LTBD2015

Long-Term Behaviour and Environmentally Friendly Rehabilitation Technologies of Dams

3rd International Workshop
Hohai University, Nanjing
October 17-19, 2015

BOOK OF ABSTRACTS

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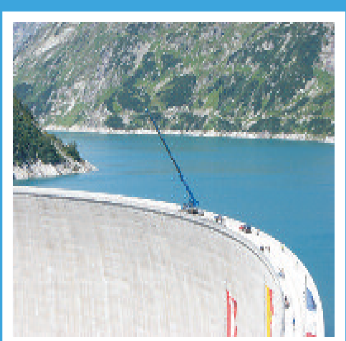
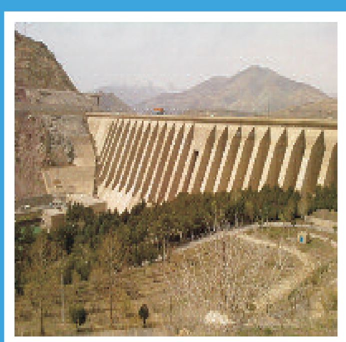
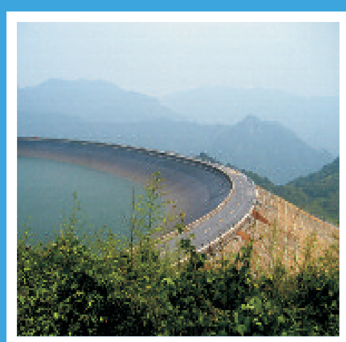

3rd INTERNATIONAL WORKSHOP ON LONG-TERM BEHAVIOUR AND ENVIRONMENTALLY FRIENDLY REHABILITATION TECHNOLOGIES OF DAMS

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Preface

The Third International Workshop on Long-Term Behaviour and Environmentally Friendly Rehabilitation Technologies of Dams, LTBD2015, will take place at Hohai University in Nanjing, China, from October 17 to 19, 2015. The city of Nanjing is the capital of the province of Jiangsu and the second largest city in eastern China, with a total population of 8.18 million. The city, whose name means "Southern Capital", has a prominent place in Chinese history and culture, not only with the stirring mountains and gentle waters which surround it, but also with its more than 2400 years of urban history. If Nanjing could be captured in a few words, they would be: the ancient seat of six dynasties, the capital city of ten dynasties, a jewel of nature and culture. Nanjing has long been a national centre of education, research, transport networks and tourism. It was the host city of the 2014 Summer Youth Olympics. Nanjing has been the educational centre in southern China for more than 1700 years. Currently it boasts some of the most prominent educational institutions in the region, including Nanjing University, Southeast University, Hohai University and Nanjing University of Aeronautics and Astronautics.

Hohai University is a state key university under the direct administration of the Ministry of Education of China. The Chinese name "Hohai" means water and sea. The university was founded in 1915 and has earned a worldwide reputation for its research and education in hydraulic engineering and water resources. It is a comprehensive university with research and study of water conservancy as its main focus, education in engineering subjects as its first priority. It has experienced a coordinated development of a wide array of disciplines covering engineering, sciences, econonics, management, liberal arts and arts. In addition, it is one of the universities implementing the “Project 211” (China's goal of building the best 100 universities in China in the 21st century) and the “innovation platform for advantage disciplines”. At present, there are more than 3000 staff members, and more than 44000 students are enrolled at Hohai University.

Water is one of the most important sources of renewable energy and hydropower generation is an emission-free and therefore environmental friendly technology, which also has a great importance in both Austria and China. For the long-term operation of water power plants not only the aspects of the service life of the mechanical and electrical equipment but also the reliability of the hydraulic engineering structures are very important. For the safe operation of hydraulic structures like earth, rockfill and concrete dams as well as for novel reinforced soil structures, the interaction of the construction with ground settlements, earthquake activities and flooding, the chemical reaction with water, overtopping and the state of weathering and aging of the construction material may play an important role. A further aspect is the rehabilitation and heightening of dams. Another new challenge for engineers is the use of alternative materials for building and repairing dams such as construction waste and mine tailings. In order to take into account the complex interaction of different factors of influence, the relevant aspects must be treated in an appropriate way by the corresponding disciplines, i.e. a multilateral co-operation is needed between the disciplines of Material Technology, Mechanics of Materials, Structural Analysis, Geotechnics and Hydraulic Structures and Environmental Engineering. To this end it is necessary to enforce and extend the international contacts, to build a network and to present and discuss the latest developments in joint conferences and workshops. The workshop LTBD2015 was initiated based on the scientific and technical cooperation between the following universities and institutions in Austria and China: Vienna University of Technology (Vienna, Austria), Graz University of Technology (Graz, Austria), University of Innsbruck (Innsbruck, Austria), Hohai University (Nanjing, China), Nanjing Hydraulic Research Institute (Nanjing, China), Tsinghua University (Beijing, China), and Tianjin University (Tianjin, China). The financial support by the Federal Minister of Science, Research and Economy of Austria (WTZ Project: CN 02/2013) and the International office of Hohai University is gratefully acknowledged.

It is the aim of the Third International Workshop on Long-Term Behaviour and Environmentally Friendly Rehabilitation Technologies of Dams to provide an opportunity for high level scientists, engineers, operators and young PhD students to present and exchange their experiences and the latest developments related to the design, performance rehabilitation and environmental aspects of earth, rockfill and concrete dams. The papers included in this workshop focus on the following subtopics:

- Methods of Design and Analysis of Earth, Rockfill and Concrete Dams
- Dam Monitoring, Instrumentation and Safety Assessment
- Properties of Construction Materials for Dams and their Constitutive Modelling
- Seismic Aspects and Earthquake Analysis
- Maintenance, Rehabilitation and Heightening
- Long-term Mechanical and Seepage Behaviour of Dams
- Environmental-friendly Reinforcement Materials for Hydraulic Structures
- Technologies for Preventing the Deterioration and Cracking of Concrete Dams

The workshop papers will be presented in nine sessions including eight keynote lectures. A couple of selected papers will be published in a special issue of the journal Water Science and Engineering. We would like to thank the authors for preparing their presentations, and the session chairs for their help. We are also grateful to the Nanjing Hydraulic Research Institute for organizing an excursion to the experimental center in Tiexinqiao, Nanjing.

On behalf of the Organizing Committee, we would like to express our profound gratitude to the following organizations which have supported this workshop:

- Hohai University
- Graz University of Technology
- Nanjing Hydraulic Research Institute
- Editorial Office of Water Science and Engineering

We also wish to thank the members of the International Advisory Committee and the Workshop Secretary for their support. Finally we would like to thank all the workshop participants for their interest in the workshop and their scientific contributions.

Sihong Liu and Erich Bauer
Chairs of LTBD2015

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Keynote Lectures

Rapid Drawdown and Landslides

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Predicting the pore pressure distribution in a slope after rapid drawdown conditions requires the solution of a coupled flow-deformation analysis in a saturated-unsaturated porous media. A fully coupled finite element code (Code_Bright), able to handle in a consistent manner the drawdown conditions, is used to simulate the pore water pressure measured in the upstream slope of an earth dam (Glen Shira Dam, Scotland) subjected to a controlled rapid drawdown event. A comparison of some calculation alternatives is then given and compared with field pressure records. The paper describes also the analysis performed to interpret a recent case of a major landslide triggered by a rapid drawdown in a reservoir. A key aspect of the case is the correct characterization of permeability of representative soil profiles. This is achieved by combining laboratory test results and a back analysis of pore water pressure time records during a period of reservoir level fluctuations.

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Comparison of the Calibration and Performance of Two Different Constitutive Models for Rockfill Material

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In this paper two different concepts for constitutive modelling the mechanical behaviour of creep sensitive rockfill materials are presented. In particular the performance of a generalized plasticity model extended by Wang [1] is compared with a simplified version of the hypoplastic constitutive model for weathered rockfill materials by Bauer [2]. Both models are able to reflect the influence of the mean stress on the incremental stiffness, the peak friction angle and the dilatancy angle. The so-called “solid hardness” defined for a continuum description and originally introduced by Bauer [2, 3] is embedded in both models. Hydrochemical, thermal and mechanical weathering is usually caused by environmental changes and taken into account with an irreversible and time dependent degradation of the solid hardness. A degradation of the solid hardness is usually accompanied with creep deformation of the stressed rockfill material. It is shown that an appropriate modelling of creep deformation requires at least a unified description of the interaction between the time dependent process of degradation of the solid hardness and the stress state. In this context the solid hardness can be understood as a key parameter for describing the evolution of the state of weathering of the rockfill material. Particular attention is also paid on the necessary procedure to determine the constitutive constants for the two different constitutive models. From mathematical point of view the adaptation of the experimental data to the constitutive constants, called calibration, is an inverse problem and usually a difficult task for high non-linear constitutive equations [4]. Finally, the performance of the two different constitutive models is demonstrated by comparing the results obtained from numerical simulations with experimental data from a creep sensitive rockfill material. In particular, isotropic and deviatoric stress paths are investigated for different confining stresses.

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Seismic Responses of High Concrete Face Rockfill Dams: A Case Study

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Seismic responses of the Zipingpu concrete face rockfill dam were analyzed using thefinite element method. The dynamical behavior of rockfill materials was modeled by avisco-elastic model and an empirical permanent strain model. The involved parameters were obtained either by back analysis using the field observations or by referring to parameters of similar rockfill materials. The acceleration responses of the dam, the distribution of earthquake-induced settlement and the gap propagation under the concrete slabs caused by the settlement of the dam were analyzed and compared with site investigations or relevant studies. The mechanism of failure of horizontal construction joints was also analyzed based on numerical results and site observations. Numerical results show that the inputted accelerations were considerably amplified within the top 1/4 zone of the dam, and the strong shake resulted in considerably settlement of the dam, with a maximum value exceeding 90 cm at the crest. As a result of the settlement of rockfill materials, the third stage concrete slabs separated from thecushion layer, and the rotation of the cantilever slabs about the contacting regions under the combined action of gravity and seismic inertia forces led to the failure of the construction joints and the tensile cracks presented above the construction joints. The effectiveness and limitation of the so called equivalent linear method are also discussed in this paper.

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Modeling Erosion-Induced Deformations in Non-cohesive Soils

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For every significant disorder of a hydraulic installation in the world today, it has been observed that the major cause is soil erosion. To study the mechanisms of soil erosion, we have developed a constitutive modelling method for granular materials based on particle level interactions with the use of a homogenisation technique as proposed by Chang and Hicher in 2005. The model requires a limited number of parameters which can easily be determined from conventional laboratory testing. Comparisons between numerical simulations and experimental results show that the model can accurately reproduce the mechanical behaviour of loose and dense granular assemblies. A modification was made on the model so that it could incorporate the physical changes due to internal erosion. Different numerical simulations were performed in order to study the mechanical properties of eroded soils. The results show that a progressive deformation of the soil takes place during erosion. Depending on the loading condition, large strains could develop up to failure. To determine the influence of the hydraulic conditions on erosion-induced deformations, we used the relationship between the percentage of eroded particles and the hydraulic gradient proposed by Sterpi in 2003. The results show that long-term erosion can lead to significant settlement of the embankment, even for usual values of the hydraulic gradient.

Application of Rock-filled-concrete Technology in the Rehabilitationof the Chang Keng III Reservoir

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The Chang Keng III reservoir, a small reservoir of Grade V whose main dam was a masonry one, was built in 1970s.Leakage of the dam becomes more and more serious.In 2009,the originalmasonry dam was demolished,and the rock-filled concrete (RFC) technology was adopted to rebuild the dam. In this paper, this rehabilitation project was introduced. Then, the environmental protection benefits of rock-filled concrete technology, including the recycling solid waste of the original masonry dam, reducing cement content and simplifying temperature-control measures,were analyzed. The monitoring data demonstrated that the new RFC dam works very well. The RFC technology, an environmental friendly mass concrete technology has many advantages, such as simple temperature-control measures and construction technology, low cement consumption, as well as good volume stability and durability, had great value for promotion and application in dam rehabilitation projects.

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Microstructure-based Constitutive Model for Granular Materials and Its Application to Rockfill Dams

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The constitutive relationship of coarse granular materials is one of the very important issues in earth-rockfill dam. Previous researches are mostly based on the macroscopic tests and engineering experience. There is only a little focus on the microscopic essence. In this study, the microscopic mechanical properties of coarse granular materials is analyzed, based on the District Element Method (DEM). A microstructural parameter S that considers both the arrangement of granular particles and the inter-particle contact forces is proposed. The evolution of the microstructural parameter S under the simulated stress paths is analyzed, from which a yield function for granular materials is derived. The way of determining the two parameters involved in the yield function is proposed. The new yield function is calibrated using the test data of one sand and two rockfill materials. Then, considering the dialtancy behavior during shearing and the compression characteristic during isotropic compression, a hardening parameter H is proposed for coarse-grained materials. Based on the microstructural parameter S and the hardening parameter H, an elastoplastic constitutive model for coarse granular materials is derived. Finally, the applications of the proposed model are introduced through two engineering projects.

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Safety Aspects of Sustainable Storage Dams and Earthquake Safety of Existing Dams

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The basic element in any structure or infrastructure project is safety. Therefore for sustainable storage dams the emphasis must be on the long-term safety of the dam. Today, dam safety requires an integral concept, which includes (i) structural safety, (ii) dam safety monitoring, (iii) operational safety and maintenance, and (iv) emergency planning. The importance of these four safety elements is discussed. The long-term safety includes, first, the analysis of all hazards affecting the project, i.e. hazards from the natural environment, hazards from the man-made environment and project-specific and site-specific hazards. The special features of the seismic safety of dams are discussed, as today the structural safety of large storage dams is often governed by the earthquake load case.

Although large dams belong to the first structures, which have been designed systematically against earthquakes since the 1930s, the seismic safety of these dams is unknown, as most of them have been designed using seismic design criteria and methods of analysis that are considered obsolete today. Therefore, we need to re-evaluate the seismic safety of existing dams based on current state-of-the-art practice and rehabilitate existing dams if necessary.

For large dam projects a site-specific seismic hazard analysis is usually recommended. These analyses are carried out by seismologists. It is important that the dam engineer, who is the end user of results of seismic hazard analyses, clearly specifies what he needs as the seismologists are not familiar with the safety concepts used in dam engineering. Today large dams and the safety-relevant elements used for controlling the reservoir after a strong earthquake must be able to withstand the ground motions of the safety evaluation earthquake (SEE). The SEE ground motion parameters can be determined either by a probabilistic seismic hazard analysis or a deterministic analysis in which worst-case earthquake scenarios are considered. During the SEE inelastic deformations may occur in a dam, therefore, the seismic analysis has to be carried out in the time domain. In general seismologists provide response spectra or uniform hazard spectra, but acceleration time histories are needed for large dams. Furthermore, earthquakes create multiple seismic hazards for dams such as ground shaking, fault movements, mass movements and reservoir-triggered seismicity (RTS) may also have to be considered. The ground motions needed by the dam engineer are not real earthquake ground motions but models of the ground motion, which allow the safe design of dams. Furthermore it has to be kept in mind that dam safety evaluations have to be carried out several times during the long life of large storage dams. These features are discussed in the paper.

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Unified Description of Clean Sand

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In this research, the mechanical behavior of sand, was systematically described and modelled with an elastoplastic model proposed by Zhang et al (2007, 2010, 2011). Without losing the generality of the sand, a specific sand called as Toyoura sand, a typical clean sand found in Japan, has been discussed in detail. In the model, the results of conventional triaxial tests of the sand under different loading and drainage conditions were simulated with a fixed set of material parameters. The model only employs eight parameters among which five parameters are the same as those used in Cam-clay model. Once the parameters are determined with the conventional drained triaxial compression tests and undrained triaxial cyclic loading tests, and then they are fixed to uniquely describe the overall mechanical behaviours of the Toyoura sand, without changing the values of the eight parameters irrespective of what kind of the loadings or the drainage conditions may be. The capability of the model is discussed in a theoretical way.

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Invited Lectures

The Importance of Bottom Outlets for Dam Safety and Operation

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Different views exist when it comes to design and construction of dams. In Germany, Austria and many other countries basic design principles are well-defined and part of the national dam safety standards. Nearly all dams in Austria and Germany do have bottom outlets – of course! Their main purpose is to allow reservoir emptying. The existence of bottom outlets is part of the national dam safety concepts. Checking and testing of the outlets are part of the dam surveillance philosophy. Anyhow, around the world the view on the importance of bottom outlets varies considerably. Worldwide there are many dams without any bottom outlet. But it is not only the question, whether a bottom outlet has to be designed or not. There are also significant differences in the layout and the positioning of those outlets. There are many dams with bottom outlets penetrating embankment dam bodies. Those designs don´t correspond to the "dam design doctrine" at many universities. Are all those dams designed in a wrong way? Of course there are different local technical boundary conditions to consider resulting in varying technical designs. Anyhow, there are also differences in the education of the engineers at the universities and during their on-job-training. Additionally there is the regional experience and the regional view on dam safety aspects leads to a very different handling of bottom outlet related issues.

State-dependent Constitutive Theory for Rockfill Materials Considering Particle Breakge

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The particle breakage is one of the important behaviors of rockfill materials. The deformation characteristics of rockfills relate to the stress state, the initial state and the particle breakage, which directly affect the stability and security of dam structure. So how to establish the state-dependent constitutive model for rockfills is the key to demenstrating the deformation and stress characteristics. Based on the critical state theory and the state-dependent dilatancy theory, a series of large triaxial experiments on rockfills are designed under different densities, gradations and confining pressures, and grain-size analysis tests on each sample are conducted before and after the shearing tests. According to the test results, considering the influence of densities, gradations and stress levels, the strain softening and hardening, volume contraction and dilation behaviors of each sample are analyzed, the particle distribution rules are studied, and the particle breakage rules are investigated. Finally, on the basis of experimental study and theoretical analysis, the state-dependent constitutive theory for rockfill materials consideringparticle breakage is established.

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The Analysis of the Excessive Deformation of the Upper-Pond of Laivi Ta Khong Hydropower Plant and Its Reiviidial Design

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Lam Ta Khong hydropower plant is a pumped-storage hydropower plant located in the north-east of Thailand. It consists of the upper-pond in order to store the water which pumped up from Lam Ta Khong reservoir. The upper-pond is arock-filled dam with asphalt facing. There was an additional design for increasing the impermeable of upstream facing by lining with high density polyethylene sheet(HDPE). The reservoir impounding has been started in 2004. The dam monitoring showed the high rate of deformation on the dam crest and downstream slope.
Dam Safety Department, Civil Maintenance Division, Electricity Generating Authority of Thailand (EGAT) is responsible for safety of EGAT dams concerning about the unusual behavior of the upper-pond. The root-cause analysisof the excessive deformation of upper-pond was done in 2011 to find out the causeand appropriate remedial design. We started with the dam and foundation investigation and testing such as standard penetration testing (SPT), field permeability testing, triaxial test, large direct shear test, durability test and resistivity survey. Then the 2D numerical model was created for the analysis. The result of numerical analysis, which was verified with the dam instrument, can be concluded that the shell material of downstream side contains high of clay stone which have high degradation with rate during each rainy season. However, the result of stability analysis showed that the upper-pond was still safe but if weneglect this problem and let the high degradation of clay stone occur, the safety offactor would be decreased. As a result, the upper-pond will not be safe in the nearly future. Therefore, the remedial design criteria are implemented by using the impermeable membrane covered on the downstream side of the upper-pond inorder to protect claystone from rain. The type of impermeable membrane is a geo-s)mthetic clay liner with textured HDPE (GCL with Textured HDPE). The remedial work has been completed in 2013.

On the Mechanism of Horizontal Extrusion Breakage of Face Slab of Concrete Faced Rockfill Dam

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Cross-sectional deformation mechanism of face slab of CFRD and its conceptualization method were investigated in this study. The relationship between deformation and slope-direction stress of face slab, and the generation mechanism of slope-direction stress of face slab were explored. It was found that the generation of face slab stress in slope-direction is mainly attributed to the drag effect of dam deformation on face slab along slope direction and the local regional bending deflection of face slab. A case study of Sanbanxi CFRD was carried out to investigate the mechanism of horizontal breakage of face slab of CFRD. It was found that the rather high slope-direction stress of face slab is mainly attributed to the fairly large creep deformation of dam body and the induced slope-direction deformation of face slab. Slope-direction stress of face slab is increased by local regional bending deflection of face slab due to reservoir water pressure, dam body settlement after construction of the first stage face slab, high horizontal face slab stress due to special terrain, and the existing bending deflection of face slab due to slope deficiency. Eventually breakage is induced in construction joints of the first and the second stage face slab where local structural defect exists.

Finite Element Implementation of Incrementally Nonlinear Constitutive Models

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In order to describe the complicated mechanical behaviour of geomaterials, various sophisticated constitutive models have been developed. For engineering applications of these constitutive models, numerical implementation of such models in a finite element program is an important step. Accuracy, efficiency and robustness are the key issues which should be addressed in numerical implementation. This work presents a comprehensive numerical study on finite element implementation of hypoplastic models[1]. Two crucial aspects, namely the local integration of theconstitutive equations (the local problem) and the formation of tangent operators for Newton-Raphson iteration (the global problem), are investigated. For solving the local problem, different integration algorithms, including explicit and implicit methods, are examined using tri-axial compression tests and incremental stress response envelopes, as well as typical boundary value problems. For solving global problems, three different ways of generating the tangent operator are compared. The numerical evidences indicate that, in terms of accuracy, efficiency and robustness, explicit methods with substepping and error control are among the best choices for constitutive integration while the so-called continuum tangent operators may be used for global iteration. Furrther study shows that in case where shear localization occurs, the continuum tangent operator has certain advantages over the so-called consistent tangent operator[2][3].

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Design Considerations and Behaviour of Reinforced Concrete Core Dams during Construction and Impounding

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The first use of a concrete core as a sealing element in dam engineering goes back to the 1920s. The construction of the Tieton Dam in the USA set the standards high, with a height of 97 meters, a concrete core thickness of 1.50 m, a fine grained material upstream as self-healing opportunity and the dam is still in operation. Since then, only a few dams of the same type but less height have been constructed. Some were built in Austria using concrete as an impermeable diaphragm which is considered to be a cost-effective and safe solution for rockfill dams. Especially for medium height dams up to approximately 30 meters - such as torrent protection dams or hydropower plant reservoirs - this can be an alternative and cost-saving solution. The main benefits are the short and weather independent construction, which represents a decisive planning factor in alpine regions. Only few theoretical principles are available for the design of this dam type. Its stress and deformation behaviour have so far not fully been investigated. The contribution gives a comprehensive study of the stress and deformation behaviour of a rockfill dam designed to be constructed in Austria. It is of high importance for the design of the dam to define the influencing factors which affect the deformation behaviour and the structural forces in the concrete diaphragm wall. In order to meet this requirement, several parametric studies were conducted with the finite element method using the Plaxis 2D software. In particular, the influence of the shell stiffness, concrete roughness and the trench backfilling are briefly described and documented. Furthermore, the bedding conditions of the diaphragm footing and their influence on the bending moment in the diaphragm is analysed. The results of the analysis show significant influence of the dam zones on the deformation behaviour of the concrete diaphragm. The structural forces are caused by arching effects in the dam body. The interaction between the bending moment and the compressive stress is considered in each construction stage for determining the bearing capacity of the diaphragm. Based on the results of the analysis, general design considerations for the dam are presented for discussion.

Synthesis of Hydraulic Structures Behavior Lessons Learned from Monitored Dams of EDF in France

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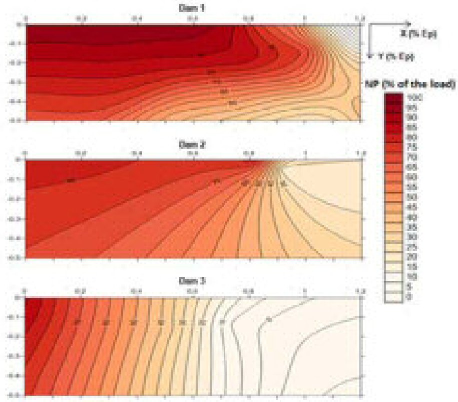
The main purpose of the synthesis of hydraulic structures' behavior is to give an overview of the hydraulic pool of EDF, on the one hand by inter-comparing dams on a given subject, and on the other hand by trying to highlight common behavior between dams. This work maximizes the value of monitoring data and improves the diagnosis of each structure by comparing it to all other similar dams.

The study of a pool of a large number of EDF's monitored dams gave useful insights for improving the diagnostic techniques and for a better understanding of behavior caused by different phenomenon.

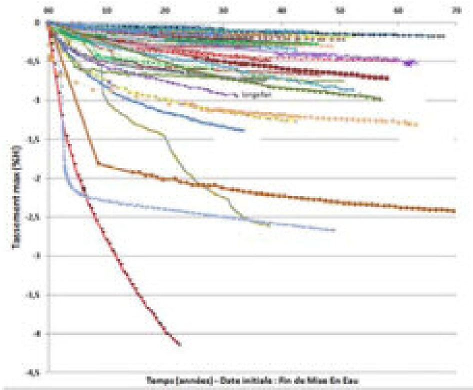
This article provides an overview of the different synthesis realized by EDF, especially concerning uplift of arch dams, swelling of concrete dams and settlements for embankments.

The synthesis shows an outlook (mapping, inter-comparison) of the different phenomenon (uplift, swelling, settlement). The explanations of the phenomenon are proposed (from geometric variables, geological, hydro-mechanical coupling…). Physical/statistical models to better characterize the pathologies are exposed.

Therefore, the global vision of this large pool of monitored dams allows to objectify the diagnostic strategy for each dam by inter-comparison and use of physic-statistical criteria.

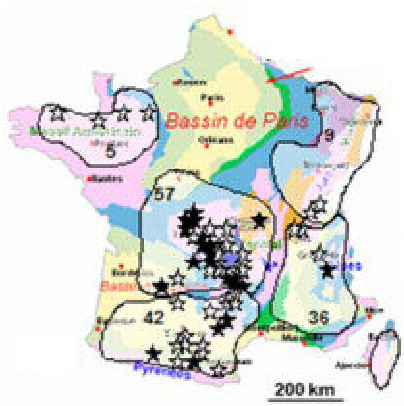


Uplift under arch dams – Pressure levels under 3 structures

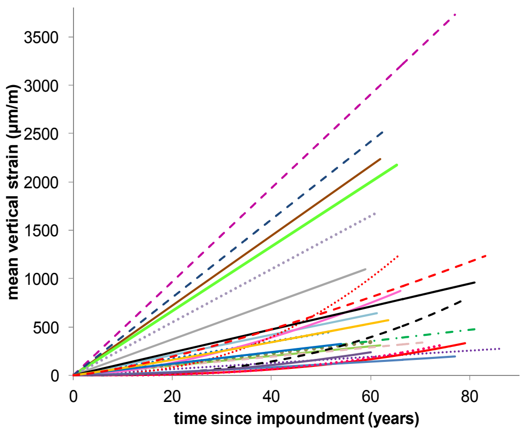


Settlement of 42 embankment dams

The presence of uplift in dam foundation should always be carefully monitored as a factor indicating a lack of sealing of the rock foundation, curtains injections and / or failure of the drainage. Propagation of uplift at the contact concrete / rock is detailed.



Location of dams with concrete swelling



Maximal strain hypothesis for 24 dams affected by AAR / ASR effects

Settlements can cause various pathologies (decreased freeboardand risk of rupture by external erosion, cracks in the sealing member...). Conversely, the settlement may be the result of a problem on a structure (internal erosion for example). This approach based on risk analyses shows the need to monitor the embankment dams in relation with the risk of settlement.

SomeEDF'sconcrete dams show a swellingeffect occurring most probably in some conditions like the geographical location.In order to assess the severity of the phenomena,theircurrentstrain rateis compared to the modeled amplitudeof the phenomenonsinceimpoundment.

Innovative Analysis Methods for the Monitoring of Dam Behavior

(Non-Linearity, Delayed Elastic Effects, Irreversible Trend Influenced by Reversible Phenomena)

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Statistical analysis methods for dam monitoring measurements allow separating the effects from the various influencing factors, such as hydrostatic load, thermal effects and irreversible trend. The HST (Hydrostatic, Seasonal, Time) model [1] has been developed by EDF since 1967. This method provides calculations for hydrostatic effect, thermal seasonal effect and irreversible changes. Many years of experience have confirmed the relevance and efficiency of this method. However, some limitations have also been clearly identified: the three calculated effects are supposed independent and the “physical” laws governing each effect are defined before modelling.

New approaches based on Artificial Neural Networks (ANN) weresuccessfully tested to analyze dam monitoring measurements (displacement, pressure, flow rate, etc.). ANN evidenced connections between the various effect laws and the thresholds associated to some phenomena such as the flow rate. ANN was proved as an interesting tool for developing physically-based models.

The new methods take into consideration delayed effects (viscous-elasticity or thermal on concrete thick structures), and are more adapted to hydraulic phenomena, in particular to permeability variation with load or temperature.They can also take into account non-linear behaviors (cracks).As an example, the uplift in contact concrete-rock depends on the influences (not simply additive) of both hydrostatic load and cracking. This latter is bounded to zero (minimum value as the crack is closed) and also depends on the level of solicitation related to seasonal, hydrostatic and time effects. This model uses the Poiseuille law as the relation between opening of cracks and uplift pressure. Thereby HST model is clearly improved (to HST-HY (HYdraulic) and HST-NL (Non-Linear)) to refine physical phenomena. Consequently, dam behavior can be better understood in order to clarify aging mechanismsoccurring over decades.

Using Liquid-gas-solid Three-phase Coupling Model to Analyze the Unsaturated Soil Slope Stability during Rainfall Infiltration

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Generally, most soil slope failures are induced by rainfall infiltration, and the rainfall infiltration process involves the interactions among liquid phase, gas phase, and solid skeleton in the unsaturated soil slope. In this study, a loose coupled liquid-gas-solid three-phase model, linking two numerical codes, TOUGH2/EOS3 used for water-air two-phase flow analysis and FLAC3D used for mechanical analysis, was established and validated by simulating a documented water drainage experiment from a sandy column and comparing the results with measured data and simulating results conducted by other researchers. The proposed model was used to investigate the features of water-air two-phase flow and stresses field in the unsaturated soil slope during rainfall infiltration. The slope stability analysis method based on the simulated water-air two-phase seepage and stresses field on a given slip surface were then performed. The sensitivities to the constitutive models and rain intensities were also explored. In the base case, the elastic constitutive model was employed. The results show that the safety factor (FS) on the given slip surface decreases during rainfall and reaches the lowest value when rain stops, and generates immediately a sudden rise, then increases slowly to a steady value. The lowest value of FS occurs when rain stops. When the Mohr model was used, the general variation of FS is similar with that of the base case, but there is a little increase during rainwater infiltration, and after rain stops the safety factor decreases continually, the occurrence of lowest value doesn't correspond with the time of rain stops, indicating the delayed effect of the safety factor occurs. The changes of FS with different constitutive models are mainly caused by the variations of total pore-air pressure and total normal stress acting on the given slip surface.

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Design of Overtopping Sections in Embankment Dams, Breaching of Embankment Dams, Research Activities in Austria

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At the Department of Hydraulic Engineering and the Hydraulic Laboratory of the Vienna University of Technology physical model tests are currently performed in order to adress the following scientific issues:

Design of overflow sections in embankment dams for floods

Approximately 30 % of smaller dams failed because of problems with the technical design of overflow sections, spillways or relevant hydraulic and hydrological design criteria. During the last decades many dams have been designed especially for flood protections measures with overflow sections. In addition to spillway structures with concrete chutes, various different methods have been used for the protection of the embankment against erosion and failure. These methods include riprap with placed or dumped rock fill material, combinations with concrete-filled geo-textiles or combinations of steel structures and crashed gravel.

The aim of the research work in this field was to prepare design and dimensioning criteria for alternative solutions to reduce costs compared with conventional concrete structures. On the other hand, the inclination of the embankment slopes of flood retention structures is usually in the range of 1:1.8 to 1:2.5. In many countries and also in Austria there are currently no design and calculation criteria for steeper slopes in existence and therefore further research work was necessary.

The second task includes ongoing studies and model tests for the breaching of embankment dams with different reservoir shapes and volumes and for dams with different sealing elements like upstream sealings (CFRD or AFRD) or central membrane sealings (asphalt concrete cores or other membranes). The model tests should characterize and identify the most important input parameters and additional numerical analyses will be performed. The research work should enable a connection to other ongoing activities and numerical analyses for evaluating the breaching of dams and assessing the outflow as base for emergency preparedness plans.

Analysis on the Working Behavior of Jinping-I Dam during Impoundment

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The Jinping-I hydropower project, located in the downstream of Yalong river, with an installed capacity of 3,600 MW, and a maximal arch dam height of 305m which is the highest existing dam in the world. The first unit commissioning of the project was in August 2013, the project was completed by the end of 2014.The reservoir is an annual regulating reservoir with a normal water level of 1880m and dead water level of 1800m. In view of huge project scale and complex geological conditions of Jinping-I hydropower project, initial impoundment of the dam project is divided into four stages from level 1650m to 1880m.

The key technical issues of impoundment safety of high dam include structural stress and deformation, seepage control, etc. In order to ensure safe operation in and after the initial impoundment of the Jinping-I dam, a comprehensive dam safety monitoring solution was conducted in the area of dam body, dam foundation, pedestal, dam flood discharge outlets, plunge pool and subsidiary dam, which include the deformation monitoring, stress and strain monitoring, seepage monitoring, temperature monitoring, environmental monitoring and special monitoring etc. Based on the results of monitoring, this paper mainly analyses the working behaviour of Jinping-I dam in the four impoundment phases and conducts a comprehensive assessment on the working behaviour of Jinping-I dam during impoundment. According to the analysis, Jinping-I dam keeps in a safe and healthy operation condition. The practice in Jinping-I dam could provide references for the safe operation of the other high concrete dams.

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Modeling the Mechanical Behavior of Very Coarse Granular Materials

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A novel approach has been developed to predict the mechanical behavior of very coarse granular materials with a constitutive model which considers both grain breakage and size effect. The behavior of granular assemblies is significantly influenced by particle breakage. A critical state double yield surface model incorporating the change in the critical state line and in elastic stiffness due to grain breakage during loading has been adopted. The amount of grain breakage was estimated by extending Weibull's size effect theory on individual grains to granular assemblies. The results from earlier studies on granular materials with parallel gradations have been usefully exploited to calibrate and to validate the model. Comparisons between experiments and simulations suggest that this approach can predict the mechanical behavior of very coarse granular materials from test results performed on a finer fraction with a homothetic gradation.

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Research on High Arch Dam Reservoir Basin Deformation & Its Effect

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There are a certain amount of super high arch dams with capacity of more than 10 billion m^3 at home and abroad. The engineering experience suggests that the maximum radial replacement of arch dam is always one of the most significant indexes to evaluate arch dam operating behavior. It is found that the reservoir basin shows a warping deformation with settlement in front of the dam and a little uplift behind the dam, according to monitoring data of high arch dam reservoir basin deformation. However, the effect of reservoir basin is always ignored in the general analysis on high arch dam operating behavior. The effect of reservoir basin deformation is not only a simple problem of the whole rigid body deformation of dam and its foundation, because reservoir basin deformation is affected by reservoir type, geological condition, reservoir water pressure, etc. In this paper, combined with Xiaowan dam, a preliminary study of high arch dam reservoir basin deformation and its effect on dam operating behavior were carried out. Research results can be used to explain the "doubtful deformation point" exist in those running hydropower projects. At the same time, due to the settlement and deformation caused by reservoir water pressure on the reservoir basin, it is recommended that reservoir basin deformation should be taken into account when analyzing and evaluating dam operating behavior.

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General Lectures

Theoretical Basis for Non-destructive Testing of Multi-component Media by Means of Sound Wave Analysis

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The theoretical investigation of sound waves in porous materials is motivated by the possible construction of non-destructive testing methods. In geotechnical applications low frequencies from zero to 100 Hz occur but also systems with higher frequency ranges may be tested non-invasively. Examples are concrete and other construction materials, road surfaces and pavements (some MHz), biological materials like bones and soft tissues (up to 3 MHz) up to surface coatings by nanomaterials (approximately 100 MHz). In this article three different geotechnical applications are considered: first the surface wave analysis of saturated soils which may be used e.g. for soil characterization. Second the wave analysis of a model whose stress-strain relations are isotropic but whose permeability is anisotropic. Especially in problems like seepage processes in road and dam constructions or tunneling in rocks different permeability in different directions plays an important practical role. The third analysis concerns three-component, i.e. partially saturated soils. The acoustic properties of the waves may be used in this case to warn against landslides.

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Study on Typical Cases of Earth-rock Dam due to Seepage Failure

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Seepage failure is one of the common failure modes of earth-rock dams. According to the statistics, 25% of the failure of earth-rock dams around the world were caused by seepage failure, and the percentage is ever higher (about 30%) in China.Investigation and analysis on case of earth-rockdam break is a very important piece of work, by collecting domestic and international analysis information on earth-rock dam due toseepagefailure[1-2],includingfailure reasons, initial seepage passages, breachprocess, final breachfeatures, disaster consequences due to dam break,The main reasons and the corresponding principles for the seepage failure were investigated in-depth.It was found that the defects within the dam and the foundation, the inappropriate seepage control measures and the defects along the contact areas between the bank slope and hydraulic structures are three main reasons that lead to seepage failure and breach of earth-dams. First, initial seepage passages form and propogate withinthe dam body and its foundation as well asthe contact area, with the expanding water erosion, lead to the collapse of the upperdam finally, water flowed over the dam, overtopping failure of the dam was happened.At the beginning of the development of seepage passages, seepageflowwas small, with the enlargement of the seepage passage, flow was gradually increasing, the above soil wedge is considerably disturbed and will collapse progres-sively, overtopping takes place and the pipe flow within the seepage passage is replaced by weir flow, the discharge through the breach was significantly increased. Since the formation and propagation of the initial seepage passages needs a certain amount of time, the duration of seepage failure is longer than that of overtopping, compared with the overtopping failure process, the seepage failure process showed more obvious asymptotic. Therefore, accident couldgenerally be avoided if thepotential danger was discovered and effective measures were taken. Regardless of the causes for seepage failure, the final shape of the breach of earth-rock dam is generally a trapezoid, with a ratioof the top width and the bottom width between 1.37~2.3.

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Numerical Simulation on Seismic Damage and Cracking of Concrete Slab for High Concrete Face Rockfill Dam

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Based on concrete mesoscopic damage constitutivemodel, and using the Weibull distribution function to characterize the random distribution of the mechanical properties of material for finely subdivided concrete slab elements, the seismic response of a 100 m high concrete face rockfill dam (CFRD) was numerically simulated by 3D finite element method (FEM) subjected to ground motion with different intensities, with emphasis on the exploration of damage and cracking process of concrete slab during earthquakes and the analysis of dynamic damage cracking characters under strong earthquakes. The calculated results show that the number of elements appearing damage and cracking is growing during the earthquake. With the increasing earthquake intensity, the damage zone and cracking zone of concrete slab tend to keep bigger. Under 7-degree earthquake, the stress level of concrete slab is low for a 100 m high CFRD, so there is almost no damage or slightly damage in the slab. While under 9-degree strong earthquake, the percentages of damage elements and macroscopic cracking elements continuously ascend, peaking at approximately 26% and 5% after earthquake, respectively. The concrete random mesoscopic damage model can preferably depict the entire process of sprouting, growing, connecting and expanding of crack in concrete slab during earthquake.

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Research on Causes and Truncation Measures of Dam Foundation Confined Water in Qinglinjing Reservoir

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Qinglinjing water storage project is a large-scale water supply project of Shenzhen and its operation safety directly affects the economical and social development. However, In December 2007, during the exploration in feasibility study stage, there were confined water wells from the hole. The related water level monitoring results showed that the zone of the confined water-headand flow had the direct relation with reservoirwater-level. In this research, in order to guide the project construction, the engineering geology and hydrogeology survey results were summarized.The source, path, recharge and drainage channel of confined water were also analyzed. On this basis, the theoretical model and numerical simulation analysis method were introduced to discover the seepage lawof confined water. As a result, the seepage law of confined water in Qinglinjing reservoir was summarized.The hydraulic interaction mechanism between confined aquifer and the overlying rock mass, architectural structures were analyzed. The reasonable control measures of dam structure on confined water, such as anti-seepage wall, were proposed. At last, the safety of the main building and the slope assessed.

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Research Progress of Dam Break Risk Analysis

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The nature of dam-break risk analysis is the study on the relations between people and Water under specific natural and social background. Dam break risk analysis is one of the most important purposesof dam break research. In this paper, we first introduce the concept and meaning of risk analysis, analysis of domestic and foreign research status and development trends. At last, introduce the calculation method of dam break risk by using probability theory and mathematical statistics methods, including burst probability estimation and burst loss calculation.

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Investigation of Failures of Embankment Dams in Operation Caused by Internal Erosion

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There are many failures of embankment dams over the world triggered by internal erosion. For instance in France, at the end of the last century, there was around one breach of water retaining structure (flood embankment, retaining navigation canal or small dam) per year caused by internal erosion. Moreover, internal erosion is a threat not clearly defined and understood, in such a matter that a research project, Erinoh, was launched in France in order to better understand the mechanisms of internal erosion and to reduce the damages caused by that hazard. First a database of incidents, reported mainly in France on water retaining structures, was developed by the Erinoh project. The investigation of the embankment failures reported on three data bases (Erinoh, Foster & Fell Erdata and NPDP program in the USA) concludes some interesting observations about the main causes and the main situations where internal erosion could initiate and trigger the failure of water retaining structures. The purpose of this paper is to point out the principal situations where failures by internal erosion were observed.

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Back Analysis of Rockfill Creep Deformation Model Parameters Based on Modified Particle Swarm Optimization

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Creep deformation of rockfills affects anti-seepage systems. In particular, it may cause structure damage, especially in a high concrete-faced rockfill dam (CFRD). The deformation mechanism of rockfill is very complex. It is very difficult to completely reflect the creep deformation characteristics. However, the back analysis is an effective method in study of the creep deformation parameters of rockfills. In this paper, the modified particle swarm optimization (PSO-ASIN) method, which improves convergence, was put forward. The back analysis model of rockfill creep model based on intelligent optimization algorithm is established. Then, a high CFRD was considered as an example, the modified PSO-ASIN method was used to inverse the creep model parameters of the CFRD. And the creep model of rockfills was applied to analysis and forecast the long-term deformation characteristics of the CFRD base on three-dimensional nonlinear finite element numerical analysis. The results show that the numerical calculation values of rockfill creep deformation fit closely to actual monitoring data. So, the back analysis of rockfill creep deformation model parameters based on the modified PSO-ASIN method is demonstrated to be reasonable.

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Seepage Characteristics of the Geomembrane Sand-gravel Dam

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In this study, the seepage field of geomembrane sand-gravel dam was studied with the method of removing the defect elements of geomembrane based on the saturated and unsaturated seepage theory, and the geomembrane was treated as soil with a certain thickness according to the principle of equal flow. The change law of seepage field was calculated, when the geomembrane existed holes or seams in different locations and sizes. The computation results based on the traditional method of correcting permeability coefficient of defect elements and the method of removing the defect elements were also compared. The results showed that the location and size of geomembrane defect had little effect on seepage field of sand-gravel dam. However, with the increase of the sizes of the defect and the decrease of the location, the seepage flow and phreatic line of the dam were increased, respectively. The effect of defect leakage was mainly concentrated in the local area of the defect. Saturated zone was formed in the cushion with smaller area corresponding to the defects, and the leakage under the defect has little effect on the vast majority of the unsaturated zone in the dam body. The seepage fields under the two different defect simulation method were basically the same, which indicated that the two methods were equivalent.

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A Nonlocal Peridynamic Study on Fracture of Concrete

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An improved non-local peridynamic approachfor deformation and fracture analysis of concrete materials and structures has been presented. A continuous function which describes the distribution of the intensity of interactions between material points and reflects the internal length effect of long-range forceshas been introduced into the peridynamic constitutive force function. A modified peridynamic constitutive model considering the different tensile and compressive behavior of concrete as well as the micropolar effect and the heterogeneous nature of concrete at mesoscale were proposed. Moreover, a set of numerical algorithms, including a local damping which is incorporated into the peridynamic equations of motion, astep-by-step loading algorithm and a non-equilibrium criterion for particle systems, were developed for loading of external forces to particle system and quasi-static analysis.

The convergence, computation accuracy and efficiency of the proposed approach have been validated through failure analysis of a typical concrete cantilever beam subjected to increasing concentrated force. The numerical results including load-displacement curves, prediction on extreme load of the structure, position of crack initiation and crack propagation paths were investigated and compared with analytical solutions and finite element analysis. To further demonstrate the capabilities of the proposed model, the cracking of a centrally straight-cracked Brazilian disk with different pre-existing cracks, and the failure of an edge-notched concrete beam subjected to external four-point shear loading, were investigated. In these simulations, the experimental observations including the crack initiation and growth maps as well as other failure characteristics were captured naturally as a consequence of the peridynamic solution. Moreover, the proposed approach was employed to analyze the possible failure process and failure mode of an ultra-high concrete dams.

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Research on Measuring Method of Water Level Based on Distributed Optical Fiber Temperature Sensing Technology

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Composition and method of water stage measuring system based on disturbed optical fiber temperature sensing technology are briefly introduced. Heating measurement experimenton different water levels (stabilityrising and falling) at three kinds of current circumstances (5A, 10A, 15A) is conducted, with its measuring result carefully analyzed. The test results showed that the optical fiber temperature difference shows three stages with time: sudden-rising, fast-rising and slow-rising. The temperature rising rate and stable temperature difference are between up and down of water level. It declines suddenly at first, and then tends slowly when the water rises, with temperature rising first at water first rising point; it rises rapidly at first and then slowly when the water drops, with temperature dropping first at water first rising point. The fiber optic temperature increases with the increment of heating current, which also demonstrates stability and repeatability.

Analysis of Dam Slope Stability under Coupled Condition of Continuous Rainfall and Changes of Reservoir Water Level

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In this study, a water-gas two phase flow model was established for the dam slope with saturated-unsaturated seepage. The finite element simulations of transient seepage was proceeded to study the rainfall, change of reservoir water level and coupling variation process of rainfall and water level. The modified Bishop method was used to calculate the slope stability. The effect of gas-phase and matrix suction during the process of water level changes and rainfall on slope safety factor was mainly analyzed. The results show that, rapid rise and drawdown of water level can cause dramatic changes in the upstream and downstream slope safety factor. The safety factor of the downstream slope decreases with the rise of water level, whereas the safety factor of the upstream slope decreases with the drawdown of water level. When the gas phase was not considered, the safety factor of the dam slope was decreased during rainfall. It is helpful to consider gas phase and matrix suction in the analysis of dam slope stability.

Numerical Investigation on the Performance of Embankment Constructing on Soft Foundation

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To learn the performance of embankment constructing on soft foundation, finite element method with coupled solid-fluid analysis was carried out, so the response of pore-water pressure during loading could be observed. The compacting process was simulated with loading steps. To give suggestion to the construction of embankment, sensitivity analysis was conducted. Sensitivity analysis show that generation and dissipation of pore water pressure were tightly connected to the velocity of compaction. When the time of compaction was long, the excess pore-water pressure generated in the soft foundation could be gradually dissipated according to the magnitude of hydraulic height of excess pore-water pressure and the hydraulic conductivity of soft foundation, hence the stability of embankment during constructing could be sustained. When the velocity of construction was fast, the generated pore-water pressure could be extremely high, and this would significantly decrease the shear strength of soft foundation, hence the stability of embankment during construciton could not be sustained. The sensitivity analysis suggests that to sustain the stability of embankment the velocity of construction should be controlled or drainage should be planted into the soft foundation to accelerating the dissipation of excess pore-water pressure.

State-dependent Dilatancy Theory for Rockfills

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The deformation characteristics of rockfills directly affect the stability and security of dam structure. The dilatancy property of rockfills is related to the stress state, as well asits initial state and the particle breakage. Classical stress dilatancy theory (Rowe, 1962) is widely used in demonstrating the deformation behaviors of clay. However it can't reflect the deformation properties of coarse materials. Correctly understanding the dilatancy properties is the key to establish the constitutive model of rockfills. Based on the critical state theory, and the state-dependent dilatancy theory of sand, a series of large triaxial experiments of rockfills are designed under the condition of different density, gradation and confining pressure. According to the test results, the strain softening and hardening, volume contractive and dilative of each rockfills samples are analyzed, considering the influence of density, gradation and stress levels; then, the dilatancy changing rules are studied; finally, the state dependent dilatancy theory of rockfills is established. Furthermore, the dilatancy theory of coarse materials is improved.

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Early Warning Diagnosis of Reservoir Dam Based on Blind Number Theory

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The current dam warning diagnosis methods can be mainly divided into two kinds, one is risk analysisbased on random probability theory and the other is fuzzy evaluationon the basis of the fuzzy mathematics theory. No matter which method above is used, the diagnosis result is presented as a quantitative form.And with the restriction of information expression by random probability and fuzzy mathematics,the uncertainty of information processing is hardly to representperfectly.

To solve this problem, in this paper, a blind diagnosis analysis method for the early warning of dam was proposed based on the blind number theory. First, the warning status reflected by warning factors was described in the blind number form. Second, the index weight ofeach factor was determined by the AHP method, and thus the warning status of each warning factor can be calculated and analysed using the blind number calculation algorithm. Finally, the results of each warning factor were performed normalization processing to obtain the dam comprehensive warning in the blind number form.

Based on the monitoring data of Tanghe reservoir,this method can provide a blind diagnosis to the early warning of reservoir dam with good effects. The diagnosis result is consistent with the conclusion of dam safety evaluation.

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Discussion of Damage Potentials in the Design and Construction Phase of Arch Dams

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Despite careful planning and construction of dams by experienced designers, damages of arch dams cannot be ruled out, as documented on the basis of a number of cases. Intensive studies are available for a wide range of such events resulting in appropriate remedial measures associated with useful understanding for further planning.The experience derived thereof led to a general refinement of design strategies, but may also in some cases lead to very sensitive conflict situations, which would be demonstrated herein on the basis of two significant damage - and rehabilitation cases.Although these events may already dated back several decades, useful evidence can be drawn from it by advanced analytical-numerical methods, particularly with regard to actual projects.
In this paper, the development, assessment and rehabilitation measures of crack-formations are treated in depth with fracture mechanics methods whereby especially the determination of corresponding material characteristics for mass concrete will be discussed. The occurrences at two Austrian dams (Koelnbrein, Zillergründl) form the basis for the fracture-mechanics interpretation - as already aforementioned- by a stepwise assessmentof risks during the design, construction and operation procedure.Intensive studies have been performed concerning these events, and are published in numerous articles. These cases are generally characterized by the appearance of pronounced macro cracks and are thus typical examples of the application of fracture mechanics concepts.

Design Principle and Guideline of Filter

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Terzaghi filter layer design criteria laid the foundation for the research of filter layer , whichis built in a homogeneous non-cohesive soil and soil particles in the filter layer exports that showed a stable geometric basis. This paper studied the uneven cohesionless soil, gravel soil and cohesive soil, and studied the design method of the filter layer, the focus of thestudy is to control the dominant diameter size which protects soil from seepage stability problem. According to the data of the filter material tests. Through theoretical analysis, the Terzaghi control particle size d_{85} based on and finally determine the various types of soilcontrol method for particle size. The method on the basis of the particle composition geometric stability increased hydraulic stability factor, which controls the uneven non-viscous protected soil as the soil particle size grading curve shape and change, can be called multiple point method. In this paper, the definition of discontinuous gradation and the determination method of fine material content, the principle of protecting <2mm fine particles in gravel soil, and the design of the filter layer is designed according to the principle of crack.

The financial support to this study by The national important basic research development program (973 program) (2014 cb047004); National science foundation for young (51409278); the special research for water resources and hydropower research of Chinese institute (Rock basic scientific research 1243) and the project of science and technology innovating in Guangdong province (No.2011-30)are deeply appreciated.

Stress-deformation of a Cut-off Wall in the Clay-core Rockfill Dam on Thick Overburden

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The cutoff wall in clay-core rockfill dam built on thick overburden layer is easily subject to a great compressive pressure under the action of the loads such as the dead weight of both the dam and the overburden, the frictional force induced by the differential settlement between the cut-off wall and its surrounding soils as well as the water pressure. Thus, how to reduce the stress of cutoff wall has become one of the main problems that need to be considered in the engineering design. In this paper, the numerical analysis for a core rock-fill dam built on thick overburden layer was conducted and some factors that influence on the stress-strain behaviors of cutoff wall were investigated. The factors investigated include the reinforcement for the overburden, the modeling approach for interfacial contact between cutoff wall and its surrounding soils, the modulus of cutoff wall concrete and the connected pattern between cutoff wall and the dam embankment.

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Stress-strain Behaviour of Moraine Soil/Rock at Low Temperatures

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With the rapid development of China's hydropower projects, more high earth and rock-fill damswill be built in plateau areas with massive moraine soils/rocks, such as the Qinghai-Tibet Plateauand the Yunnan-Kweichow Plateau. Although moraines are suitable to be used in the construction of earth and rock-fill dams owing to their good gradations, they may suffer from frost action at low temperatures in alpine cold regions. In this study, a series of temperature-controlled tri-axial compression tests were conducted on some moraines at the negative temperatures of -2℃, -5℃ and -10℃under a confining pressure of 5MPa. It has been found that a significant particle crushing occurred during the tri-axial compression. The stress-strain curve at every temperature condition presented a strain-hardening behaviour under the confining pressure of 5MPa.The particle crushing ratio$B_r$increased with thedecreasing of the temperatures. A frozen moraine subjected to a lower temperature exhibits a greater brittleness, which leads to a larger compression strength as well as a greater particle crushing amount.

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Visualization of Data's from Automatic Dam Monitoring

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JSC Macedonian Power Plants (ELEM) owns and operates eight hydropower plants in the Republic of Macedonia, located in south-eastern Europe, with a total installed capacity of 528 MW. The hydropower assets include the five embankment dams with clay core of Mavrovo, Spilje, Globocica, Tikves and Kozjak as well as Sveta Petka arch dam.

Responsible for dam monitoring of all dam "Mavrovo", "Globocica", "Spilje", "Tikves", "Kozjak", "Sveta Petka" in ELEM is Employment for dam monitoring in scope of HES "Crn Drim", Struga

In 2011 a comprehensive program for the automation of the monitoring instrumentation and transmission of the monitoring data to a central auscultation center for all dams under ELEM's responsibility was initiated. Project was finished at 2014 year. With this project was obtained more than 1000 instruments in all dams. Among other things, in frame of project was formed server with SQL database where is stored data's from automatically monitoring.

Automatically monitoring produces a huge number of data's. This causes a slow and uneasy preparing of report on the behaviour of all instruments.

From this reason Employent for dam monitoring develope a methodology and software for visualization and reporting of the data's stored in SQL database.

Software for visualization and reporting of the data's is a good tool to quickly generate reports for behavior of measuring points, from the data's obtained by automatic monitoring.

These reports are well illustrated with tabular and graphic items and with small corrections and additions are suitable for presentation to the competent institutions.

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Guidelines for Closure of Landbridges Used in the Mining Industry

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Landbridges used in the mining industry are embankments constructed to facilitate access between high points in the natural landscape. An extensive literature review found no current legislation, regulation, or industry best practice relating to the rehabilitation and closure of these structures. This paper presents a risk based framework for developing and selecting appropriate closure recommendations for landbridges to achieve predefined closure objectives. The framework presented seeks to provide industry best practice guidance for the closure of landbridges.

The approach presented has been developed for, and applied to, an operation in Western Australia with more than 20 landbridges ranging from 200 m to 4 km in length and up to 100 m in height. Typical closure issues associated with those landbridges include erosion and material degradation, static and seismic stability, water overtopping and piping potential, long term liability, and possible impact to flora and/or heritage sites.

The methodology applied considered, in general terms, the main elements of a risk management process, as outlined in AS/NZ 4360:2004 Risk Management (AS4360, 2004). It involves establishing the context and identifying the risks, analysis and evaluation of the inherent risks, treatment of the risk by application of controls, and review of the expected residual risk or outcomes to verify control efficiency.

The following recommendations were raised after the analysis of closure options:

a) To remove cross-valley fills when the risk rating is other than ‘Low’. Otherwise, the site-specific closure guidelines for waste dumps may be applied.
b) To rehabilitate side hill fills and/or crest ridge fills in the same way as waste dumps.
c) To *leave and close with the superseding landform*, landbridges or landbridge sectors that will be superseded by future waste dumps, or that fall within pit areas, as they will not exist at closure or will be closed in conjunction with those landforms (as waste dumps or pits voids).

d) To reform and blend the surrounding landscape, landbridges that otherwise could potentially be used for transportation after closure, to avoid potential liabilities.
e) To dump in strategically placed lifts (such as waste dumps) future landbridge sectors with fill heights over 20 m to reduce the cut-and-fill work required for rehabilitation.
f) To carry out a risk assessment for future landbridges already during landbridges planning, to allow timely identification of closure issues, some of which can be addressed during construction, thereby minimising future rehabilitation work.
g) To instrument rehabilitated landbridges and waste dumps to monitor the actual erosion due to rainfall. To verification and improve the criteria regarding material erodibility classification and recommended slope angles for rehabilitation.
h) To treated the Risk Assessment Forms as baseline documents to be populated by users when new hazards are identified, and used as a dynamic tool for future risk evaluations.

Modeling for Long-term Performance of Arch Dams Affected by Alkali-aggregate Reaction

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Alkali-aggregate reaction (AAR) is the leading cause of concrete deterioration. It is a chemical reaction between existing alkali in cement and reactive silica in some kind of aggregate. Swelling, creating micro cracks and the presence of gel outside the cracks can be mentioned as the apparent signs of this reaction. Hundreds of concrete dams have been reported suffering from AAR over the world. Long term prediction of performance of AAR-affected concrete dams and stability evaluation of the structures are important issues, and thus we propose a comprehensive model to deal with the problem. The proposed model combines the AAR kinetics and the plastic-damage behavior of concrete, being a chemical and mechanical phases coupled model. In the model, various features are considered. Temperature and humidity have significant effect on AAR. Stress state of the concrete influences the AAR velocity and the induced anisotropic expansion. Long-term creep strain is considered. Accuracy verification is carried out according to the accelerated tests, in which the specimens are confined with steel rings and subjected to axial loads. The computed strains of the specimens are in good agreement with the experimental measured strains, demonstrating acceptable results for long-term analysis of AAR-affected concrete. The model is applied to analyze the long-term performance of AAR-affected Kariba dam, a 128 m high concrete arch dam located on the Zambezi River between Zambia and Zimbabwe. It is found from the result there is expansion deformation of the arch dam during its service life. The radial and vertical displacements of the dam induced by AAR are reproduced with sufficient accuracy. The stresses within the dam are significantly redistributed in the AAR process. Severe damage appears to occur in the dam heel and the downstream face near the dam-foundation interface. It demonstrates Kariba dam is facing an increased risk of collapse associated with the increasing compressive stresses within the dam and developing cracks on the downstream face during the development of AAR.

Study on Hydraulic Concrete Cracking Criterion in Smeared Crack Numerical Model

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In major hydraulic engineering, concrete structures are usually in the environment of high water pressure, and the dams have more or less cracks. However, most cracking concrete dams are still able to operate safety, which gives rise to the problems of whether or not to allow the appearance of cracks in concrete structures, how wide cracks that won't cause damage, and what a reasonable index can be used to describe and judge the extent of concrete cracking. Concrete dam as a retaining structure, firstly, must has the function of preventing leakage, thus if the dam cracks are limited in a specified width, which cannot form the flow channels and can ensure the function of preventing leakage, then these cracks can be considered allowable. Equivalent plastic strain as a representation of yielding and failure of material, is used to reflect concrete failure in crack numerical simulation for the smeared crack model. In this paper the criterion of "allowed cracks" is defined from the angle of ensure the function of preventing leakage. So it must be studied that the value of equivalent plastic strain which corresponds to the "harmful cracks" in numerical simulation. According to the same permeability requirements of the cracked dam with the anti-seepage curtain, the allowable permeability coefficient is found. And based on the test relationship between the tension strain and permeability coefficient for concrete in the related literatures, the value of the relevant tension strain is determined, which is as the cracking criterion of hydraulic concrete. When the tension strain is lower than this value, the distinct flow channels cannot be formed in concrete, and the effect on the behavior of dam is very little. Through the numerical simulation of concrete uniaxial tensile with concrete damaged plastic model, the parameters of which are determined according to the design code of concrete structures, the relationship among crack width, equivalent plastic strain and principal tensile strain is established, and the equivalent plastic strain criterion and the criterion represented by crack width for concrete cracking are obtained. The application of the research results to the cracking analysis of a concrete gravity dam presents that the relationship between equivalent plastic strain and principal tensile strain is very consistent with the result of numerical simulation of concrete uniaxial tensile. The above results play an important role in the determination of the cracking region of concrete dam.

Incorporating the SMP Criterion into Duncan-Chang Model

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In Duncan-Chang constitutive model, the failure criterion is adopted, so that the effect of the intermediate principal stress is not taken into account. As a result, the tangent elastic modulus is underestimated and thereby the calculated deformation is larger than the real one. Some methods that based on the Mohr-Coulomb criterion have been proposed to solve this problem. However, as they are essentially two-dimentional failure criterion, the effect of the intermediate principal stress is still not taken into account. In this paper, the SMP criterion that is essentially three–dimensional failure criterion is incorporated into the Duncan-Chang model. By using this modified model, the FEM analysis for a concrete face rockfill dam was carried out, and it has been found that the calculated deformation of the dam is smaller than that by using the original Duncan-Chang model, illustrating the reasonability of the modified Duncan-Chang model.

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A Study on Safety of Slopes in Earthen Dam

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A slope is an unsupported, inclined surface of a soil mass which are natural or manmade. These may be above ground level as embankments or below ground level as cuttings. Instability may result due to gravity, rainfall, increase in groundwater table, construction on top of slope and change in stress conditions. The sliding will occur if shear stress developed in the soil exceeds corresponding shear strength of soil. However certain practical considerations make precise stability analyses of slope difficult in practices. The engineering solutions to slope instability problems require good understanding of analytical methods, investigative tools and stabilization measures. The computerized slope modeling is a novel method of solving geotechnical problems. From previous investigation bearing capacity, angle of friction, unit weight and cohesive of soil for computerized model have been considered, the Geo-Slope software is used in identification and behavior of the earth embankment or earthen dam due to varying the soil parameters and its effect on safety of slopes.

The limit equilibrium method is well known for a statically indeterminate problem and assumptions on the distributions of internal forces are required for the solution of the factor of safety. The critical failure surfaces from the limit equilibrium method and the factor of safety appear to be the primary quantity of interest. In the present study, two slip surface options are used for finding the critical failure surface and factor of safety, for different limit equilibrium methods under different conditions. With this intension, limit equilibrium method like SLOPE/W, is adopted to study the causes of failure and to avoid the failures of slope as for as possible. From the parametric study, it is observed that the factor of safety increases with the increase in cohesion and friction of the soil.

Research on Materials and Mechanical Properties of the Cut-off Wall in Earth Rock Cofferdam

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Operation and safety of earth rock cofferdam is closely related to materials and their mechanical properities of the cofferdam. Researching on the impervious wall materials in the earth-rock cofferdam, this paper studies the mechanical properties of the flexible material and plastic concrete by using the uniaxial compression test. In this paper, a measurement method of the flexible material and plastic concrete is first put forward, considering that there is no corresponding test specification for these two kinds of unconventional materials. To reflect and obtain the mechanical properties accurately, the different mixture ratio of the flexible material and plastic concrete are analyzed and determined. Due to the big strain and creep deformation of cut-off wall, the uniaxial compression test is performed. The results show that the compressive strength and initial tangent modulus of the flexible material have a large increase with the age. But the growth rate of the compressive strength is bigger than that of the initial tangent modulus. The ratio of modulus to strength gradually decreases with the age and trends to be stable. The research is of great significance for the earth rock cofferdam and the results can provide useful reference for similar projects.

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Theory and Application of Uncertainty Analysis for Modeling of Engineering Geology Problems

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Generalized uncertain damage mechanics is helpful for complete establishment of engineering catastrophic theory. The study on generalized damage mechanics needs the couple simulation of uncertain math coverage and material constitutive model. Hence, one intelligent model is useful and should have these functions: under damage development and with measure for elastic distance in damage topological space, the model can identify fuzzy denotation of generalized damage field and can simulate auto-adaptively complicated damage field from engineering. The origin and development of fuzzy stochastic damage mechanics were introduced in order to describe damage mechanics with the harmonized analysis on damage conception, probability and fuzzy degree of membership in interval [0, 1]. Under complete normed linear space, it was proved that generalized damage field can be simulated by βprobabilistic distribution. Three kinds of fuzzy conditions of damage variableswereformulated and translated,by which,setup were the corresponding fuzzy mapping distributions,namely, half depressed distribution,swing distribution,combined swing distribution that could simulate various fuzzy evolution under diverse stochastic damage situation. Furthermore, by the demonstration of damage variable′s generalized probabilistic characteristics， adjusted were， under expansion theory， Cumulative Distribution Function and Probabilistic Density Function of fuzzy stochastic damage variables that submit to β probabilistic distribution. Meanwhile, damage model, with equivalent normalization theory, was clarified by the introduction of three fuzzy stochastic damage functional for constitutional model, by which, realized concurrently were reliability calculation and fuzzy stochastic damage analysis on the basis of fuzzy stochastic finite element method. 3D fuzzy stochastic damage mechanical status of Longtan Rolled-Concrete Dam, Jianshan Iron Ore Mine Slope and Jingnan Main Dike of Yangtse Rive, was researched here by fuzzy stochastic damage finite element method. Random field parameters' statistical dependence and non-normality were considered comprehensively in fuzzy stochastic damage model of this paper, by which, damage uncertainty's proper development and conception expansion as well as fuzzy and randomness of

mechanics were hybridized overall in fuzzy stochastic damage analysis process. It was showed that introduction of comprehensive statistical analytic initial damage field model helped avoid so many inconveniences on damage mechanics study as experimentation and numerical algorithm. Merits in this paper are able to extend generalized uncertain damage mechanics and update generalized reliability analysis theory.

Mechanism of Sudden Failure of an Embankment on Soft Foundation during Constructing

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For the reason of finance, technology, or environment, embankment is usually constructed on soft foundation, and failure would be encountered sometimes. Hence study the failure case of such is helpful to understanding the failure mechanism and to guide future construction. Here a failure case of a embankment during constructing over soft foundation soil is studied. The studied embankment was compacted by layers on soft foundation. One month later, when the compacted height was about 3 m, fissure was observed at the outside platform of embankment, but no sign of deformation was observed from the surface of embankment. Hence the outside platform was compacted, and the construction was continued 10 days later with deformation monitoring. 75 days later, when the constructed height was about 4.4 m, no sign a failure was shown from the surface of embankment and the monitoring data. But on the next day, the compacted embankment was suddenly failed. After failure, site investigation and failure mechanism analysis were carried out. It shows that the excess pore water pressure and lateral deformation were the main cause of failure. This case study suggest that when embankment or dam constructed on soft foundation, it is important to monitoring the pore water pressure of foundation, and if necessary drainage should be installed to control the pre water pressure to insure the stability of embankment or dam.

Analysis of Dynamic Characteristics for High Concrete Face Rockfill Dam under Different Reservoir Models

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The hydrodynamic pressure generated by the reservoir water during the earthquake has a great influence on the dynamic response of the dam.In this paper, the additional mass model and the fluid and solid interaction model which bases on principle of potential-based fluid are used to analyze the response of high concrete face rockfill dam under effect of hydrodynamic pressure, and the effect in differentcanyon shape of dynamic response of dam is researched based on the fluid and solid interaction model. The calculated results show that the displacement and acceleration distribution of the dam calculated respectively by no hydrodynamic pressure model, additional mass model and fluid and solid interaction model are similar, and the values of displacement and acceleration of the damare increased with the increase of dam height. Because of the effect of reservoir water, the natural frequency of the dam has decreased, but the displacement and acceleration have increasedobviously.The dynamic response value of the dam calculated by additional mass model is larger than the value calculated by potential fluid model.The dynamic response between dam and reservoir waterin the unsymmetrical valley is more significant than the dynamic response in symmetrical valley.

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Scaling Principle and Method in Seepage Experiment on Sand and Gravel Materials

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China's code for seepage experiments does not specify the scaling method for oversize treatment, and this problem will disturb testers. The discussion of scaling principle and method for the oversize treatment have practical significance. The impact of scaling method for the oversize treatment of the results of seepage tests is revealed through laboratory experiments so as to improve the reliability of the test results. The results show that the similar grading method is commonly used in the mechanical strength tests, but not suitable for seepage experiments. The equivalent alternative method is only used in the situation that the middle size substitutes the oversize portion. It is suggested that the oversize treatment of seepage experiments should keep 30%~40% of fine content unchanged in order to reduce the impact of changes of the fine content on permeability coefficient.

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Spectral Behavior of Blasting Caused Vibration of Arch Dam Using Wavelet Analysis

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We apply wavelet transform to investigate the spectral behaviors of particle vibration velocity of a stone masonry arch dam, which is located adjacent to a tunnel blasting. Vibration characteristics (e.g., PPV, spectral energy, and time duration, respectively) of the bedrock velocity records are extracted within given frequency bands using the discrete wavelet transform (DWT). The result shows the dam is safe on the basis of existing blast damage criteria. We then cross-correlate the bedrock and dam top vibration records using the crosswavelettransform (XWT). Significant high power located around 15~500 Hz over the interval [0~0.25] second are observed for both series. Finanly, we adopt the wavelet coherence (WTC) to discuss the energy amplification of dam top vibration with reference to bedrock. The result shows the amplification is sensitive to the low-frequency components. Moreover, no phase locked behavior is observed in the frequency where the natural frequency of the dam located, indicating no resonance would occur to the dam. Our results are instructive for developing damage criteria and regulations for blasting.

Study on Seepage Control Effect of Tuo Xing Reservoir Reinforcement Measures

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Tuo Xing reservoir dam is a large (2) type reservoir in Hainan province China. The main components of the dam include masonry retaining dam, spillway dam, earth dam and the water diversion culvert. The first-stage project of the reservoir was completed in 1977. After a long term operation, the dam is suffered from many seepage safety problems, such as leakage along the dam toe which about 5.0m outside the dam, seepage flow was related to reservoir water level, the amount of leakage of the spillway dam was too large, etc, thus the dam should be reinforced. At the same time, the further modification and extension scheme should be designedin order to meet the operational requirements of the reservoir. Therefore, the reinforce measures should be proposed and the the optimization of the modification and extension scheme should be studied. Firstly, based on the analysis of the seepage monitoring data, the field situation and other historical data, the finite element model is established. Then the seepage parameters of main materials,such as the dam body, the curtain grouting and the dam foundation, are determined according to the seepage inversion analysis to the masonry retaining dam. Thus thecurrent operation state of the reservoir seepage can be obtained. The results show that the dam should be reinforced. Based on these results, there are three different seepage expansion designscheme of the dam proposed.Then the seepage distribution of the overflow dam and non overflow section for these three design scheme are studied. The uplift pressure distribution are also proposedunder different operating conditions. Thus the influence to the uplift pressure and the distribution of seepage are evaluated under these expansion design scheme, such as the backward movement of the curtain and the addition of the front panel. Finally, the expansion designscheme that the addition of the reinforced concrete impervious panel and the curtain grouting in front of the dam is determined to be the best seepage control scheme. By the above expansion designscheme, the free surface of the dam is lower and the uplift pressure is smaller, which means it has a good anti-seepage and drainage effect to improve the seepage stability of the dam. Meanwhile, it also can meet the standard requirements.

Study on the Internal Erosion of Earth-rock Dam

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The earth-rock dam internal erosion may cause dams running irregularly, or lead to various types of accidents, even influence economic benefits of the hub.50 percent of such earth-rock dam construction accidents was mostly caused by internal corrosion.Recentyears, both domestic and foreign experts have done a lot to probe the internal erosion of embankment dams to avoidsuch a risksituation. Some physical variables corresponding to the early embankment, such asstress, strain andpore pressure are obtained by means of laboratory experiments, finiteelement analysis and continuous model calculated dam. On one hand, we can gain a deeper understanding of the causes of internal erosion and assess the risk of many accidents caused by internal erosion; on the other hand, we can also predict the time of internal erosion and of crack initiation and study the changes of filter layer caused by the dam maturing. Thus, appropriate measures are sure to be taken to complete the repairwork, so that losses will drop to the minimum. This paper provides applications of temperature measurement in the field of erosion exploration by a number of cases.The reservoir temperature seeping through the dam is a natural tracking index. Not only dangerous areas can be found by measuring changes of temperature measurement, but also changes of seasonal reservoir water temperature estimated. This is a new concept with the value of improving dam safety.

Insights into Interfacial Effect on Effective Elastic Properties of Granular Composites

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Interfacial effects are known to be crucial in a variety of fields and can dramatically affect the physical properties of granular media. However, it is an open problem with great significance how to determine interfacial properties such as the interfacial volume fraction and to quantitatively evaluate the effect of such an interfacial property on effective elastic behaviors as homogeneous features of macroscopic mechanical responses of granular materials with complex geometric particles. So far, the preponderance of previous researches on the interfacial volume fraction and the effective elastic properties of composites has been performed only on a case-by-case basis. Here we first present a theoretical framework to symmetrically display the soft interfacial volume fraction by hard core-soft shell structures with mono-/polydisperse non-spherical particles.we further put forward a theoretical model to predict the effective moduli of three-phase heterogeneous particulate composites containing shape-anisotropic particles,soft interfaces, and homogeneous matrix.The theoreticalschemes provide an efficient and accurate tool for materials design contrast with time-consuming or costly experimental studies.Herein, the derivation of effective moduli of two-phase structures is firstly presented by the variational principle. Subsequently, the effective moduli of such three-phase systems including soft interfaces are derived by the generalized self-consistent scheme. These theoretical schemes are compared with experimental data, numerical results, and theoretical approximations reported in the literature to evaluate their validities. Moreover, the theoretical frameworks provide quantitative insights into the dependence of effective elastic modulus on the interfacial properties and geometric characteristics of anisotropic particles. The results show that the interfacial volume fraction and the effective elastic modulus of granular materials are strongly dependent on the aspect ratio, geometric size factor, volume fraction, and particle size distribution of anisotropic particles.

Numerical Simulation on Three-dimensional Seepage Characteristics of High Concrete Face Rockfill Dam on Thick Overburden Foundation

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The seepage control design of high concrete face rockfill dam built on thick overburden foundation is very important. The related numerical simulation methods of three-dimensional seepage behaviour are proposed recently. In this paper, the finite element method (FEM) was used to analyze three-dimensional seepage characters of Hekoucun concrete face rockfill dam engineering, including the related seepage characteristics under the conditions of normal operation and crack on concrete face. The calculation results show that the seepage control system composed of the concrete face, the concrete toe slab, the concrete anti-seepage wall and the grouting curtain can effectively control the leakage of reservoir water. However, if some penetration cracks appear on the concrete wall, the hydraulic gradient grows and leakage quantity raises in the related area with the number of cracks increasing. In this case, the anti-seepage effect of concrete face is abate, which may affect the safety of the dam body.

The financial support to this study by The national important basic research development program (973 program) (2014 cb047004); National science foundation for young (51409278); the special research for water resources and hydropower research of Chinese institute (Rock basic scientific research 1243) are deeply appreciated.

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Research on the Construction of Information Management Platform for High Concrete Face Rockfill Dam

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The construction of information management platformin water conservancy is a new and popular research field. In this paper, the domestic and foreign existing informatization development situation and main technical systems aresummarised.On this basis, according to the functional requirements of the information management system platform construction of the concrete face dam, the key technology research and development are developed and the systems areintegrated. In the procedure, a 3D intelligent geological modelling method was proposedto build the geological model of the reservoir dam more accurately, which was based on the drilling information and can make full use of existing geological exploration data. Meanwhile, a advanced laser scanning technology of hydropower engineering based on the image processing is introduced to model the distribution for main buildings, the foundation, the reservoir dam and ground surface. As a result, the information management platform of Hecoucun reservoir project was built and the relatedsystem interface, function and basic information, the main office automation systemetc. were also presented.

The financial support to this study by The national important basic research development program (973 program) (2014 cb047004); National science foundation for young (51409278); the special research for water resources and hydropower research of Chinese institute (Rock basic scientific research 1243) are deeply appreciated.

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Study on the Permeability of Concrete Cut-off Wall with Defects

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Cutoff wall is the main measure for the rehabilitation and improvement of anti-seepage capacity of earth dams.It may appear many kinds of quality defects in the process of construction and operation .The kinds of defects may have an effect on the whole permeability of engineering. In this paper, the 3D seepage finite element method is used to investigate the effects of quality defects, including the cracks in the concrete anti-seepage wall, bifurcation of the cutoff wall, entrained mud in the wall, and suspension of the anti-seepage wall, in the concrete anti-seepage wall on the seepage control of dam. Taking Duanxin dam as a research case, when the cutoff wall appears quality defects, the influence of the defect on the seepage stability of the dam is determined by analyzing the range of the seepage failure zone of the dam foundation overburden. The numerical simulation results show that if the cutoff wall is in good condition, the seepage control can satisfy the safety requirements of the engineering project; however, the defects of the anti-seepage wall may result in seepage failure in soil layers of the dam foundation. It also indicates that the size of defects is of great influences on the seepage stability and ranges of seepage failure zones of the dam foundation.

Internal Stability Analysis of Reinforced Embankment with Extensible Reinforcement Subjected to Oblique Pullout Using Pseudo-dynamic Method under Earthquake Loadings

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Earthquake is one of the most important factors resulting in damages of embankments and extensible reinforcements are wildly employed to fix or reinforce structures such as embankments. The existing studies on internal stability of embankment under seismic loadings mainly focus on the axial resistance of the reinforcement to pullout. However, the kinematics of failure indicates that reinforcementsare subjected to oblique pullout force, then bending deformations of reinforcements are presented.In this paper, internal stability analysis of reinforced embankment with extensible sheet reinforcement subjected to oblique pullout has been presented that properly considers complicated soil-reinforcement interaction and deformation of extensible reinforcement.

Pseudo-dynamic approach, slice method (HSM), and non-linear elasto-plastic subgrade model are used to calculate the safety factor of embankment. A parametric study is conducted to evaluate the influence of various parameters on the seismic internalstability of embankment. Results are compared with published data and the difference is analyzed.

Conclusions

Based on the pseudo-dynamic method, the internal stability of embankment under earthquake loads is analyzed and the safety factor is calculated accounting for the kinematics of failure and the following bending deformation of reinforcements.A non-linear elasto-plastic model is used to represent subgrade and HSM is employed to clarify the analysis process. The study has shown that:
(1) The bending deformation can result in more pullout resistance of extensible reinforcement, then causes a more stable embankment when angle of failure surface with horizontal is small.
(2) When ratio of the reinforcement stiffness to the axial pullout capacity is large, the safety factor, FS_T is close to the results of internal stability analysis

of reinforced embankment with inextensible reinforcement; however, when this ratio is small, the embankment reinforced with extensible reinforcements are less stable than those with inextensible reinforcements.
(3) The safety factor, FS_T of the reinforced embankment reduces with increases in earthquake intensity. Both k_h and k_v have significant influences on the internal stability of reinforced embankments.
(4) The safety factors obtaining by using pseudo-dynamic approach present acceptable agreement. With the results by using pseudo-static approach. More specifically, the parameter study shows the safety factor, FS_T obtaining by using pseudo-dynamic approach is less than those by using pseudo-static approach. Hence, pseudo-dynamic approach presents more conservative results of internal stability analysis of reinforced embankment.

Fish Protection Measures of Building Water Conservancy and Hydropower Weir Class Project

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Water Resources and Hydropower Engineering in promoting social and economic sustainable development, protection of national energy security played a huge role, but environmental problems it generates are gradually emerging, especially the impact of damming class project on fish resources is more serious. It has become the focus of attention of the community. Through the study of China has built water conservancy project on fish to survive the impact of proposed measures to protect fish stocks. Before the dam construction, the first of the river where the fish species, population investigation, study their lives, breeding habits. When the dam by certain ecological simulation, construction conforms river fish passage measures, including fish passes, raw fish machine, fish gates, to ensure the effectiveness of fish over the measures. Artificial reproduction and releasing supplement group did meet the breeding habits, put survive. Using laboratory trained to use fish measures, then back; you can even make bionic fish guide fish through fish. The last to do a number of species of fish upstream and downstream monitoring, timely change measures to achieve harmony water project and fish.

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Cause Analysis for Cracks on Concrete Slabs of Xianlin Concrete Face Rockfill Dam

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Except the first slab on the left side, many cracks appeared on concrete face slabs of Xianlin concrete face rockfill dam in varying degrees. The total number of slab cracks is 224. The cracks are basically horizontal long cracks and mainly locate in the height of 1/4 to 3/4 of face slab. According to preliminary analysis, these cracks are structural cracks. Rheology of dam material, secondary dam filling, soft rock (softened) are the main reasons for the dam's continuous settlement after concrete slabs were constructed, which cause to a lot of horizontal long cracks on the face slabs.

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Three-dimensional Effects on Stability of Earth Dam/Embankment

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The assessment of earth dam embankment stability uses idealized two-dimensional (2D) geometry –classifying as a plane-strain analysis. Such a 2D idealization significantly simplifies the evaluation of a dam constrained by a narrow valley or an embankment limited by rigid structures (e.g., rock formation), by ignoring stabilizing effects posed by three-dimensional (3D) characteristics. Based on the kinematic approach of limit analysis, a 3D rotational failure mechanism is adopted here to investigate the influence of 3D end effects on stability of earth dams/embankments. The calculated results are used to produce stability charts to conveniently estimate the safety factor of 3D earth dam/embankment limited to a narrow constraints. An example is presented to demonstrate the difference in the safety factors obtained from 2D and 3D analyses. When an earth dam/embankment is constrained to a large length (the ratio of the length to the height $L/H \geq 10.0$), the 3D effects can be neglected and the plane-strain analysis is appropriate to assess its safety. However, the 3D effects could significantly increase the stability of earth dam/embankment, especially for short failure lengths.

Stress and Strain Analysis on Earth Core Rock-fill Dam with the Consideration of Anisotropy

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Most popularly applied soil constitutive models are developed based on the symmetric triaxial tests, in which the load is applied from the major principal stress direction and the other principal stress directions are symmetric. These axial-symmetric testing data is applied to other kinds of loading problems with isotropic assumption. It is assumed that the same Young's modulus and the Poisson's ratio are applied to describe the stress and strain relationship in all three principal directions. But true triaxial tests show that there are quite different stress and strain in different principal directions. Traditional model with isotropic assumption, such as Duncan-Chang hyperbolic E-v model, which is popularly applied in China, cannot describe such anisotropy induced by stress. When isotropic models are applied to the stress and deformation computation of rock-fill dam, there may be lots in accordance with the practice. Many high and ultra-high rock soil filled dams have been or to be constructed in current China. It is necessary to carry out the safety assessments on dams during the design, construction and operation process. It is important to give reasonable simulation and evaluation of the stress and strain ofthe dam body and core wall and the results directly related to the dam reservoir safety. Water pressure is applied in a direction towards the minor principal stress of dam body during the impounding procedure. Thus the additional stress increment in earth core wall of rock-fill dam is applied from the minor principal direction.

Series of true triaxial tests were carried out on geomaterial, by which the practical stress path of impounding can be described to some extent.The testing process was described as following steps: First, a certain confining pressure σ_3 was imposed from three different principal directions; all principal stresses were loaded from zero to σ_3. It gives an isotropic stress state to supply initial strength stabilizing the sample under different confine stress. Second, the major principal stress σ_1 and the intermediate principal stress σ_2 were increased to certain values proportionally according to the different b values, so that the specimen was set in the initial three-dimensional stress state to simulate the different original three dimensional stress states. Third, stress increment $\Delta\sigma_1$ (or $\Delta\sigma_2$, $\Delta\sigma_3$) was applied from the major principal stress σ_1 direction (or from the intermediate principal stress σ_2 direction, from the minor

principal stress σ_3 direction) until the specimen fails.Based on the true triaxial tests, there are different Young's modulus and the Poisson's ratio in minor principal direction and major principal direction.
Considering the limitation of Duncan model in describinganisotropic deformation under complex stress states, taking account of anisotropy of soil flexibility matrix of the law based on above true triaxial testing results, Duncan E-v model was revised by adjusting model parameters related to the establishment of its ability to a certain extent, reflect the stress anisotropy. In the revised anisotropic model, three elastic modulus and six Poisson's ratios are applied in different principal stress directions.
The traditional Duncan-Chang E-v constitutive model and revised anisotropic model were then applied respectively in the FEM analysis on an high earth core wall dam. The stress induced anisotropy effects were discussed.

Data fusion of velocity structure for propagation media in simulating of ground motions at dam sites

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The determination of ground motion input is a key technical problem for dam design in the seismically active region. However, reasonable prediction of earthquake ground motion at a specific dam using the numerical simulation methods is still a challenging issue because it is related to many factors, including focal mechanism, propagation path, and local site effect. Especially, the propagation media may significantly different in different places. For Southwestern China, a region with abundant water power but high seismic hazard, the resolution of the media velocity model is dozens of kilometers, which is hard to simulate the ground motion well for dam safety evaluation since the simulated frequency is too low from the point of view of engineering design. In this paper, a new three-dimensional velocity model is built by mining the relationship between the velocity and the local surface lithology distribution; the relationship between the velocity and the local deep density distribution. Meanwhile, some data fusion techniques like interpolation and smooth processing are used to combine the multi-source data such as well logging data and upper crustal wave structure of some profile. Based on the generated medium velocity structure, the ground motion at Hongshiyan region caused by the 2014 Ludian earthquake is simulated using the spectral element method (SEM) and compared with the ground motion records. The results show that the synthesized results is comparable with the records. Furthermore, the reason why the landslide happened at the Hongshiyan is investigated.

Experimental Study on the Force Penetration in Granular Materials

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The granular stuff, such as the sand and gravel, is one of the most common and widely used materials in both civil and hydraulic engineering. The point is the granular materials are not like solid or liquid, the force inside of the granular system would never distribute homogeneously even the global homogeneous pressure is applied. The force penetrates the granular system as chain, which could be clearly observed by the photoelastic technology. Hence, the quasi-static photoelastic granular tests were conducted to investigate the force evolution properties after the external force is applied on the system. The displacement field and the global force network of the granular system are analyzed. Moreover, the Probability Distribution Function of coordinate number and the pressure of each individual particle are discussed.

Limit Analysis of Earth Dams under Water Drawdown conditions

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A 2D kinematically admissible rotational failure mechanism is extended to take into account the effects of water drawdown for earth dams. In the strict framework of limit analysis, an analytical approach is derived to obtain the upper bounds on stability of earth dams with a phreatic surface defined by the Dupuit's formula. Several stability charts are presented to conveniently estimate the safety factor of earth dams under four different types of drawdown processes. An example earth dam subjected to rapid drawdown is provided to illustrate the use of stability charts. For earth dams during rapid drawdown, the safety factor reaches its minimum after the reservoir has been fully drained. During a slow drawdown or drawdown with a constant drop in water levels, the factor of safety decreases to the minimum and then increases slightly.

Appendix I

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Appendix II

Brief Introduction to the WTZ Project CN 02/2013

Brief Introduction to the departments and institutes involved in the joint scientific and technical co-operation Project

Institute of Applied Mechanics, Graz University of Technology, Graz, Austria

The focus of the scientific work in this institute is on modelling the mechanical behaviour of soil and rockfills based on the framework of hypoplasticity. Herein the evolution of state variables is described by isotropic and non-linear tensor-valued functions depending on the current state variables and the rate of deformation. With a version developed by Gudehus and Bauer the influence of the current density and of the pressure level on the incremental stiffness was successfully modelled for a wide range of pressures and densities using a single set of constants. The concept of critical states is included in the model for a simultaneous vanishing of the stress rate and volume strain rate. Polar effects within shear zones are investigated by an extension of the basic hypoplastic concept to a Cosserat continuum. Together with colleagues from Hohai University the model was applied to study shear strain evolution in granular materials. Another novel application is the numerical modelling of environmental friendly soilbag structures. Recently the hypoplastic model was also extended to weathered and moisture sensitive rockfill materials. Disintegration of the material is taken into account using a moisture dependent solid hardness. Creep and stress relaxation are also captured by the model. First applications of the model to rockfill dams were also carried out with colleagues from Hohai University and the Nanjing Hydraulic Research Institute.

In this institute, the partners of the co-operation Project are Bauer Erich, Taferner Bianca, Hackl Jürgen and Tapley Joshua.

Institute for Hydraulic Engineering and Water Resources Management, Vienna University of Technology, Vienna, Austria

Concerning the safety of embankment dams already the ICOLD investigation of 1995 stated that overtopping was the number one cause of failures of embankment dams. The aging of dams and changed design criteria together with risk assessments evaluations have raised new questions related to the overtopping of embankment dams and the rehabilitation of existing structures. There are many alternatives available for the designer to protect an embankment dam that is predicted to fail during overtopping. The method of protection chosen depends on the height, the location of the dam, the expected flow magnitude and duration and the susceptibility of the material to erode. Research is underway with the goal of providing a means of evaluating the performance of overtopped embankment dams, by means of laboratory testing and numerical calculations. These investigations will provide the basis for predicting the extent of overtopping that may be withstood without breach, the timing of the breach when failure occurs, and the hydrograph resulting from a failure. It is supposed that the slope protection measures and design criteria are strongly influenced by the properties of the secured overtopping sections of embankment dams and the unprotected - or protected areas of the downstream dam toe.

Another topic in dam research is the influence and additional load of earthquakes on dams. Incidents of earthquake induced damages are few in number and it is mainly accepted that embankment dams are basically safe structures, but we should not forget that most existing dams are younger than 150 years, while earthquakes have almost indefinite return periods and appurtenant structures like spillways, bottom outlets or intakes are more sensitive to dynamic loads.

Our institute also deals with the general assessment of existing dams and the evaluation of guidelines for the instrumentation as well as the monitoring of dams. This work includes the preparation of standards based on international experiences and adaptable to the various dam designs. A special task is related to the aging of various materials and in particular the aging of asphalt concrete faced dams

The goal of the ongoing research is to provide the knowledge required to develop a physically based algorithm to simplify procedures for the design and rehabilitation of embankment slopes, for the investigated protection and sealing measures.

A further major task of the Institute is the fracture mechanics of cementitious materials–especially directed to the investigation of cracking in dams. Apart from the already often tested analytic-numeric methods both in the linear

elastic range of application and in the nonlinear mode of application the determination of adequate fracture mechanics material parameters (fracture toughness, fracture energy) for mass concrete is of great importance.
In this institute, the partners of the co-operation Project are Tschernutter Peter, Linsbauer Herbert, Kisliakov Dimitar, Kampel Irina and Schüll Markus.

Unit for Strength of Materials and Structural Analysis, University of Innsbruck, Austria

The Unit for Strength of Materials and Structural Analysis is part of the Institute of Basic Sciences in Civil Engineering at the Faculty of Civil Engineering of the University of Innsbruck. The unit is a member of the research initiative “Computational Engineering”, being one of the three research initiatives of the Department of Civil Engineering; it participates in the research platform “Scientific Computing” of the University of Innsbruck and in the doctorate program “Computational Interdisciplinary Modelling”, funded by the Austrian Science Fund (FWF).
Research Activities are related to Computational Mechanics, in particular to (i) numerical modelling of concrete and FE-analyses of concrete structures and (ii) numerical modelling of partially saturated soils and FE-analyses of multi-phase problems in geotechnical engineering.
Recent research activities focus on a multi-phase model for concrete, in which concrete is modelled as a porous material, consisting of a solid phase and pores, the latter being filled by liquid water, vapour and dry air. The model allows considering coupling effects between mechanical, thermal, hygral and/or chemical processes. Hence, it is also suited for predicting the material behaviour of young concrete, in particular for predicting the risk of crack initiation and propagation in young concrete.
The second main topic of research activities is devoted to numerical modelling of partially saturated soils, to the implementation of a three-phase soil model (the three phases consist of the deformable soil skeleton and the interstitial fluid phases water and air) into an object-oriented open-source FE-code and to the extension regarding the application of compressed air for displacing the groundwater in tunnelling below the groundwater table. Different stress update algorithms for partially saturated soil models are investigated with respect to robustness and efficiency for large-scale FE-analyses.
In this institute, the partners of the co-operation Project are Hofstetter Günter, Schaber Matthias and Gamnitzer Peter.

Unit for Hydraulic Engineering, University of Innsbruck, Austria

The research group on applications of distributed fibre optic temperature (DFOT) measurements focuses mainly on leakage detection and seepage monitoring in embankment dams, dykes and canals. The method has been used successfully during the last 15 years in a number of installations in hydraulic engineering works. With DFOT measurements, small changes in temperature can be observed continuously and economically over very large scales along robust fiber optic cables that are installed in or next to the monitored structure. Water detection is possible either through water temperatures that deviate from its surrounding thermal settings or via a relationship of the soils moisture contents to their thermal properties and conductivities. The high spatial resolution of the system allows the detection of defects with an accuracy of ±1 meter over a surveillance section of several kilometres.
Current research aims for a better understanding of the physical processes in order to develop quality standards for the application of DFOT measurements in hydraulic structures. Therefore, large scale model tests are carried out in the hydraulic laboratory at the University of Innsbruck. The experiences gained in these works will also be used to develop and improve automated monitoring systems.
In this institute, the partners of the co-operation Project are Aufleger Markus and Etzer Thomas.

Institute of Hydraulic Structures, Hohai University, Nanjing, China

The Institute of Hydraulic Structures in Hohai University has a total staff of 38 (one academician of the Chinese Academy of Engineering, 18 professors, 12 associate professors). It has a research centre for the safety of Hydraulic and Hydroelectric Engineering projects and several labs for studying hydraulic structures (dams, powerhouse caverns, etc.) and their materials. The Hydraulic Structure Engineering Discipline, which is part of the institute is the oldest one founded in China and is now the Chinese National Key Discipline. More than 10,000 students have graduated from this discipline, most of them are still active and they play very important roles in the construction and management of the hydraulic and hydroelectric projects in China. The main researches carried out in the Institute of Hydraulic Structures are as follows:
Analytical and numerical methods for the modern design of hydraulic structures (covering the special disciplines: modern design theory and analytical methods for hydraulic structures
high slope stability and underground engineering, large-scale sluice, ship lock and water conveyance structure, dam seepage and its control, hydraulic

structure construction and management, new hydraulic structure materials), safety monitoring and modern experimental technology for high dams and dam foundations.
In addition to the scientific research, the Institute of Hydraulic Structures in Hohai University also offers the technical services for the national construction projects such as the Three-Gorges Project, the South-to-North Water Transmission Project and most of the hydropower projects in western China.
In this institute, the partners of the co-operation Project are Liu Sihong, Wang Runyin and Wang Liujiang.

Geotechnical Research Institute, Hohai University, Nanjing, China

Hohai University (formerly known as East China Technical University of Water Resources) is one of the national key universities administered directly under the Ministry of Education. It is also one of the first universities empowered by the State Council to confer Bachelor's, Master's, Doctor's degrees and approve the qualifications of professor, and doctoral supervisor.
The Geotechnical Institute of Hohai University (GeoHohai) was founded in 1952 by Huang Wen-Xi, member of the Chinese Academy of Sciences and pioneer in geotechnical engineering in China. Subsequently, the institute was developed steadily under the leadership of professors Qian Jia-Huan, Xu Zhi-Ying and Jiang Pu. It was one of the institutes authorized by the State Council to confer Master's and Doctor's degrees in 1981 and 1982, respectively. It has been accredited by the Ministry of Education as the national key subject since 1988. The post-doctoral program was commenced in 1991. In 1994, it was approved by the Ministry of Water Resources as the key geotechnical engineering laboratory. In 1999, it was commissioned by the Ministry of Education to establish distinguished professor positions for “Chiangjiang Scholars”.
GeoHohai employs 42 qualified staff, including 16 professors (14 of them are PhD supervisors), 8 associate professors and 18 lecturers. 26 of them have PhD degrees. Currently GeoHohai employs 33 qualified staff, including 14 professors, 17 associate professors and 2 lecturers. For the past four years GeoHohai has enrolled 107 PhD students and 503 master students. There are five major research directions in GeoHohai, namely (i)fundamental soil behaviour and constitutive theory, (ii) computational theory and method for high earth and rock-fill dams, (iii) safety and disaster prevention of high slope, (iv) ground improvement for dike and road engineering, (v) seepage and geo-environmental engineering.

In this institute, the partners of the co-operation Project are Chiu Chungfai and Li Shoude.

Research Institute of Tunnel and Urban Rail Engineering, Hohai University, Nanjing, China

The Research Institute of Tunnel and Urban Rail Engineering in Hohai University (TunHohai), was found in 2010 in terms of the demands of national development and infrastructure construction. It shares the common research platforms and resources with the Institute of Geotechnical Engineering and the Institute of Structure Engineering under the unified leadership of College of Civil and Transportation Engineering. It has the platform of National Key Subject of Getechnical Engineering and the Key Laboratory of Embankment and Geotechnical Engineering accredited by the Ministry of Education, as well as the program of Master's and Doctor's degrees and post-doctoral research in subjects of Getechnical Engineering and Structure Engineering. TunHohai employs 6 qualified staffs, including 1 professor, 1 associate professor and 4 assistant professors. TunHohai has enrolled about 10 PhD students and 30 master students and two classes of undergraduate students. The staffs from TunHohai have focused on the problem of seepage and coupled with deformation in Geotechnical Engineering for long time. The international centre of Numerical Maniford Method is herein established by Dr Shi Genhua who is the founder of some modern numerical methods such as DDA (Discontinuous Deformation Analysis), NMM (Numerical Maniford Method) and KB (Key Block Theory). There are five major research directions, namely (i) seepage failure mechanisms on tunnel groundwater disaster, (ii) component flow and control of underground waster disposal, (iii) modern numerical method and risk assessment for underground engineering, (iv) design and construction of shield structure tunnel, (v) systematic optimization of tunnel support structures.
In this institute, Wang Yuan participates in the co-operation Project.

Institute of Mechanics for Materials and Structures, Hohai University, Nanjing, China

The Institute of Mechanics for Materials and Structures is one of 6 research institutes in the College of Mechanics and Materials. With 4 university professors and 3 associate professors, the institute is a platform for the researches in the mechanical properties and behaviour of engineering materials and applications. The head of the institute, Prof. W. Huang, completed his PhD study at Graz University of Technology in 2000 through an Austrian

Government Scholarship program. His main research interests are in constitutive modelling of geomaterials, failure mechanism, and numerical solutions of geotechnical engineering problems. In Recent years, he has been the chief investigator of an ARC (Australian Research Council) Discovery Research Project, a NSFC (National Natural Science Research Funding) research project, a sub-project in a National Key Fundamental Research and Development Program and some other research projects; authored and co-authored more than 60 peer reviewed journal and international conference papers. He is also a reviewer of many important international journals on geomechanics and geotechnical engineering. In the present cooperative research program, Prof. Huang and his assistants will focus their researches on the long term deformation properties and failure mechanism of rockfill materials and numerical modelling.

In this institute, Huang Wenxiong participates in the co-operation Project.

Geotechnical Engineering Department, Nanjing Hydraulic Research Institute, Nanjing, China

Nanjing Hydraulic Research Institute (NHRI), set up in 1935, originally called Central Hydraulic Research Institute, is the oldest of its kind in China. The institute was designated by the Chinese Government as one of the national non-profit research institutions for public service in 2001. NHRI is a multipurpose national hydraulic research complex, mainly dedicated to basic research, applied research and technological development, and undertaking directional, principal and comprehensive researches for water conservancy, hydroelectric power and waterway transportation projects as well as researches on soft science and macro decision making. At the same time, the Institute acts as the Dam Safety Management Center, the Research Center for Climate Change, the Engineering Quality Inspection Center and the Nanjing Engineering Measurement Examination Center of the Ministry of Water Resources.

The Geotechnical Engineering Department is the oldest geotechnical research body in China, founded by Prof. Huang Wenxi, academician of the Chinese Academy of Sciences and founder of the Chinese geotechnical science. The Department has trained a great number of famous experts and scholars, represented by Prof. Shen Zhujiang, academician of the Chinese Academy of Sciences. The Department has a total staff of 80. The administrative offices of the Rock and Soil Mechanics Committee and Geotechnical Test Committee of the Chinese Hydraulic Engineering Society, the Geotechnical Test Committee of the Chinese Civil Engineering Society and the Plastic Drainage Committee of the Harbour Engineering Branch Society of the Chinese Civil Engineering

Society, and the Editorial Office of the Chinese Journal of Geotechnical Engineering are stationed in the Department. The areas of interest of Geotechnical Engineering Department include: Fundamental theories and method of geotechnical engineering and soil mechanics; Soil-structure interaction; Key technology of high earth and rock-fill dams; Foundation treatment and reinforcement; Safety monitoring and disaster mitigation of getechnical engineering; Environmental geotechnical engineering and Analysis and treatment of geological and seismic disasters.
In this institute, the partners of the co-operation Project are Chen Shengshui, Cai Zhengyin, Li Guoying, Fu Zhongzhi and Zhong Qiming.

Institute of Hydraulic Engineering, Tsinghua University, Beijing, China

The Institute of Hydraulic Engineering is one of the six institutes under the Department of Hydraulic Engineering. It has a total staff of 35, including 3 academicians, 12 professors and 9 associate professors. The institute offers 2 sub-disciplines: one is Hydraulic Structure, and the other is Water Resources and Hydropower, both authorized to confer Ph.D degrees. The subject of Hydraulic Engineering was awarded national key discipline since 2008. There are six major research divisions including (i) High Concrete Dam Engineering, (ii) Earthquake Engineering of Concrete Dams, (iii) Constitutive Modeling of Rockfill Material and High Embankment Dam Engineering, (iv) High Rock Slope and Rock Foundation Engineering, (v) Underground Cavern Engineering, (vi) New Hydraulic Structures and New Material and, (vii) Engineering Hydraulics. The institute has been carrying out research on high dams in China since the 1950's. Particularly the research work on hydraulic structures and earthquake engineering has been at top one level in China and achieved a worldwide prestige.
Zhang Chuhan, Professor in the Hydraulic Engineering Department, Tsinghua University, is a member of the Chinese Academy of Sciences, a member of American Society of Civil Engineers, concurrent Professor of Concordia University, Canada, and also, a member of the State Committee of the South-North Trans-Basin Water Transfer, member of the Advisory Committee, National Science Foundation of China and member of Science and Technology Committee, Ministry of Water Conservancy of China. His research group is engaged in research on hydropower and dam structures, especially on earthquake resistance of high dam structures. He presented the infinite boundary element and a time domain model of concrete dam-foundation-reservoir interactions, and coupled with nonlinearities due to arch dam contraction joints, concrete damage and steel bar reinforcement. This model has been used in earthquake resistance design of 300-m level high arch

dams such as Xiaowan and Xiluodu Projects in China. A cracking propagation model of concrete dams was also presented and further extended to nonlinear and anisotropic material problems. The model was employed in several concrete dam designs to resist earthquakes. In addition, he has extended the distinct element method to include rheology and applied it to the behaviour predictions for high rock slopes in the Three Gorges ship locks. He has published more than 180 papers and four books. He received 11 prizes including the State Natural Science Prize, State Outstanding Educational Prize, State Science and Technology Congress Prize and four Science and Technology Advancement Prizes of the State Education Commission and of the State Power Ministry. He has been actively engaged in international cooperation with the U.S., Germany, Switzerland and Austria etc. in academic research, personal exchange and organizing joint workshops in the field of Hydropower development and high dam construction to resist earthquakes. In education, more than thirty graduate students including twenty PhD in the field of Water Resource and Hydropower have graduated under his supervision.
In this institute, the partners of the co-operation Project are Zhang Chuhan, Jin Feng, Duan Yunling, Xu Yanjie and Wang Jinting.

Department of Hydraulic and Hydropower Engineering, Tianjin University, Tianjin, China

Department of Hydraulic and Hydropower Engineering is one of the six departments in the School of Civil Engineering, in which there are 55 full-time faculties and researchers, among them there are 22 professors, 18 associate professors, 34 Ph.D. Supervisors and 44 master tutors. The department has one State Key Laboratory, one National Engineering Laboratory, one Engineering Technology Center of Ministry of Education and one Tianjin Key Laboratory. In recent 3 years, the department has undertaken more than 100 provincial and national major engineering research projects. The main research areas of this discipline include: Simulation and Quality Monitoring of Major Hydraulic and Hydropower Engineering Projects, High Dam Discharge and Hydropower station Safe Operation, Long-Distance Water Transfer Projects, Harbor, Coastal and Offshore New Structures, Sediment Movement and Evolution of Estuary and Coast, Sea Ice Mechanics and Ice Engineering, Marine Soil Dynamics and Foundation Engineering, Offshore Wind and Wave Tidal Energy Development, Coastal Utilization and Protection, Engineering and Urban Water Ecological Environment.
In this institute, the partners of the co-operation Project are Feng Ping, Sun Dongmei, Li Fawen and Li Jianzhu.

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