The 57th International October Conference on Mining and Metallurgy
05 - 07 October 2026, Bor Lake, Serbia
https://ioc.irmbor.co.rs

DOI: 10.5937/IOC26157M Original Scientific Paper-Mineral Processing

APPLICATION OF INTERNATIONAL STANDARDS IN TAILINGS FACILITY DESIGN

Sandra Milutinović[1a], Ljubiša Obradović[1b], Sanja Petrović[1c], Srđana Magdalinović[1d], Ivan Svrkota[1e]

[1a] Mining and Metallurgy Institute Bor, Alberta Ajnštajna 1, 19210 Bor, Serbia

[1a] sandra.milutinovic@irmbor.co.rs, https://orcid.org/0000-0003-0146-8636

[1b] ljubisa.obradovic@irmbor.co.rs, https://orcid.org/0000-0002-6715-4173

[1c] sanja.bugarinovic@irmbor.co.rs, https://orcid.org/0000-0001-5197-1614

[1d] srdjana.magdalinovic@irmbor.co.rs, https://orcid.org/0000-0002-2916-2850

[1e] ivan.svrkota@irmbor.co.rs, https://orcid.org/0000-0002-1105-1554

Abstract

Safe design and management of flotation tailings storage facilities represent one of the most important aspects of modern mining, considering the potential technical, environmental, and social consequences of possible dam failures. Following major tailings storage facility failures worldwide, international standards and guidelines have been developed to define requirements for the design, construction, operation, monitoring, and closure of tailings facilities. This paper provides an overview of the most significant international standards and recommendations applied in the field of flotation tailings facility design, with particular emphasis on risk management, geotechnical investigations, stability analyses, water management, and monitoring. The possibility of their application in domestic engineering practice is also considered, highlighting the benefits that the implementation of modern standards can provide in terms of improving the safety, reliability, and sustainability of tailings storage facilities. The paper presents an overview of current international guidelines and may serve as a basis for improving the practice of designing and managing flotation tailings storage facilities.

Keywords*: flotation tailings storage facility, international standards, design, dam stability, risk management, monitoring*

1. INTRODUCTION

Flotation tailings storage facilities (TSFs) are critical structures in the mining industry, providing controlled disposal of waste material generated during mineral processing. Their design and management require the integrated consideration of geological, geotechnical, hydrological, seismic, environmental, and other site-specific conditions that may influence facility performance throughout its service life. A particular challenge is that tailings properties and hydraulic conditions may change during operation, while storage capacity is often increased through successive dam raises.

The safety of tailings facilities is of paramount importance due to the potential occurrence of various failure mechanisms, which may threaten human life, infrastructure, and the environment. Experience gained from major tailings dam failures has demonstrated the need to improve traditional design approaches by shifting from safety assessment based solely on individual engineering calculations toward comprehensive risk management throughout the entire life cycle of the facility [1].

In response to these challenges, several international standards and guidelines have been developed to establish principles for the safe management of tailings facilities. Among the most influential is the Global Industry Standard on Tailings Management (GISTM), which applies to both existing and new TSFs and integrates design, construction, operation, monitoring, closure, and post-closure activities within a unified safety management framework. The standard places particular emphasis on multidisciplinary data management, robust engineering design, water management, continuous monitoring, clearly defined responsibilities, and systematic risk management.

In addition to tailings-specific guidelines, internationally recognized standards for geotechnical and seismic engineering play a fundamental role in TSF design. Eurocode 7 (EN 1997) establishes the principles for geotechnical investigations, ground characterization, and geotechnical design, while the seismic aspects of geotechnical engineering are complemented by the requirements of Eurocode 8 (EN 1998) [2].

The aim of this paper is to present the most important international standards and guidelines relevant to the design of flotation tailings storage facilities and to review their principal requirements in the fields of geotechnical investigations, stability analysis, water management, seismic safety, monitoring, and risk management. Particular attention is given to the applicability of these principles in domestic engineering practice, with the objective of improving the safety, reliability, and long-term performance of tailings storage facilities.

2. INTERNATIONAL STANDARDS AND GUIDELINES FOR TAILINGS FACILITY DESIGN

The development of international standards and guidelines for tailings management has been driven by the need to establish a systematic framework for safety, environmental protection, and risk management. Modern engineering practice no longer considers tailings facility design as an isolated phase, but as part of an integrated process encompassing site selection, design, construction, operation, monitoring, closure, and post-closure management.

One of the most influential documents in this field is the Global Industry Standard on Tailings Management (GISTM). The standard was developed to improve the safety of tailings facilities through an integrated approach that combines technical, environmental, social, and economic considerations. Its requirements are structured around 15 principles and 77 auditable requirements, covering the entire life cycle of tailings storage facility. Particular emphasis is placed on site characterization, consequence classification of potential failures, data-driven engineering design, water management, continuous monitoring, and systematic risk management.

Unlike GISTM, which provides a comprehensive governance framework for tailings management, the International Commission on Large Dams (ICOLD) guidelines offer specialized engineering recommendations for the design, construction, and safety assessment of dams and tailings storage facilities. Their significance is particularly evident in the application of principles related to slope stability, seepage control, structural behavior, and safety evaluation during different phases of a facility's operational life.

For the geotechnical aspects of design, Eurocode 7 (EN 1997) provides the fundamental engineering framework. This standard establishes general principles for geotechnical design, including requirements for site investigation, ground characterization, laboratory and field testing, and the development of reliable geotechnical models. In the context of tailings facilities, accurate material characterization and the assessment of groundwater conditions are essential for ensuring long-term stability.

The seismic component of design is addressed by Eurocode 8 (EN 1998), which complements Eurocode 7 by defining requirements for geotechnical structures subjected to earthquake loading. For tailings storage facilities, seismic design is particularly important because earthquakes may alter the stress–strain state of tailings materials, reduce shear strength, trigger liquefaction in susceptible deposits, and compromise overall dam stability.

These documents should not be regarded as competing standards, but rather as complementary frameworks operating at different levels of engineering practice. GISTM establishes the overarching principles of safety governance and risk management, whereas Eurocode 7, Eurocode 8, and ICOLD provide the technical basis for the detailed design and assessment of tailings facilities. Their combined application enables a comprehensive evaluation of safety by integrating engineering analyses, site conditions, water management, monitoring systems, and organizational risk control measures.

Such an integrated approach forms the foundation of contemporary tailings facility design, where structural safety is assessed not only through engineering calculations but also through the systematic identification, evaluation, and management of risks throughout the entire life cycle of the facility.

3. KEY ASPECTS OF TAILINGS FACILITY DESIGN ACCORDING TO INTERNATIONAL STANDARDS

The application of international standards in tailings facility design requires the facility to be assessed through several interconnected aspects. In addition to the dam structure itself, site conditions, tailings characteristics, water regime, stability, seismic effects, construction and raising methods, as well as the behavior of the facility during operation must be taken into consideration. In this way, the design solution should be based on a reliable assessment of the conditions that may affect the safety of the facility.

3.1. Geotechnical Investigations and Site Characterization

Reliable characterization of the geological and geotechnical conditions is fundamental to the design of tailings storage facilities. Investigations should enable the identification of the lithological composition, structural and tectonic characteristics of the site, groundwater levels and regime, as well as the properties of the materials used for dam construction and the tailings to be deposited. Particular attention should be given to determining the relevant physical and mechanical properties of the tailings, including grain-size distribution, bulk density, permeability, strength parameters, and deformation characteristics. The data obtained provide the basis for developing the geotechnical model and selecting the parameters used in engineering analyses. Eurocode 7 specifically addresses geotechnical design and ground investigation and testing,

emphasizing the direct relationship between the quality of site investigations and the reliability of design verifications.

3.2. Stability Analysis

Stability assessment is one of the fundamental elements of tailings dam design. The analysis should consider potential slip surfaces through the dam body, the deposited tailings, and the foundation, while accounting for the characteristic conditions that may occur during construction, operation, and after closure of the facility. The calculation model should take into account the geometry of the structure, geotechnical properties of the materials, stress state, groundwater regime, and relevant design situations. Depending on the characteristics of the facility and the available data, different methods of stability analysis may be applied, with the selected method being consistent with the geotechnical model and the complexity of the problem. For tailings storage facilities, particular attention should be given to changes in conditions over time. As the dam is progressively raised, the geometry of the facility changes, while the volume of deposited material increases, and seepage conditions and the stress state may also change.

3.3. Water Regime and Seepage Management

The presence of water is one of the key factors affecting the stability of tailings storage facilities. Therefore, the design must address the control of water inflow, accumulation, and movement through the dam body, tailings, and foundation soil. Particular attention should be paid to the water level, seepage flows, pore water pressures, and the potential occurrence of erosion or other seepage-related processes. The design solution should provide adequate control of the water regime through drainage systems and surface water management measures, in accordance with the specific characteristics of the site. In geotechnical design, water cannot be considered as an isolated factor since its influence directly affects the assessment of the stress state and overall stability. **Eurocode 7** requires consideration of actions arising from groundwater conditions as part of geotechnical design.

3.4. Seismic Safety

Seismic loading represents a specific aspect of tailings facility safety, particularly for large structures and materials that may exhibit unfavorable behavior under dynamic loading. Depending on local seismic conditions, material characteristics, and the importance of the facility, additional analyses of the behavior of the dam and tailings during an earthquake may be required.

In addition to assessing overall stability under seismic loading, the potential for excessive deformation, settlement, and, where appropriate conditions exist, loss of bearing capacity or liquefaction of the materials should be considered. **Eurocode 8** provides additional provisions for seismic geotechnical design, complementing the requirements of **Eurocode 7**.

3.5. Monitoring and Risk Management

The modern approach to tailings facility safety assumes that the design process does not end with the preparation of calculations and technical documentation. During construction and operation, the behavior of the facility must be monitored, and measured parameters should be compared with the expected performance defined by the design. Monitoring may include the assessment of displacements and deformations, groundwater levels and pressures, flow rates through drainage systems, and other parameters relevant to facility safety. The data obtained enable timely identification of deviations and implementation of appropriate corrective measures. GISTM further extends this approach by requiring systematic risk management throughout the entire life cycle of the tailing's facility, while ICOLD guidelines address issues related to the safety, design, construction, operation, and rehabilitation of tailings dams [3–5].

4. APPLICATION OF INTERNATIONAL STANDARDS IN DOMESTIC ENGINEERING PRACTICE

The application of international standards and guidelines in domestic engineering practice can represent a significant step toward improving the safety of flotation tailings storage facilities. However, their application should not be viewed as a simple adoption of individual criteria, but rather as the establishment of a systematic approach to design and risk management, adapted to the specific geological, geotechnical, hydrological, and seismic conditions of the site. During the initial design stage, particular importance should be given to high-quality geological and geotechnical investigations, which provide the basis for defining site conditions and material characteristics. The results obtained form the basis for developing the geotechnical model and selecting appropriate design parameters [6-9]. In accordance with the principles of **Eurocode 7**, site investigations and material testing should be considered an integral part of the geotechnical design process, rather than a separate activity completed before the commencement of engineering analyses. In the subsequent stage, an appropriate dam design and construction and raising method should be defined, while simultaneously considering stability, seepage, and deformation. Analyses should be performed for relevant design situations corresponding to the different stages of the facility's life cycle. For more complex sites, such as areas characterized by significant heterogeneity, the presence of groundwater, or unfavorable geological structures, additional analyses should be conducted and, where necessary, more advanced numerical methods should be applied.

Particular attention should be given to seismic safety. The selection of seismic parameters and design situations should be based on the characteristics of the site and the importance of the facility, while for materials susceptible to increases in pore water pressure, their behavior under dynamic loading should also be assessed. **Eurocode 8** provides additional provisions for seismic geotechnical design, thereby complementing the geotechnical principles established by **Eurocode 7**.

International guidelines also emphasize the importance of water management and monitoring. In domestic practice, this involves the design and maintenance of appropriate systems for controlling surface water and groundwater, as well as the establishment of monitoring programs for assessing the behavior of the dam and tailings. Monitoring should

enable the assessment of parameters relevant to facility safety, such as deformations, displacements, groundwater levels, pore water pressures, and flow rates through drainage systems. Monitoring data should be used to compare the actual performance of the facility with the design conditions and to enable timely implementation of corrective measures.

The application of international principles in domestic practice is particularly important for existing tailings storage facilities that are progressively raised. In such cases, the design of the new configuration should be based on updated data regarding the actual condition of the facility, monitoring results, and additional site investigations, rather than relying exclusively on the assumptions made in the original design. Table 1 provides an overview of the relevant standards and their significance for tailings management and design.

Table 1. *Overview of international standards and guidelines and their importance for the design and management of tailings ponds*

Standard / guideline	Main subject	Key aspects relevant to tailings facilities	Application in engineering practice
GISTM	Tailings management throughout the entire life cycle	Risk management, consequence classification, design, monitoring, water management, closure, and emergency response	Establishment of an integrated safety and risk management system
ICOLD Bulletin 106	Design, construction, operation, and rehabilitation of tailings dams	Site selection, design, construction, operation, and rehabilitation	Basis for the technical assessment of different phases of the dam life cycle
ICOLD Bulletin 121	Hazardous events and lessons learned from failures	Failure mechanisms, lessons learned from previous incidents, and measures to improve safety	Identification of potential failure mechanisms and preventive measures
ICOLD Bulletin 139	Improving the safety of tailings dams	Design, management, monitoring, risk management, and closure	Application of risk management principles and safety control measures
EN 1997 (Eurocode 7)	Geotechnical design	Geotechnical investigations, soil characterization, design models, and geotechnical verification	Development of the geotechnical model and selection of design parameters
EN 1998 (Eurocode 8)	Design under seismic conditions	Seismic loading, geotechnical aspects, and structural behavior during earthquakes	Verification of seismic stability and material response

5. CONCLUSION

The safety of flotation tailings storage facilities requires a comprehensive approach that integrates both sound engineering design and effective risk management throughout the construction, operation, and closure phases of the facility. International standards and guidelines have been developed in response to the need for higher safety levels and provide a robust framework for the systematic management of tailings facilities. The

implementation of these international standards in domestic engineering practice can significantly improve the reliability of design solutions and strengthen safety management systems for both existing and newly constructed tailings storage facilities. Their application, however, should be adapted to the specific geological, geotechnical, hydrological, and seismic conditions of each site while remaining consistent with applicable national regulations. Based on the presented review, the adoption of internationally recognized principles offers considerable potential for advancing the design and management of flotation tailings storage facilities. Integrating these principles throughout the entire life cycle of a facility contributes to more effective risk prevention, early hazard identification, and timely decision-making, ultimately enhancing the safety, sustainability, and long-term reliability of tailings management systems.

ACKNOWLEDGEMENTS

Ministry of Science, Technological Development and Innovation of the Republic of Serbia, Agreement on the implementation and financing of scientific research work of the National Research Institute in 2026, No. 451-03-33/2026-03/ 200052.

REFERENCES

[1] Global Tailings Review (2020). *Global Industry Standard on Tailings Management*. Global Tailings Review, ICMM, UNEP and PRI. https://globaltailingsreview.org/global-industry-standard/?utm_source=chatgpt.com

[2] CEN (2004). *EN 1998-5:2004 Eurocode 8: Design of Structures for Earthquake Resistance – Part 5: Foundations, Retaining Structures and Geotechnical Aspects*. European Committee for Standardization, Brussels.

[3] ICOLD (2001). *Tailings Dams: Risk of Dangerous Occurrences – Lessons Learnt from Practical Experiences*. Bulletin 121. International Commission on Large Dams, Paris.

[4] ICOLD (2011). *Improving Tailings Dam Safety – Critical Aspects of Management, Design, Operation and Closure*. Bulletin 139. International Commission on Large Dams, Paris.

[5] ICOLD (1996). *A Guide to Tailings Dams and Impoundments: Design, Construction, Use and Rehabilitation*. Bulletin 106. International Commission on Large Dams, Paris.

[6] CEN (2004). *EN 1997-1:2004 Eurocode 7: Geotechnical Design – Part 1: General Rules*. European Committee for Standardization, Brussels.

[7] CEN (2007). *EN 1997-2:2007 Eurocode 7: Geotechnical Design – Part 2: Ground Investigation and Testing*. European Committee for Standardization, Brussels.

[8] UNEP (2020). *Global Industry Standard on Tailings Management*. United Nations Environment Programme. https://www.unep.org/resources/report/global-industry-standard-tailings-management

[9] Rico, M., Benito, G., Salgueiro, A. R., Díez-Herrero, A., Pereira, H. G. (2008). Reported tailings dam failures: A review of the European incidents in the worldwide context. *Journal of Hazardous Materials*, 152(2), 846–852.