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Dynamic evaluation of RCC dam Interlayer bonding quality considering the influence of compaction quality

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Abstract: Evaluation of the interlayer bonding quality is the key way for controlling the roller compacted concrete dam (RCC dam) construction. The existing study only considered the influences of layer processing and the interval time, which ignored the influence of the compaction quality on the interlayer bonding quality. Besides, there is no dynamic evaluation study of the interlayer bonding quality. In this study, an interlayer bonding quality dynamic evaluation model considering the influence of the compaction quality and its uncertainties based on the real-time monitoring system is proposed and the model contains three main contents: (1) processing the concrete characteristic parameters based on the entropy-blind number theory, and the compaction degree dynamic calculation method considering the uncertainties of the parameters is proposed. The compaction degree calculation results will be used in the interlayer bonding quality evaluation; (2) the deference value between the concrete initial setting time and the interval time is calculated as the evaluation factor, which solves the feasibility problem of the model in different seasons; and (3) a three level evaluation factors system is built, and the mapping relationship between the interlayer bonding quality and the interval time and the compaction degree is established. Combining the practical engineering, the interlayer bonding quality of an RCC dam is evaluated dynamically using the model based in the real time monitoring system. The evaluation results proved that the study model can evaluate the interlayer bonding quality and provide more information including the parameter uncertainty. The dynamic evaluation model of interlayer bonding quality can give more practical results.

Keywords: RCC dam; interlayer bonding quality; interval time; compaction degree; entropy-blind number; uncertainty

Safety analysis of flood discharge structures of the control cascade reservoir under extreme operating condition

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Abstract: The risk of the whole cascade reservoirs of the earth rockfill dams under extreme operating condition is rely on the security of the control cascade reservoir. Such earth rockfill dam with extra height is classified into Class Ⅰ and Class Ⅱ dam based on the existing Chinese dam classification systems recently, but which one should design the unusual discharge facilities to reduce the risk level of the dams during the extreme operating condition is blank. Based on the theoretical framework of single DB-IWHR model, a cascade dam break flood simulation software was firstly established. Considering the extreme operating condition (super standard flood combine with discharge gate failure caused by earthquake)and the discharge capacity, the paper simulated the dam break discharge, flood routing and water level of the control cascade reservoir to evaluate the safety of the whole cascade dams. The simulated results show that, for the layout 'Class Ⅰ dam-earth rockfill dams-Class Ⅰ', the unusual discharge facility should be considered in the design of the up Class Ⅰ dam. For the layout 'Class Ⅱ dam-earth rockfill dams-Class Ⅰ dam', by adding unusual discharge facility or improve the discharge capacity for the Class Ⅰ dam, it can lower the water level of the reservoir obviously after the break of the up Class Ⅱ dam which vacate larger storage capacity to deal with this break discharge. This analysis and discharge capacity improvement method not only can be used as an important tool to evaluate cascade dams risk under extreme operating condition, but also provide supports for the design criteria of the unusual discharge structures for extra height dam.

Keywords: cascade reservoirs; control cascade reservoir; discharge structure; cascade dam break; super standard flood

Experimental study on mechanical properties of marble under hydraulic weathering coupling

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Abstract: Aiming at the deterioration of performance under the action of hydraulic weathering of rock mass located in reservoir water fluctuating zone, the marble of Jinping hydropower station is chosen as the research object. A series of uniaxial and triaxial compression experimental tests on the marble under dry-wet cycling have been carried out to study the mechanical properties of marble, such as strength, deformation behavior and failure mode. The experimental results show that there is a negative correlation between the uniaxial peak strength of marble and the number of dry-wet circulation, and the degradation effect under the initial stage of cycle is remarkable; the internal friction angle of the marble after a small number of cycling times is almost constant, while the cohesion has decreased remarkably. In general, the effect of dry-wet cycling on marble cohesion is more sensitive than internal friction angle. The dry-wet cycling has a certain degree of softening effect on the marble and the elastic modulus of the marble decreases to the critical value after multiple repeated cycles. The increase in confining pressure can effectively weaken the softening effect.

Keywords: rock mechanics; marble; dry-wet cycling; mechanical properties; experimental study

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Comparative study on effect of induced joints of different interface patterns

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Abstract: Induced joints are commonly used to control cracks in the design of RCC arch dam. At present, Radial twist stitches are used in some projects. In those projects, it occurred that cracks appeared around the induced jointsbut the joint itself is not open during the construction period. In the view of fracture mechanics, it is about the split of induced joints under different interfaces. In this paper, a tutorial of a finite plate containing different interface patterns of joint cracks and a cylindrical arch dam is set, based on the stress change characteristics of RCC arch dam and the law of induced crack change, using virtual crack closure technique and Richard brittle fracture criteria to obtain equivalent Stress Intensity Factor of interface and study on the law of variation of crack intensity factor following the joint angle change. In order to acquire the effect of induced jointsfor different interface patterns, correction coefficient of equivalent strength namely theinterface space form factors $\lambda(\theta)$ for induced crack in the seam surface is achieved by getting the reciprocal of the normalized Stress Intensity Factor. The research shows that with the increase of the angle between the surfaces, it would be harder for the interface to be open, which means that the equivalent strength for joint surface is gradually increasing. Therefore, in practical design of RCC Arch Dam, it is better to use vertical seams, and the maximum angle of seam surface should not exceed 10° if radial twist stitch is used.

Keywords: RCC arch dam; induced joints; equivalent strength; space form; virtual crack closure technique

Derivation of the aggregation-decomposition principle for optimal load distribution of hydropower station

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Abstract: Inner-plant economical operation is the key factor of improving water power utilization efficiency of hydropower station, while the solution to the optimal load distribution (OLD) model is heavily restricted by the complex hydraulic connection and constraints. Aiming at this issue, this paper presents an OLD model for the hydropower station with complex conduit systems through analyzing the complex hydraulic connection between the conduit systems and the relationship among units' dynamic indexes and decomposing the complex system into different subsystems with imparity level according to the distributary node. Then this paper proposes a stratified hierarchical structured method to solve the complex conduit systems hydropower station OLD model by constituting the parallel units (series units) with the same unit-block water-head (unit flow) as an equivalent unit in subsystem. The principle and method are not only simple and clear, but also have some advantages such as flexibility, practicality and generality, which will lead to a promising prospect when it comes to the field of the parallel computing means dealing with the short-term optimal operation problem of giant-scale hydropower plant groups. The efficiency, adaptation and stability of the principle and method has been testified by the case study.

Keywords: complex conduit systems; optimal load distribution; aggregation-decomposition; equivalent unit

Using $\delta^{15}N$ and $\delta^{18}O$ values to identify sources of nitrate in the Dianbu River in the Chaohu Lake Basin

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Abstract: Since nitrate pollution in aquatic system has become an environmental problem in many regions of the world, it is of great importance to identify the sources of nitrate for pollution control. To identify different NO_3^- sources in surface water and to estimate their proportional contribution to nitrate mixture, a dual isotope approach ($\delta^{15}N-NO_3^-$ and $\delta^{18}O-NO_3^-$) and a Bayesian model (Stable Isotope Analysis in R, SIAR) were applied for the water of Dianbu River, a tributary of Chaohu Lake, during the period of dry season (January 2016) and flood season (July, 2016). Four potential sources (NO_3^- atmospheric deposition, AD; NO_3^- derived from soil organic matter nitrification, NS; NO_3^- derived from chemical fertilizer nitrification NF; NO_3^- and manure and sewage, M&S) were identified. The results indicate that the different nitrogen fractions in the water possess significant spatial-temporal variability. The average concentrations of total nitrogen(TN) and NO_3^--N in the up-stream water during the flood season were 4.87 mg/L and 2.73 mg/L respectively, higher than those(3.09 and 1.17 mg/L) during the dry season, while NH_4^+-N concentrations during the dry season were higher than that during the flood season. TN, NO_3^--N and NH_4^+-N concentrations at middle-lower reaches during the flood season were 6.62, 3.23 and 1.57 mg/L respectively, significantly lower than those(10.52, 4.26 and 3.66 mg/L)during the dry season. Nitrate is the dominant form of inorganic nitrogen, while the ammonium in sewage. The $\delta^{15}N-NO_3^-$ values of water ranged from 3.89‰ to 9.35‰ (with a mean value of 6.38‰) during the dry season, which were higher than those during the flood reason (in the range of 1.98‰-9.12‰, with a mean value of 5.02‰); however, the $\delta^{18}O$ values of NO_3^- during the flood season (in the range of 5.11‰-11.86‰, with a mean value of 9.17‰) were lower than those during the dry season (in the range of 1.46‰-7.53‰, with a mean value of 4.50‰). Manure and sewage, soil N and chemical fertilizer might be the main NO_3^- polluted sources to the water of Dianbu River. Both chemical and isotope characteristic indicate that denitrification is not the main N cycling process in the study area. Using SIAR, the contribution of each source is apportioned. The source apportionment results showed that the contribution of AD, NS, NF and M&S were 7%-18%, 24%-29%, 18%-30% and 28%-48% respectively. Therefore, it will be more effective to reduce the nitrate pollutant loads of the river to lake by control the agricultural non-point source pollution input at the up-stream of Dianbu River, and the strictly prohibited discharge of domestic sewage from towns, as well as the industrial waste water according to the watershed spatial distribution.

Keywords: nitrate pollution; nitrogen and oxygen isotope; SIAR model; contribution rate; Dianbu River

Numerical simulation research on the flood propagation and riverbed deformation in the Inner Mongolia reach of the Yellow River

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Abstract: Research on the flood process in the Inner Mongolia reach of the Yellow River can provide the key support to the river regulation and water resource development in the upper reach of the river. The aim of this study was to investigate the response to the different scales of floods in the Inner Mongolia reach through a three-dimensional model, in which the simulation region is from Bayangaole gauging station to Toudaoguai gauging station. The simulation results show that currently the time of flood propagation from Bayangaole to Toudaoguai generally requires 7-9 days, behaving larger than that in the 1980s due to the persistent deposition. Thereinto, the flows primarily discharge through the main channel in the reach between Bayangaole gauging station and Sanhuhekou gauging station. Meanwhile, the extent of overbanking gradually intensifies downstream. With respect to the riverbed deformation, it is effective to control the relationship between the incoming water and sediment to restrain the shrinkage of the main channel; and surely that there exists a nonlinear relationship between channel scouring and incoming water-sediment conditon. Additionally, the process of curve cut-off in the local reach is simulated by keeping the continuous large floods at the upstream. It indicates that the behavior of curve cut off could improve the sediment conveying capacity, which can benefit the river training in this reach.

Keywords: Inner Mongolia reach of the Yellow River; flood process; numerical simulation; curve cut-off

Elastic foundation beam model of frost heave damage of trapezoidal canal considering interaction between frozen soil and lining stucture

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Abstract: The article proposes a method to calculate frost heave force on lining plates for trapezoidal lining canal in open system by treating frozen soil as Winkler elastic foundation. Through introducing additional term proportional to deformation to reflect reduction of frost heave force caused by frost heaving deformation, differential equations of deflection of the beam on frozen soil are derived. The models of canal bottom and slope plates are established respectively, then analytic formula of deflection, moment and shearing force of both bottom and slope plates are proposed by solving aforementioned equations. By taking a trapezoid canal in Tarim irrigation area as prototype, frost heave displacements of lining plates are calculated. The comparative analysis between the results calculated by the article method, material mechanical and observed value is carried out. The comparative results show that the results calculated by the article method are in accordance with observed value better, and are less than results calculated by material mechanical because of considering reduction of frost heave force caused by frost heaving deformation. The research will be useful for anti-frost design of trapezoidal channel.

Keywords: frozen soil engineering; irrigation canal; frost heave; elastic foundation beam; differential equation of deflection curve

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Unsteady rainfall infiltration model for swelling soil

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Abstract: The soil swelling and deformation will happen when swelling soils absorb water. Soil swelling and deformation has great influence on soil water infiltration process. Based on Green-Ampt, an algorithm considered soil swelling and deformation was proposed for simulating infiltration into swelling soil under unsteady rainfall (GJGAM). The soil saturated hydraulic conductivity and soil saturated water content considered soil swelling were introduced to account for the effect of soil swelling on soil rainfall-infiltration, and could be approximately determined by soil physical properties. Meanwhile, the model (GJGAM) and the traditional Green-Ampt model without considering soil swelling (TGAM) were applied to simulate runoff rate and cumulative infiltration, and compared with the observed data in the experiments. The results indicate that the calculated runoff rate and cumulative infiltration by the GJGAM model were all in good agreement with the observed values. However, when using the TGAM model, the calculated runoff rate was less than the observed value, and the calculated cumulative infiltration were larger than the observed value.

Keywords: soil swelling; Loess soil; Green-Ampt model; soil infiltration-runoff

Filling transient analysis in pipelines with air valves

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Abstract: Air valve plays a critical role in prevention of column separation and water hammer in pipeline systems. The existing research on air valve application focuses on full pipe flow field, but few studies on water hammer protection with air valve in filling process are considered. To this end, the mathematical model of air valve during pipeline filling is built. A method that combines improved Newton iteration method with direct solving method is proposed in order to calculate the air valve model. On this basis, three different types of air valves including air admission valve, air inlet and release valve, and air inlet and micro exhaust valve are employed to study the effect of air valve on filling transients. It is indicated that the air inlet and micro exhaust valve is the most appropriate air valve type for the water hammer protection during pipeline filling. This research provides the reference value for the filling transient analysis in pipelines with air valves.

Keywords: air valve; pipeline filling; water hammer; hydraulic transient; improved Newton iteration method

Analysis of three-dimensional flow characteristics of Chinese sturgeon spawning ground

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Abstract: Chinese sturgeon is facing a serious population resource problem. Identifying the water flow characteristics of Chinese sturgeon spawning ground can provide more accurate and reasonable technical parameters for rehabilitating the spawning ground and protecting natural population. In this paper, Chinese sturgeon spawning ground under the Gezhouba dam was taken as the simulation reach, fluid dynamics software Fluent was used to simulate a three dimensional water flow process of the simulation reach in the spawning period. Change rule and value range of velocity, vorticity and turbulence kinetic energy in different functional zones of spawning ground was analyzed. The results show that hydraulic parameters for different functional zones are placed in different range. The bottom flow velocity is basically greater in the spawning area than that in the sowing spawn area, and the smallest is in the attachment & hatch area. The vertical variation of flow velocity in the sowing spawn area is bigger than that in the spawning area. Vorticity is basically greater in the sowing spawn area than that in the spawning area, and the smallest is in the attachment & hatch area. Strongly turbulent flow is located substantially in the upper and middle part of water column. Bottom turbulent kinetic energy has little change in various functional areas, especially the value in the attachment & hatch area is not obviously different from that in the sowing spawn area. Water flow condition of the spawning ground under Gezhouba dam is not particularly conducive to fertilization and spread of Chinese sturgeon eggs. In order to clarify the spawning characteristics of Chinese sturgeon, we need to carry out numerous simulation, comparison and analysis.

Keywords: three dimensional flow simulation; change rule; value range; Chinese sturgeon spawning ground