dyke constructed of poorly compacted, loose or uncompacted tailings sand, which is potentially liquefiable and contractive when subjected to shear stress. (3) Poor separation of the sand from the silts in the impoundment used to build the retaining dyke. (4) Upstream deposition of dykes over impounded silts [16]. The timeline of the reported earthquake failure of active/inactive tailings dams is illustrated in figure 7. It can be seen from the figure that seismic induced failures are occurred in both active and inactive dams. The most recent seismic induced failures of tailings dam are presented in table 6.

Table 6- Recent reported tailings dam failures due to earthquake

Name	Year	Location	Ore type	Active/Inactive
Cominor	2010	Chile	Cu	Inactive
Cuajone	2001	Peru	Fluor	Active
TranqueAntiguo	1997	Chile	Fe	Active





2.7 Mine subsidence:

If the impoundment or dam is constructed above an underground mine, the underground mine may collapse which leads to release of the tailings. The timeline of the reported mine subsidence failure of active/inactive tailings dams is illustrated in figure 8.In this figure it has been shown that just three tailings dam attributed to mine subsidence, which were all active mines. Despite its few frequency, the severity of reported failures are very serious (Figure 9). All reported mine subsidence failures of tailings dam are presented in table 7.

Table 7- Recent reported tailings dam failures due to mine subsidence

Name	Year	Location	Ore type	Active/Inactive
IMC-Agrico	1994	USA	P	Active
Roan	1970	Zambia	Cu	Active
Iwiny	1967	Poland	Cu	Active

2.8 Erosion (External erosion)

External erosion related to face of a dam mostly caused by precipitation run-off, which is not repaired. There is currently no suitable theoretical model to simulate the external erosion of the tailings dams. From 1915 to 2019 totallyeight external failures have been reported. The timeline of the reported erosion failures of active/inactive tailings dams is illustrated in figure 9 and the most recent external erosion failures of tailings dam are presented in table 8. However, the reported failure types have to be evaluated carefully since a combination of different causes can occur in an incident [15]

Table 8- Recent reported tailings dam failures due to mine subsidence

Name	Year	Location	Ore type	Active/Inactive
Johson	2012	Philippine	Au	Active
Cerro Negro	2003	Chile	Cu	Active
Aitik	2000	Sweden	Cu	Active

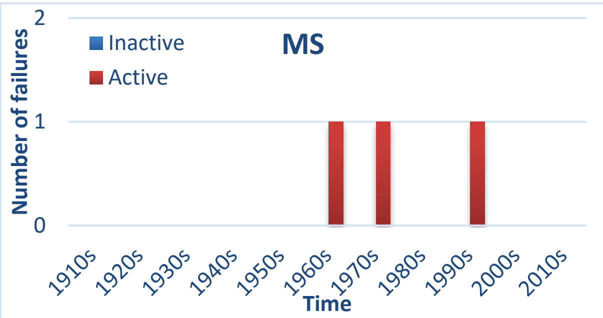


Figure 8. Timeline illustrating reported mine subsidence failure of tailings dams

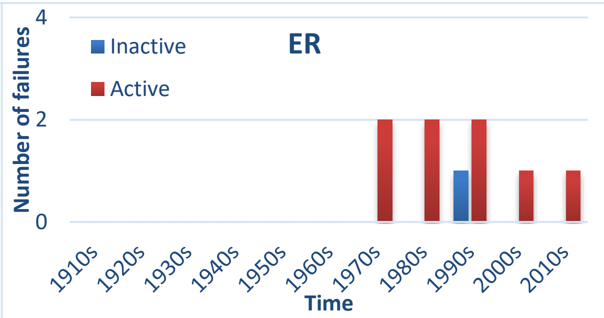


Figure 9. Timeline illustrating reported erosion failure of tailings dams

Table 9- Severity classification considering tailings dam failure mode

Tailings dam location	SI	SE	FN	OT	ST	EQ	ER	MS	Total
Very serious	6 (18%)	3 (17%)	4 (31%)	8 (19%)	6 (33%)	3 (17%)	2 (28%)	2 (67%)	34
Serious	10 (30%)	3 (17%)	2 (15%)	7 (16%)	6 (33%)	10 (28%)	2 (28%)	NR	40
Minor	4 [illegible]	12 [illegible]	7 [illegible]	28 [illegible]	6 (33%)	22 [illegible]	3 [illegible]	1 [illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	18 (100%)	[illegible]	[illegible]	[illegible]	[illegible]

NR= Not reported

3. TAILINGS DAM FAILURE FACTORS

Multiple factors often interfere in failure of tailings dam especially external environmental influences as earthquake, floods and rainfall. Rico et al. (2007) stated that the fundamental indicators reside in the properties of tailings storage facilities. The basic factors that can influence the tailings dam stability are the properties of embankments material, foundation conditions, type of construction, deposition rate and tailings properties, dam height, total storage volume, outer slope angle, seismic and storm design considerations, and water management (control of phreatic surface of downstream slope and pore water pressure) [5,13]. In this paper, some factors considering the failure modes of tailings dam is discussed. However, there is inadequate data on many of these factors in an official compilation for correlation analysis with failure modes of tailings dams, and it is not attributable to fill in the blanks with available public reports. Earthquakes, extreme flood, and operational practices can initiate failures. Table 10 shows the triggers that can cause failure events.

Table10- leading causes of failure and common triggers. Adapted from Gindy et al. (2007) [14]

Floods	Earthquakes	Operations
Slope instability	Slope instability	Slope instability (WM and CM)
Seepage	Foundation failure	Seepage (WM and CM)
Overtopping	Structural inadequacies	Foundation failure (CM)
Structural inadequacies		Overtopping (WM)
Erosion		Structural inadequacies (CM)
		Erosion (WM and CM)

WM = Water Management, CM = Construction Material

Tailings dam construction method can be either (1) upstream; (2) downstream (3) centerline; and (4) any of the previous methods combination. Statistical evaluation of reported failure modes considering construction method of tailings dam is presented in table 11. The upstream construction method is very economicalbut the least secure because it relies on the tailings stability themselves as a foundation. Due to the Brumadinho dam failure (2019), the upstream construction method have been banned by the Brazilian authorities. Centerline construction method considering the chronology of failures, seems to be the safest type of tailings dam construction from a seismic standpoint

Table11-Statistical evaluation of reported failure modes considering tailings dam type

Tailings dam type	SI	SE	FN	OT	ST	EQ	ER	MS	Total
Upstream	28 (80%)	6 (50%)	4 (33%)	15 (72%)	6 (60%)	35 (85%)	2 (67%)	NR	96
Downstream	6 (17%)	4 (33%)	3 (25%)	3 (14%)	2 (20%)	5 (12%)	1 (33%)	NR	24
Centerline	1 (3%)	2 (17%)	5 (43%)	3 (14%)	2 (20%)	1 (3%)	NR	NR	14
Total	35 (100%)	12 (100%)	12 (100%)	21 (100%)	10 (100%)	41 (100%)	3 (100%)	NR	134

NR= Not reported

One of the key factors that govern the tailings dam failure is the dam height. Statistical evaluation of reported failure modes considering tailings dam height is presented in table12. It can be seen that the majority of the failures occur in tailings dams with less than 15 meters height and the number of tailings incidents with increasing the dam's height shows a decreasing manner. This trend shows that tailings dam with lower height have more potential of each failures and shall not be underestimated.

Table12- Statistical evaluation of reported failure modes considering tailings dam height

Tailings dam height(m)	SI	SE	FN	OT	ST	EQ	ER	MS	Total
>100	NR	1 (6%)	NR	NR	NR	NR	NR	NR	1
60-100	NR	NR	1 (6%)	1 (4%)	2 (22%)	2 (5%)	NR	NR	6
30-60	11 (33%)	1 (6%)	1 (6%)	4 (15%)	1 (11%)	10 (24%)	1 (17%)	1 (100%)	30
15-30	14 (42%)	5 (31%)	5 (31%)	7 (26%)	3 (33%)	14 (33%)	1 (17%)	NR	49
<15	8 (25%)	9 (57%)	9 (57%)	15 (55%)	3 (33%)	16 (38%)	4 (66%)	NR	64
Total	33 (100%)	16 (100%)	16 (100%)	27 (100%)	9 (100%)	42 (100%)	6 (100%)	1 (100%)	150

NR= Not reported

The other key factor of tailings dam failures is the dam fill materials. Statistical evaluation of reported failure modes considering tailings dam fill materials is presented in table 13. As it can be observed from this table, the majority of tailings dam failures occur in dams fill with tailings and Earthfill and the minatory of the failures is attributed to Rockfill tailings. Tailings fill dams have shown to be the most vulnerable dams and Earthfill dams the most resistant against earthquakes.

Table 13- Statistical evaluation of reported failure modes considering tailings dam fill materials

Tailings dam fill materials	SI	SE	FN	OT	ST	EQ	ER	MS	Total
T	15 (41%)	4 (28%)	5 (25%)	11 (46%)	5 (50%)	18 (75%)	2 (25%)	NR	60
CST	7 (19%)	1 (7%)	NR	1 (4%)	NR	4 (17%)	NR	NR	13
MW	2 (5%)	2 (14%)	3 (15%)	2 (8%)	2 (20%)	NR	1 (12%)	NR	12
E	13 (35%)	6 (44%)	9 (45%)	10 (42%)	2 (20%)	1 (4%)	4 (51%)	NR	45
R	NR	1 (7%)	3 (15%)	NR	1 (10%)	1 (4%)	1 (12%)	NR	7
Total	37 (100%)	14 (100%)	20 (100%)	24 (100%)	10 (100%)	24 (100%)	8 (100%)	NR	137

T= Tailings, CST= Cycloned Sand, MW= Mine waste, E= Earthfill, R= Rockfill, NR= Not reported

4. TAILINGS DAM SAFETY APPROACHES

4.1 Overview

Monitoring is a procedure in which a tailing dam will be routinely inspected, recorded, tested, and evaluated on key characteristic of them. Monitoring includes tracking of performance, conformance with objectives and operational controls.

4.2 Monitoring methods of tailings dam

4.2.1 Visual inspections: It is compulsory to inspect the tailing dams every day. Other visual inspections should be conducted in special situations such as earthquake, extreme weather and prolonged inactivity. Structural monitoring also should be done to detect movement or change in tailing dams [2]

4.2.2 Seepage monitoring:Seepage management should be a key consideration in operating and designing of tailing dams. This can be done with installing piezometers wherever we think seepage is in unmoral condition. In addition, adequate monitoring well should be installed to check water table around cavities [16].

4.2.3 Phreatic surface monitoring: In this kind of monitoring, a number of boreholes should be excavated in the tailing dams. Phreatic surface can be easily estimated wherever the water table stands in boreholes [9]

4.2.4 Pore pressure monitoring:In presence of pore drainage, pore pressure monitoring will be a critical state. In order to monitor the pore pressure of tailing dams, strategically placed piezometer can be used [6].

4.2.5 Seismic monitoring:Seismic events should be measured in local basis of tailing dams to instrument dams for seismic responses. Interpretation and implementing this kind of monitoring is best conducted by seismologists [3]

4.2.6 Deformation monitoring:It is recommended to use slope stability radar for monitoring of tailing dams movement. Settlement instruments are often concentrated in centerline; however, they can be installed in every part of a dam such as crest or foundation [6].

4.2.7 Monitoring for environmental purposes:In this type of monitoring, we try to check the environmental state of a tailing dam as it expected to be. Environmental monitoring includes monitoring well requirements, checking limitations for leak detection systems, overburden and waste rock evaluation and at the end, meteoric water mobility procedure [9]

4.2.8 Deviation monitoring: The diversionary of tailing dams can be easily monitored with inclinometers. It can be used for monitoring of over slope instability dams [6]

4.2.9 Crack monitoring: In order to monitor the discontinuity in tailing dams, crack-monitoring device may be needed which should be installed in appurtenant structure [6].

4.2.10 Agronomical monitoring: In this kind of monitoring, we should monitor soil and plant tissue near tailing dams and fertilizers [2].

4.2.11 Temperature monitoring: Keeping the temperature of tailing dams in a specific range is vital sometimes. Therefore, there is some kind of instruments such as optical fiber temperature sensors to help us for this purpose [3]

5. CONCLUSION

In this paper, failure modes of tailings dam, and up-to-date monitoring techniquesare presented. The frequency, severity, key factors, and recent examples of each failure mode is statically discussed. Although the design tools,regulations,oversight and corporate responsibility are increasingly developing, failures still occur. Due to the presented number of tailings impoundments failures throughout the world, most of them can be prevented.Preventing failures of tailings dam requires effective management and engineering, enhanced physical understanding, and enforcement of regulations. Further, all tailings dam failure modes underscore the need for better technologies to better characterize impoundments, new monitoring instrumentations, and appropriate retrofitting strategies.

References

1. S. Azam and Q. Li, Tailings Dam Failures: A Review of the Last 100 Years, Geotech. News (2010). 28 (4), pp. 50–53.Atluri, S.N. and Shen, S. (2013),“The Meshless Local Petrov–Galerkin (MLPG) Method”, Tech Science Press, USA.

2. Kossoff, D., Dubbin, W. E., Alfredsson, M., Edwards, S. J., Macklin, M. G., & Hudson-Edwards, K. A. (2014). Mine tailings dams: characteristics, failure, environmental impacts, and remediation. Applied Geochemistry, 51, 229-245.

3. Vick, S. G. (1999, October). Tailings Dam Safety–Implications for the Dam Safety Community. In Proceedings of Canadian Dam Safety Association Annual Conference, Sudbury (pp. 1-12).

4. Incidents, T. D. (1994). US Committee on Large Dams. USCOLD (compilation and analysis of 185 tailings dam incidents). Denver, Colorado.

5. International Commission on Large Dams. (2001). Tailings dams: risk of dangerous occurrences: lessons learnt from practical experiences (Vol. 121). United Nations Publications.

6. National Research Council. (1983). Safety of existing dams: evaluation and improvement. National Academies.

7. Silveira, F. A., Gama, E. M., Dixon, K. W., & Cross, A. T. (2019). Avoiding tailings dam collapses requires governance, partnership and responsibility. Biodiversity and Conservation, 28(7), 1933-1934.

8. Lyu, Z., Chai, J., Xu, Z., Qin, Y., & Cao, J. (2019). A Comprehensive Review on Reasons for Tailings Dam Failures Based on Case History. Advances in Civil Engineering, 2019. Luke Clarkson & David Williams (2019): Critical review of tailings dammonitoring best practice, International Journal of Mining, Reclamation and Environment, DOI:10.1080/17480930.2019.1625172

9. Clarkson, L., & Williams, D. (2019). Critical review of tailings dam monitoring best practice. International Journal of Mining, Reclamation and Environment, 1–30. doi:10.1080/17480930.2019.1625172

10. Xin, B., & Wan, L. (2019). Evaluation Index System and Grading Standard for Major Hazard Source of Tailings Pond. In IOP Conference Series: Earth and Environmental Science (Vol. 252, No. 5, p. 052156). IOP Publishing.

11. A. T. ¨ Ozer and L. G. Bromwell, “Stability assessment of an earth dam on silt/clay tailings foundation: a case study,” Engineering Geology, vol. 151, pp. 89–99, 2012.

12. T. G. Harper, H. N. McLeod, and M. P. Davies, “Seismic assessment of tailings dams,” Civil Engineering, vol. 62, no. 12, p. 64, 1992.

13. Zhang L.M., Y. Xu& J.S. Jia (2009) Analysis of earth dam failures: A database approach, Georisk: Assessment and Management of Risk for Engineered Systems an Geohazards, 3:3, 184-189, DOI: 10.1080/17499510902831759

14. Gindy, M., Thomas, N., Madsen, R. (2007). Assessment of Downstream Hazard Potential for Dam Failure in Rhode Island., Rhode Island Water Resources Center.

15. Villavicencio, G., Espinace, R., Palma, J., Fourie, A., Valenzuela, P., (2014), Failures of sand tailings dams in a highly seismic country, Canadian Geotechnical Journal, Vol. 51, No. 4 : pp. 449-464 doi: 10.1139/cgj-2013-0142

16. G. Blight, Geotechnical Engineering for Mine Waste Storage Facilities (CRC Press, 2010).