SPECIAL SESSION ON TAILINGS DAMS (TC221 – ISSMGE)

ISSMGE launched the TC221 on Tailings and Mine Waste in March 2020 with the aim of providing a platform to discuss, exchange, and disseminate scientific advances, expert knowledge, and practical know-how in geotechnical engineering issues associated with the storage of waste materials generated by mining processes. Tailings dams are among the largest and most complex modern earth structures. The occurrence of catastrophic failures in the past have shown the enormous risk to people and the environment and, for this reason, demand the greatest technical expertise and the best level of geotechnical engineering available. In this context, this Special Session on Tailings Dams should contribute towards a sustainable development of the extractive industry.

Moderator:

Mr. Luis Valenzuela (MSc)

Speakers:

1.- Ms. Christina Winckler
The Risk of the Factor of Safety

2.- Dr. Davis Solans
Simulating the Construction, Operation, and Seismic Response of a Downstream Tailings Sand Dam

3.- Prof. Fernando Schnaid
Geotechnical Tailings Characterization for Filtered Stacks

4.- Sr. Edgar Quiroz (MSc)
IA y ML en Gestión de Relaves: un Nuevo Enfoque para el Futuro

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Advancements in Numerical Modeling for Tailings Dam Stability Assessment

6.- Dr. Osvaldo Flores
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7.- Mr. José Campaña (MSc)
Acceptability Criteria of Physical Stability of Tailings Dam

8.- Dr. Ramón Verdugo
When static liquefaction is a concern in the stability of tailings dams.

9.- Prof. Roberto Cudmani
Constitutive Modelling of Tailings: Challenges and perspectives

Ms. Christina Winckler

Christina Winckler has worked three years with Anglo American as a Principal Engineer on the corporate tailings team. Prior to joining Anglo American, she worked 20 years as a consulting engineer with AECOM. Ms. Winckler is a geotechnical engineer with experience in site and laboratory investigations, analyses, design, and construction services for water resources and mining projects. The majority of Ms. Winckler's technical work is focused on tailings and foundation material characterization, stability, seepage, and deformation analyses for earth embankment and tailings dams. She has been the lead geotechnical engineer on several tailings and embankment dam projects, engineer of record for both active and inactive tailings dams, and senior independent reviewer.

The Risk of the Factor of Safety

A commonly communicated "measure of safety" is the factor of safety. The presentation will explore how and why this is not a safety metric and the pitfalls that are associated with this portrayal. A holistic approach for tailings dam design need to include detailed site and laboratory characterization, understanding of material and deformational behavior, and incorporation of performance-based design.

Dr. Davis Solans

After graduating from the University of Chile in 2010 as a Civil Engineer, BSc and MSc in Geotechnical Engineering, Dr Solans worked in the industry for about eight years as a project engineer and geotechnical leader for different projects for mining geotechnics and urban underground infrastructure. Dr Solans moved to the Department of Civil & Environmental Engineering at Imperial College London in 2016, awarding an MSc in Soil Mechanics and Engineering Seismology and a PhD in Computational Geomechanics in 2023. Currently, Dr Solans is a Teaching Fellow in Geotechnics at Imperial College London. His area of specialization is the numerical modelling of geotechnical infrastructure under static and seismic loading conditions.

Simulating the Construction, Operation, and Seismic Response of a Downstream Tailings Sand Dam

This talk will examine a tailings sand dam's construction, operation and seismic performance during a strong motion using 2D plane strain time domain finite element (FE) analyses. The hydro-mechanical (HM) coupled consolidation formulation implemented in the Imperial College Finite Element Program (ICFEP) is employed in the simulations. Initially, a state parameter-based bounding surface plasticity model (BSPM) is calibrated against the laboratory for the tailings materials. Then, the construction and operation of the tailings dam are simulated, following the detailed construction sequence before applying any seismic loading. Finally, the seismic response is examined, comparing the results with the available recorded data. The computed results suggest satisfactory agreement with the monitoring data, encouraging the use of advanced numerical modelling in these types of man-made structures.

Prof. Fernando Schnaid

Fernando Schnaid is currently Professor in Geotechnical Engineering at Federal University of Rio Grande do Sul, Brazil; holds a PhD at Oxford University and is the author or co-author of over one hundred peer-reviewed articles and conference papers, as well as 5 books, including the title In Situ Testing in Geomechnics published in 2009. Key research focus on in-situ testing, geotechnical site characterization, foundation systems, marine geotechnics and prediction of soil and rock properties. Delivered international lectures including the State-of-the-Art Report in Soil Properties at Osaka Conference in 2005 and the James Mitchel Lecture in 2019 for the ISSMGE.

Geotechnical Tailings Characterization for Filtered Stacks

Filtered tailings stacks have been increasingly used in the mining industry as an alternative to traditional slurry tailings impoundments, especially after recent accidents triggered by static liquefaction of upstream tailings dams. The method involves dewatering the tailings by filtration or other technologies, and placement in situ followed by mechanical compaction to ensure stable fabric at prescribed densities. Although compaction is a well-established engineering technique, there is still considerable uncertainty in design associated to factors such as: variability in geology and weathering of mine ores, transitional fine content behaviour, changes in material properties emerging from chemical processes, strength and stiffness anisotropy, unsaturated response and the onset of saturated conditions, high stresses levels associated to unprecedent heights. A critical appraisal of some of these effect on the geomechanical behaviour of tailings is presented in this lecture.

Sr. Edgar Quiroz (MSc)

Ingeniero Civil con más de 25 años de experiencia en grandes proyectos mineros e infraestructura. Especialista en diseño de tranques de relaves, botaderos de estéril y geotecnia en Chile, Brasil, Canadá, Australia y Perú. Mg. Sc. en Ingeniería Civil con mención en Geotecnia y estudios de especialización en USA. y Chile. Líder de disciplinas civiles, estructurales y geotécnicas en empresas como Antamina, Ausenco, Nexa Resources y Stantec. Consultor senior geotécnico en tranques de relaves, botaderos y pilas de lixiviación. Participante en Juntas de Revisión Independiente internacionales. Miembro activo de sociedades científicas y asociaciones profesionales. Profesor a tiempo parcial y coordinador académico en geotecnia. Actualmente Gerente de Relaves y Aguas en MMG Las Bambas.

IA y ML en Gestión de Relaves: un Nuevo Enfoque para el Futuro

La inteligencia artificial (IA) y el aprendizaje automático (machine learning) ofrecen soluciones innovadoras para optimizar la gestión de relaves mineros. Estas tecnologías permiten el monitoreo y detección de fallas, modelado y simulación, optimización de procesos, inspección y mantenimiento, pronóstico y planificación, así como el seguimiento de la estabilidad. Además, facilitan la predicción y análisis de riesgos, optimización del almacenamiento, monitoreo en tiempo real, tratamiento y reciclaje de relaves, cumplimiento regulatorio y reportes. Aunque aún en etapas iniciales, estas aplicaciones representan herramientas prometedoras para mejorar la seguridad, eficiencia y sostenibilidad en la gestión de relaves mineros.

Dr. Arcesio Lizcano

Arcesio Lizcano, PhD, is a Corporate Consultant at SRK's Vancouver office, and Adjunct Professor at UBC, with over 40 years' experience in practical engineering works, research, and teaching. His work in mining engineering has been focused on tailings dams, waste dumps and foundation engineering for plant site structures. Shear and deformation of soft soils, creep of ice and ice reach clays and sands, and cyclic behavior of sands and gravels are some of his works in design, construction and closure of tailings dams and dumps. His geotechnical research includes the development of soil testing devices, analytical methods, and constitutive laws for saturated and unsaturated soils. He has applied his expertise in USA, Canada and countries in Africa, Europe, and South America. He has published over one hundred twenty papers in journals and conferences.

Advancements in Numerical Modeling for Tailings Dam Stability Assessment

In geotechnical engineering, particularly in the stability of conventional tailings deposits, there is a significant shift from limit equilibrium methods to numerical methods. This transition is primarily because numerical methods provide a more comprehensive capability, including the generation of pore pressures and the resulting softening, which are characteristic responses of saturated and loosely packed tailings under undrained shear conditions. These methods not only facilitate detailed stability analyses but also enable the simulation of the entire lifecycle of tailings deposits —from deposition, burial, and saturation/desaturation processes to the evaluation of the structure's vulnerability to flow liquefaction. The crucial topic highlighted is the necessity for a broader adoption and refinement of numerical modeling techniques in evaluating and ensuring the stability of tailings dams. The future task outlined involves enhancing these modeling approaches for more accurate prediction and prevention of potential failures, emphasizing the role of flow liquefaction in dam safety assessments.

Dr. Osvaldo Flores

Maestría y Doctorado en Mecánica de Suelos de la Facultad de Ingeniería de la UNAM. Académico y responsable del Laboratorio de Mecánica de Suelos del Instituto de Ingeniería (UNAM) y profesor del Posgrado de la Facultad de Ingeniería de la UNAM. Responsable de la Comité Técnico de "Depósitos de residuos sólidos mineros" de la Sociedad Mexicana de Ingeniería Geotécnica (SMIG). Miembro del grupo de trabajo de Flopac Geotecnia, empresa cuya línea de trabajo está orientada principalmente al diseño y revisión de depósitos de relaves en México.

Influencia de los finos en el comportamiento hidráulico y mecánico de relaves

Para el análisis de las condiciones de estabilidad de depósitos de relaves, sobre todo los construidos con el método "aguas arriba" (aún utilizado en varios países), es indispensable la caracterización geotécnica de estos materiales, tanto con pruebas de campo con en ensayos de laboratorio. De acuerdo con los múltiples estudios realizados, una de las variables que mayor influencia tienen en este comportamiento es el porcentaje de finos, de ahí la importancia en su identificación y correcta caracterización. En la presentación se hace la descripción de la influencia del porcentaje de finos en el comportamiento hidráulico y mecánicos (estático y dinámicos) de los relaves, a partir de resultados de pruebas experimentales de campo y en laboratorio.

Mr. José Campaña

Professional with over 28 years of experience in the geotechnical field. He has been involved in multiple projects related to water reservoirs and tailings dams. He has served as a Project Manager, Head of Geotechnics Department or Geotechnical Engineer in studies in several industrial projects, civil works and mining infrastructure. In parallel, from 2002 to 2017, he worked as a professor in University of Santiago (Soil Mechanics for Civil Engineers) and previously as assistant professor in Geotechnics in Universidad de Chile for Civil Engineers (1998-2001). Currently, he is a professor at the University of Chile for Tailing Degree (postgraduate courses). Since 1995 he has employed at ARCADIS, where he currently holds the position of Senior Geotechnical Consultant. Since February 2021, he has served as the EoR for CODELCO.

Acceptability Criteria of Physical Stability of Tailings Dam

In recent years, the number and relevance of 2D and 3D numerical deformation analysis developed to assess the physical stability of various structures in the mining industry, including tailings storage facilities, mine waste dumps, and heap leaching deposits, have increased. The analysis of the results of this type of models is difficult due to the lack of an acceptance criteria, for example, to define under which conditions the displacement or fissures do not represent a mayor risk for the facility and can be repaired, or when the deformations can or cannot affect the drainage systems. This is in contrast with displacements that can produce significant irreparable damage, or those that can ultimately cause the collapse of the facility. The main concept of presentation will be discussed about the rational criteria of acceptability from dynamics analysis and pseudostatic analysis, which could be implemented.

Dr. Ramón Verdugo

Civil Engineer Universidad Católica de Chile. Master and Ph.D., University of Tokyo, Japan, Post-Doctoral research at the Norwegian Geotechnical Institute. He was Head of the Geotechnics Area of the Materials Research and Testing Institute, IDIEM, and director of the graduate program in Geotechnical Engineering at U. of Chile. Past-President of the Chilean Geotechnical Society. After the El Maule Earthquake (Mw = 8.8) he led the development of the new seismic site classification of Chile. Founder Partner of CMGI Ltda. He has more than 40 years of experience in complex geotechnical problems, with emphasis on liquefaction, soil dynamics, seismic stability of earth and tailings dams. Dr. Verdugo is currently the Chair of TC221 on Tailings and Mining Waste of the ISSMGE.

When static liquefaction is a concern in the stability of tailings dams.

Tailings materials that are geotechnically classified as silty sand, sandy silt, silt, clayey sand, sandy clay and whose fines are non-plastic or of low plasticity, generally exhibit a sand-like behavior, so they may liquefy in a similar way to sands. On the other hand, both conventional tailings impoundments with dams constructed by the upstream method and filtered tailings dams may have saturated tailings zones under states of stresses and density where the undrained residual strength is not high enough compared to the driven stresses. In the presentation these issues are developed.

Prof. Roberto Cudmani

Chair of the Institute of Soil Mechanics, Rock Mechanics, Foundation Engineering, and Tunnelling at the Technical University of Munich since 2015. M.Sc. UFRGS/Brazil, Dr.-Ing. KIT/Germany. Worked as geotechnical engineer in two leading German construction companies, and a consulting company in Stuttgart. Main fields of expertise include behavior of soils and soil-like materials, laboratory and field testing, constitutive modelling, soil dynamics and earthquake engineering, SSI, foundation engineering, ground improvement, numerical methods, sustainability and resilience of critical infrastructure. Member of the German Society of GE, DIN Standards and Vice-chairman of the TC 221 on Tailings and Mine Waste of the ISSMGE.

Constitutive Modelling of Tailings: Challenges and perspectives

This lecture addresses the complex challenges of modeling the constitutive behavior of mine tailings, essential to ensure the safety of Tailings Storage Facilities (TSFs). Tailings, characterized by their loose state, high compressibility, and low shear strength, pose significant geotechnical challenges. Their heterogeneity, influenced by mineral composition and processing techniques, complicates constitutive modeling. Exemplarily, the performance of advanced constitutive models is compared using available triaxial test data from failed tailing dams. Emphasizing the need for ongoing research, the lecture highlights the importance of enhancing and validating constitutive models to prevent catastrophic failures related to TSFs.