XI International Conference on Adaptive Modeling and Simulation
ADMOS 2023
B. Bursa, P. Stefaniak, I. Kakogiannos, I. Garcia-Milà Vidal and R. Protasiuk

SEC4TD PROJECT TO IMPROVE THE SAFETY OF TAILINGS STORAGE FACILITIES

BARTŁOMIEJ BURSA[*], PAWEŁ STEFANIAK[†], IOANNIS KAKOGIANNOS[#], IGNASI GARCIA-MILÀ VIDAL[#] AND RAFAŁ PROTASIUK[*]

[*] GEOTEKO Serwis Ltd.
Wałbrzyska 14/16, 02-739 Warsaw, Poland
e-mail: bartlomiej.bursa@geoteko.com.pl, web page: https://www.geoteko.com.pl

[†] KGHM Cuprum Ltd. Research and Development Centre
W. Sikorskiego 2-8, 53-659 Wroclaw, Poland
e-mail: pawel.stefaniak@kghmcuprum.com, web page: https://www.kghmcuprum.com

[#] Worldsensing SL
Viriat, 47 10th floor, 08014 Barcelona, Spain
e-mail: ikakogiannos@worldsensning.com, web page: https://worldsensing.com

Key words: Tailings Storage Facility, Tailings Dam Stability, Tailings Management, AI Engineering Models

Summary. *Tailings storage facilities (TSFs) are structures designed to contain tailings (a by-product of extracting valuable minerals and metals from mined ore) and to manage associated water. Despite all the data collected and a basic understanding of the mechanisms resulting in tailings dam failures, these large structures have consistently failed over the past 50 years, causing human and economic losses and huge environmental consequences to ecosystems and local communities. Therefore, the day-to-day management of these structures is a very challenging task. One needs to focus not only on keeping the tailings discharge plan but also on the construction (the constantly raised embankments) and the structural safety of the TSFs. The operational controls comprise inspections, surveys, installation of the monitoring instrumentations, interpretation of the monitoring readings, and safety analysis of the structure. The article presents the SEC4TD project as a tool to assist the engineering and management staff in day-to-day operations related to keeping the safety of the facility structure.*

1 INTRODUCTION

The tailings storage facilities (TFS), commonly known as tailings dams, are large engineering structures designed to store water and tailings produced during mining and ore processing.

Tailings are a waste product of the mining process. In other words, the material excavated from the mine is categorized as either ore or waste, and waste is generally hauled to a waste rock storage facility while ore is hauled or conveyed to a mill and plant for processing. Ore is processed to extract a desired commodity, and the remaining material is considered tailings, which also includes any chemical additives and water that may have been used during processing. The design, construction, operation, and monitoring of tailings dams are critical to ensure their structural integrity and minimize the risk of dam failure.

Dam failures can lead to catastrophic consequences, such as the release of large volumes of toxic tailings, causing widespread environmental damage, and posing threats to human health and safety. As a result, tailings dam management has become an important focus within the mining industry, with increasing emphasis on environmental protection and sustainable practices. To improve the safety of tailings storage facilities, the new innovative project called SEC4TD has commenced.

The basic idea of this project is to combine IoT infrastructure with a numerical modeling approach and AI algorithms, thus creating a self-thinking system to help the TSF engineering staff manage the structure. The article presents the whole concept of the SEC4TD project, as well as the architecture and main functionalities of the system.

2 TAILINGS STORAGE FACILITIES FAILURES

In the recent year, the increased demand for raw materials has been observed, resulting in higher tailings production and the need for larger TSFs. Unfortunately, the number of incidents and severity of consequences associated with facility failure increased. The chart below presents the data[1, 2] on TSF accidents over the years and the information about the cause of TSF failures. Based on the data, the three primary reasons for failure are slope instability, earthquakes, and overtopping.

The increase in frequency and severity of TSF failures has become an alarming issue. During the short period from 2014 to 2019, three very significant TSF failures occurred, i.e., Mount Polley TSF in August 2014 (British Columbia, Canada), Fundao dam in November 2015 (Samarco mine in Minas Gerais, Brazil), and Dam 1 in January 2019 (Corrego de Feijao mine in Minas Gerais, Brazil). Failure of Mount Polley TSF for gold and copper mine released an estimated 10 billion liters of water and 4.5 million m^3 of metals-laden tailings into the environment[3]. An independent expert review panel determined the failure was due to an inadequate foundation investigation where a glaciolacustrine unit was not identified during facility design[4]. Failure of the Fundão tailings embankment at the Samarco iron ore mine resulted in a release of an estimated 43 million m^3 of tailings (80% of the total contained volume), 19 fatalities, and pollution of 668 km of watercourses extending to the Atlantic Ocean[3, 5]. An independent expert review panel determined the failure was due to static liquefaction, enabled by the migration of tailings slimes through a shared facility embankment into the sand tailings and drainage blanket failure[6]. Failure of Dam 1 at the Córrego do Feijão iron ore mine resulted in 270 fatalities and a release of approximately 12 million m^3 of slurry tailings and embankment materials[2, 7]. An independent expert review panel determined the failure was due to static liquefaction, enabled by inadequate internal drainage and water management deficiencies[8]. As evident, there is a pressing need to take action and enhance the safety of the Tailings Storage Facility. The SEC4TD project aims to achieve this objective by incorporating IoT sensors, advanced numerical modeling techniques, and AI algorithms.

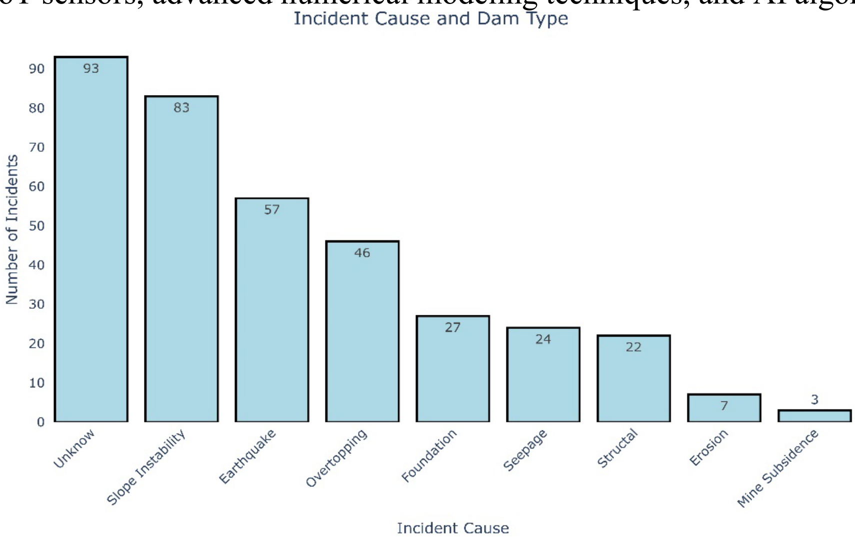

Figure 1: The causes of tailing storage facilities incidents

3 FUNCTIONALITIES OF SEC4TD SYSTEM

SEC4TD project aims to increase the security of tailings storage facilities by implementing the complete analytical system which collects all of the data from different sensors, laboratory, and field tests to analyze them, providing the forecast of the TSF structure mechanical behavior or, in case of the unwanted events, to alarm the engineering staff. The system design is based on three main products: IoT infrastructure, numerical modeling kernel, and the AI-based analytical system.

3.1 Workflow

The workflow of the system will be as follows. Firstly, it collects information from existing infrastructure. Three main types of sources of information are IoT systems with different sensors (displacement, pore water pressure sensors, inclinometer sensors, et cetera), field tests (boreholes, CPT, DMT tests, et cetera), and laboratory tests (simple shear test, triaxial tests, oedometer tests, et cetera). Apart from that, other accessible sources include archive documentation, satellite, and drone data. The system will collect all of that data and analyze it to generate the numerical models for computational purposes, as well as to validate the models and to use some of the sensors' data as the backward analysis or early warning system.

3.2 Challenges

The challenge at this stage is to integrate all of the data from different sources and to create reasonable models for computational purposes. The AI algorithm will be used to perform the complex task automatically. The most challenging task is to create the geotechnical numerical models with all the material parameters for different constitutive approaches from the laboratory and field tests. A statistical approach will be employed to account for the variability of the various parameters, followed by the utilization of the Monte Carlo method to conduct multivariate computations.

3.3 Models

One of the major tasks in the SEC4TD project will be the implementation of different constitutive models to assess TSF safety and to use them as a forecast toll. The constitutive models will be implemented using the Finite Element Method, employing a "simple-to-complex" approach. This method involves using simple linear elastic perfectly plastic models like Coulomb-Mohr to conduct basic factor of safety and displacement analysis.

More sophisticated models will be employed additionally to evaluate the potential risk of static or dynamic liquefaction. The computational module will calculate the threshold and send this data to the IoT infrastructure. If a specific value is exceeded, it will trigger an alarm signal.

3.4 Frontend

The system shall be accessed through a user-friendly frontend designed as a simple dashboard displaying the most relevant engineering information and results clearly and concisely. The figure below presents the complete functional architecture of the system.

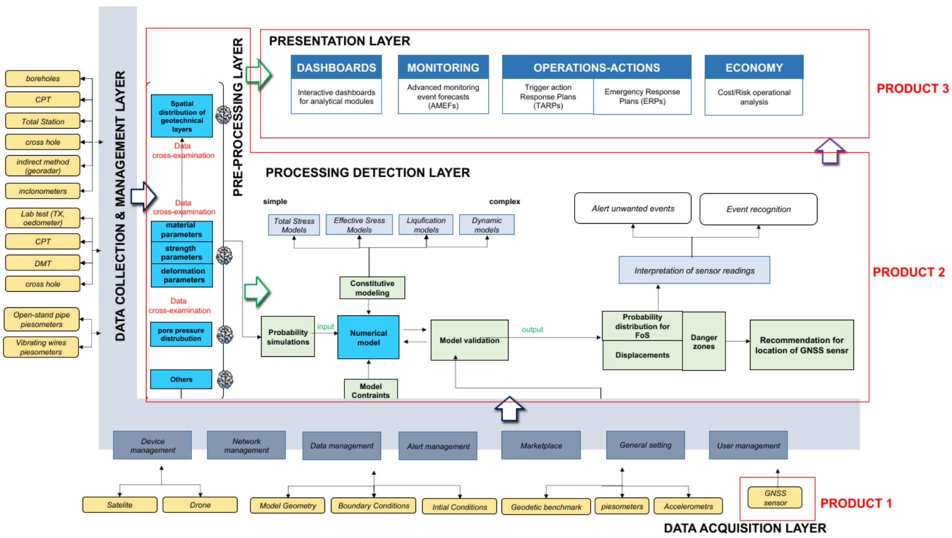

Figure 2: The architecture of the SEC4TD system

4 CASE STUDIES

To test the SEC4TD system in a real-world setting, two tailings storage facilities located in Poland and Bosnia will serve as test sites.

4.1 Gilow TSF

The first TSF is called Gilow, located near Lubin (Lower Silesian Voivodeship in SW Poland).

The TSF Gilow is considered the largest inactive post-floatation waste reservoir in Poland. It was built in 1968 to store the post-flotation waste of the nearby copper mine Lubin. Decommissioned in 1977, TSF Gilow, with an area of 620 ha, reached its maximum level (177.5 m asl) in June 1980, after which the liquidation process began. Until 1990 it served as an emergency retentive facility connected to another TSF called Zelazny Most. In total, 68 million m^3 of post-flotation waste was deposited in this reservoir. Now the area is subjected to water and forest reclamation activities. Currently, the area is covered by forest and self-seeding plants due to water and forest reclamation activities.

Figure 3: Gilow TSF

4.2 Gradina Lake TSF

The second TSF, Gradina Lake, is located in the Omarska Mine and belongs to ArcelorMittal Prijedor. The Gradina Lake TSF is a valley fill-type facility with containment provided by the natural topography and one engineered embankment (Medjedja Dam) to the northeast. The facility was designed in the early 1980s, constructed between 1983 and 1986, and first used in 1985. The total area of Gradina Lake is approximately 80 ha. Tailings were disposed of as a wet slurry with low solid concentration, pumped through a pipeline, and then transported by gravity via an open channel toward the southwest corner of the TSF. Supernatant water was transferred under/through the embankment via an overflow system to a steel pipeline within a concrete tunnel for discharge to the environment. Deposition in Gradina Lake TSF has ceased in the last few years. The remaining storage capacity was left for emergency discharge or future use as required. Tailings are currently being disposed of in another TSF, called Jezero in-pit.

Figure 4: Gradina Lake TSF

5 CONCLUSIONS

In recent years, it has become evident that the failure of Tailings Storage Facility structures can lead to severe environmental disasters and the loss of human lives. As such, managing these structures requires great care and the involvement of specialists with extensive experience. Unfortunately, history has shown that meeting these criteria is challenging.

A new approach has been adopted to address this issue. The SEC4TD project was launched last year to enhance the safety of tailings storage facility structures by combining IoT infrastructure, analytical AI algorithms, and advanced constitutive modeling approaches into one system, which will enable the management of these structures with greater awareness. The system will collect critical parameters from the field and serve as the core of the monitoring system. Secure long-range communication protocols will be implemented to transmit data. To identify the security of the TSF, a software module based on mathematical models and advanced AI data processing algorithms will be developed, together with completely modular services, featuring data preparation and mining, prediction, recommendation, anomaly detection, and response management.

The SEC4TD system aims to assist engineering and management staff in preventing tailings storage facility failures.

REFERENCES

[1] Strachan, C., and Van, B. 2017. Conclusions from evaluations of tailings dam incidents. Presented at the U.S. Society on Dams (USSD) Annual Conference and Exhibition, Anaheim, CA.

[2] WISE (World Information Service on Energy) Uranium Project. 2020. Chronology of major tailings dam failures.
[3] Morrison, K.F. 2020. Tailings dam failures and regulatory or social response: A reflection of lack of trust? In Mine Tailings-Perspectives for a Changing World. Edited by R. Furey and J.F. Lupo. Englewood, CO: SME. pp. 97-104.
[4] Morgenstern, N.R., Vick, S.G., and van Zyl, D. 2015. Independent Expert Engineering Investigation and Review Panel: Report on Mount Polley Tailings Storage Facility Breach. Victoria, Canada: Province of British Columbia.
[5] Morrison, K.F., Pedrosa, H.G., dos Santos, G.J.I., et al. 2018. Changes to tailings dam regulations in Brazil in the aftermath of failures. In Tailings and Mine Waste 2018: Proceedings of the International Conference on Tailings and Mine Waste. Vancouver, Canada: University of British Columbia. pp. 27–34.
[6] FTDRP (Fundão Tailings Dam Review Panel). 2016. Report on the Immediate Causes of the Failure of the FundãoDam.
[7] Morrison, K.F., and Gomide, P.C.R. 2019. Post-Córrego do Feijão: Continued evolution of tailings dam regulations in Brazil. In Tailings and Mine Waste 2019: Proceedings of the International Conference on Tailings and Mine Waste. Vancouver, Canada: University of British Columbia. pp. 391-400.
[8] Robertson, P.K., de Melo, L., Williams, D.J., et al. 2019. Report of the Expert Panel on the Technical Causes of the Failure of Feijão Dam I. https://bdrblinvestigationstacc.z15.web.core.windows.net/assets/Feijao-Dam-I-Expert-Panel-Report-ENG.pdf