Research on ecological impacts of the joint operation of cascade reservoirs in the upstream of the Yellow River

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Abstract: Aiming to reveal the impacts of the joint operation of cascade reservoirs on riverine ecosystems, this study adopts Indicators of Hydrologic Alteration (IHA) to analyze hydrologic alterations in the upstream of the Yellow River in different reservoir operation periods which is based on long-term measured flow data. A multi-series contribution rate division method is developed to quantify the influences of different factors. Sediment transport rate method and cross-section deposition patterns analysis are used to show the erosion and deposition in the upstream of the Yellow River using long-term measured sediment data. The results show that reservoir operation has significant ecological impacts on both runoff and sediment transport which have been altered dramatically. The runoff has become steadier after reservoir operation: the monthly average flow has increased in the non-flood season while decreased in the flood season; the frequency and magnitude of high flow events has declined. Moreover, sediment deposition has become more and more serious in the Ningxia-Inner Mongolia reach. Besides, the typical cross-section has become wider and shallower. This study proves that reservoir operation is the most important cause of the hydrologic alterations in Lanzhou, and it is also an important cause in Shizuishan and Toudaoguai. It is revealed that the decrease of high flow events has aggravated the channel sedimentation, which can impose negative ecological impacts on this river. For better conservation of river health, it is necessary for reservoirs in the upstream of the Yellow River to adopt ecological operation, increasing water release in the rising-water season and flood season and creating high flow events. This study provides important information to the ecological impacts assessment of the joint operation of cascade reservoirs and the ecological operation of cascade reservoirs.

Keywords: cascade reservoirs; flow regime; erosion and sedimentation; contribution rate; ecological operation

Experimental study on properties of compressive strength and failure criteria of river ice under triaxial compression

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Abstract: In order to study the mechanical properties and failure criteria of river ice under complex stress state, constant axial loading rate (0.4 mm/min) triaxial compression experiments were carried out on columnar freshwater ice at four temperatures (−6, −12, −18 and −24 °C) and three confining pressures (500, 1000 and 1500 kPa). The stress−strain curves and the relationship between the peak value of generalized shear stress with temperature and confining pressure have been obtained. The Mohr Coulomb criterion was used to analyze the influence of temperature and confining pressure on the intensity parameters of river ice. The results indicate that the failure types of the columnar ice are mainly as shear failure and ductile failure under the selected experimental conditions. The peak value of generalized shear stress increases approximately linearly with the increase of confining pressure at constant temperature, and decreases approximately linearly with the increase of temperature at constant confining pressure. To explain the failure criterion of columnar ice by Mohr Coulomb theory under four experimental temperatures, the internal friction angles are 21°, 45°, 42° and 52°, and cohesive strength are 1191.6, 513.2, 861.6 and 933.4 kPa, respectively. Considering the energy characteristics, the energy dissipated by triaxial compression of the columnar ice increases gradually with the increase of the confining pressure.

Keywords: river ice; triaxial compression; strength; failure criteria

Field investigations on lateral and bottom melting of lake ice and thermodynamic analysis

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Abstract: The melting of lake ice under weak hydrodynamic conditions is a complicated thermodynamic process. In the melting period, field observation of the melting of lateral and bottom sides of ice cover near the open water in the Ulansuhai Lake was conducted, and the meteorology and hydrology factors were measured. The results showed that the ice lateral surface melt and leaned to inside with increased depth, and the ice thickness decreased. The temperatures of water and ice varied in layers, and those in the top layer had large daily changes. A parameterization model was established to estimate the melting rate with net solar irradiance and water temperature. The ice-bottom heat flux is an important thermodynamic parameter. Based on the energy balance, the ice-bottom heat flux near the open water can be determined, which was 11.47~135.61 $W \cdot m^{-2}$ indicating that the water under ice was transferring heat to ice.

Keywords: lake ice; melting; water temperature; solar radiation; ice-bottom heat flux; field investigation

Research on the determination of permeability coefficient of unsaturated remolded loess under wetting condition

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Abstract: The suitability of three direct methods i.e. wetting front advancing method, Boltzmann transformed method and instantaneous profile method for determining the permeability coefficients of unsaturated remolded loess under wetting condition were studied and the improvement of the three methods were made. Firstly, horizontal infiltration was carried out on the remolded loess. The first two method were improved and the effectiveness was checked. The unsaturated permeability obtained by the two improved method, instantaneous profile method and two other indirect methods were compared. Then software Hydrus was used to simulate the infiltration test by adopting the permeability parameters determined by the different methods and the relationship of wetting front and time were compared with the measured value, and the hypothesis in wetting front advancing method and Boltzmann transformed method were analyzed. In addition, the improvement of instantaneous profile method on the layout of measurement points and the effectiveness were also studied. The laboratory test results indicate that the permeability coefficient obtained by wetting front advancing method adopting the new formula for hydraulic gradient is more stable. The relation between the new Boltzmann transformed parameter λ^* and volumetric water content is more unified. The unsaturated permeability coefficients obtained by instantaneous profile method deviates from that obtained by other methods due to large space between measure points. The numerical simulation results indicate that the hypothesis in wetting front advancing method, that is, the moisture profile move forward in parallel, and the hypothesis in Boltzmann method, that is, the relation between the Boltzmann transformed parameter and volumetric water content is unified, are reasonable only after the water infiltrating a certain distance. After adopting the improved placement location and space of measurement points, the unsaturated permeability coefficient under different suction determined by the instantaneous profile method is more near to that obtained by the first two improved methods. However, these values determined by the first two improved methods are more close to the input values.

Keywords: unsaturated permeability coefficient; loess; instantaneous profile method; wetting front advancing method; Boltzmann transformed parameter

An impact factor for underwater explosion considering effects of spherical wave

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Abstract: Safety and protection of hydraulic structure is significant in national defense. There is no effective index to evaluate the dynamic responses caused by underwater explosion. Generally, the shock wave generated by underwater explosion propagates spherically. This paper derives the total energy of structure subjected to spherical wave. A new impact factor is established, which can be used to evaluate the vibration and deformation responses of structures. Numerical modeling and centrifugal underwater explosion test were conducted on air-backed structure to investigate the capability of the impact factor. The numerical results indicate that changes of standoff distances almost have no influence on the strain energy and kinetic energy on plate as long as the impact fact is kept constant. Then, the impact factor is used to characterize the centrifugal test results. The impact factors in this paper are more suitable for both near and far field underwater explosion compared with scaled distance or plane wave impact factor.

Keywords: impact factor; spherical wave; underwater explosion; plate

Acceleration distribution behavior of concrete face rockfill dams in the near-fault region

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Abstract: In the strong seismic zone of western China, many rockfill dams with heights over 200m have been built or designed. Some of these high dams are located in the near-fault region. At present, the design code is only applicable to the dams lower than 150m, and it doesn't consider the characteristic of near fault ground motions. In this study, the finite element analysis is performed for 40m, 70m, 150m and 200m dams to compare the dynamic acceleration responses of the dams subject to the near-fault ground motions and standard earthquake waves. The results show that the peak accelerations of the dams subjected to the near-fault ground motions are significantly greater than that subjected to standard earthquake waves. Therefore, a suggested acceleration distribution figure of the rockfill dam in the near-fault region is proposed, which offers a reference for the aseismatic design.

Keywords: rockfill dams; acceleration distribution; near-fault ground motion; seismic design intensity

Discrete gradient progressive optimality algorithm for mid-long-term optimal operation of multi-reservoir system

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Abstract: Making full use of existing hydropower resources and carrying out mid-long-term optimal dispatch of reservoirs is important for building a clean, low-carbon, safe, and efficient modern energy system. The progressive optimality algorithm (POA) converts multi-stage problems into multiple two-stage sub-optimization problems. It is an effective and widely used algorithm for solving mid-long-term optimal operation of multi-reservoir system. However, with the increase in the number of reservoirs, POA will still face serious "curse of dimensionality". Based on the gradient descent method, the concept of discrete gradient and the discrete gradient progressive optimality algorithm (DGPOA) are proposed. This algorithm makes full use of local discrete gradient information to determine the optimal search direction without derivation and can quickly obtain optimal results. Finally, the algorithm was applied to the cascade system of the 5 reservoirs of the Lancang River Basin. The results of POA, POA-DPSA, and DGPOA with different discrete precisions and inflow scenarios were obtained. The results show that the DGPOA computing performance can reach 8 to 12 times the POA-DPSA algorithm and 50 to 250 times the POA algorithm without significantly reducing the global search capability. The conclusion can be drawn that DGPOA is an effective algorithm to solve the "curse of dimensionality" problem in the mid-long-term optimal operation of multi-reservoir system.

Keywords: optimal operation of multi-reservoir system; gradient descent method; progressive optimality algorithm; curse of dimensionality

Uncertainty analysis of surface water and groundwater coupling simulation model based on Monte Carlo method

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Abstract: In order to analyze the influence of the uncertainty of the parameters on the output results of the surface water and groundwater coupled simulation model, this paper uses the Monte Carlo method to analyze the uncertainty of the surface water and groundwater coupling simulation model, and carries out the risk assessment on the basis of the results of uncertainty analysis. In this paper, the coupling simulation model of surface water and groundwater is established by taking the water catchment of the Yin Ma River in the upper reaches of the Shitoukoumen Reservoir as example, and the HydroGeosphere (HGS) software is used to solve the model. Local sensitivity analysis method is used to identify the parameters with high sensitivity in the coupled simulation model as random variables. Then the Monte Carlo method is applied to analyze the uncertainty of the simulation model. In order to reduce the computational load in the process of uncertainty analysis, a surrogate model of simulation model is established by using Kriging method. The results show that the most sensitive parameters in the coupling model of surface water and groundwater are hydraulic conductivity, porosity and Manning roughness coefficient. The Kriging surrogate model can significantly reduce the computation load under certain accuracy. The risk assessment results show that the risk probability of groundwater ecological environment deterioration is 6%, and the probability of surface water environment deterioration is 15%.

Keywords: the surface water and groundwater coupled simulation model; sensitivity analysis; surrogate model; uncertainty analysis; kriging model

Experimental study on mode-I fracture toughness and its correlation with strength characteristic of sandstone under dry-wet cycles

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Abstract: Taking the actual environment of the hydro-fluctuation belt of a typical bank slope in the Three Gorges Reservoir Region as background, by means of prefabricating mode-I cracks in the sandstone specimens, one test scheme of drying-wetting cycles is adopted to explore the mechanical characteristics and damage degradation mechanism of mode-I sandstone specimens immersed in different chemical solutions. The variation regularities in the physical and mechanical prosperities were analyzed under the effects of chemical solutions and drying-wetting cycles. Experimental results show that sandstone specimens have a significant damage deteriorating trend under effect of chemical solutions and drying-wetting cycles. In the first 0~1 drying-wetting cycles, the degradation degree of sandstone specimens immersed in alkaline Na_2SO_4 (pH=12.0) solutions is the smallest, however, its damage degree in Na_2SO_4 (pH=12.0) solutions gradually increased with the increasing of F-T cycles, but it is still less than that in the acid Na_2SO_4 (pH=3.0) solution and was greater than that in neutral Na_2SO_4 (pH=7.0) solutions. There is a difference in the damage deterioration degree of mechanical properties under effect of chemical solution and drying-wetting cycles, that is, the damage deterioration degree of fracture toughness K_{IC} is the greatest, that of compression strength is the smallest. Meanwhile, there are obvious linear relationship among fracture toughness K_{IC}, compression strength and tensile strength under the effects of different chemical solutions and drying-wetting cycles. Meanwhile, there are also obvious consistency relationship among the damage degree of mechanical proprieties, its damage degree of physical proprieties and the ions concentration dissolved in the corresponding chemical solution. Therefore, the correlation relationships among physical and mechanical proprieties of sandstone, damage variables and the ions concentration of calcium and magnesium are obtained. The crack propagation radius can be used to indicate the damage deterioration degree of mechanical proprieties under chemical solutions and drying-wetting cycles.

Keywords: jointed rock mass; chemical erosion; dry-wet cycle; mode-I fracture toughness; correlation

Long-range precipitation forecasting based on multi-pole sea surface temperature

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Abstract: Long-range precipitation forecasting is very important for reservoir flooding control and comprehensive utilization operation. However, due to the complexity of weather system, existing approaches for long-range precipitation forecasting suffer from relatively large biases, and consequently they are still inadequate to provide enough references in practice. This study proposed a multi-pole method based on sea surface temperature to forecast long-range precipitation, and applied it to the upper Yangtze River. The results indicate that the multi-pole method is able to forecast monthly precipitation during flooding seasons from 1961 to 2017. Compared to the traditional linear regression, multi linear regression and canonical correlation analysis methods, the multi-pole method is more robust and accurate, particularly during the early and late periods of flooding season.

Keywords: monthly precipitation; long-range forecasting; multi-pole method; the upper Yangtze River

Multi-objective optimization and its application on irrigation scheduling based on AquaCrop and NSGA-Ⅱ

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Abstract: In order to develop reasonable deficit irrigation schedules in arid area, a multi-objective simulation-optimization model, which is based on crop growth model (AquaCrop) and non-dominated sorting genetic algorithm (NSGA-II), for irrigation scheduling was proposed and applied on the optimization and decision-making of irrigation scheduling. Two years' (2014-2015) field experimental data of spring wheat under various irrigation-mulching treatments in the oasis of Shiyang River basin, Gansu Province were used to calibrate and validate the AquaCrop model. The typical years of 25%, 50% and 75% precipitation assurance were determined by optimum curve-fitting method according to the historical meteorological data (1963-2016). Taking maximum crop yield and minimum irrigation as the objectives, the relationship curves between irrigation amount and crop yield were solved under different conditions. The influence of film mulching on the optimized results was analyzed, and the decision-making for both farmers and farm corporations were made. The results show that: (1) The marginal yield of crops would decrease with the increase of irrigation amount. The crop water production function after optimization of irrigation scheduling could be fitted by quadratic function. (2) With the increase of irrigation amount, the enhancing effect of film mulching on crop yield would decrease. (3) Under the condition of non-mulching, less irrigation times would be preferred under the low irrigation amount and more irrigation times would be preferred under the high irrigation amount. (4) Various irrigation scheduling decisions could be achieved by using different effective functions for decision-makers.

Keywords: AquaCrop; NSGA-II; optimization of irrigation scheduling; film mulching; simulation-optimization

Transient process pressure analysis of hydroelectric power station based on isoentropy principle

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Abstract: Transient process test of hydraulic machinery is an effective way to verify the calculation model for regulating guarantee. By now, due to the lack of relevant guidance for the data analysis of transient process, there is often a significant deviation between the test results and the calculation results of regulating guarantee model. Therefore, permutation entropy (PE) and empirical mode decomposition (EMD) were introduced and isoentropy principle method was proposed for transient pressure data analysis. Firstly, EMD was applied to obtain intrinsic mode functions (IMFs) for the measured pressure signal. Secondly, by implementing entropy-increasing process, synthesize IMFs from high to low orders until the PE values of synthesized signal and regulation calculation result are identical; then use the synthesized signal to check regulation guarantee calculation model. The case research indicates that combining with EMD the pressure trend of signal manipulated by isoentropy principle can be obtained in hydraulic machinery transient processes, and the evaluation of regulation guarantee calculation can be achieved.

Keywords: hydraulic machinery; transient process; pressure data analysis; empirical mode decomposition; permutation entropy

Influence of hub ratio on hydraulic performance and structural strength of bulb tubular turbine

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Abstract: In order to deeply study the influence of hub ratio on the hydraulic performance and structural strength of the bulb tubular turbine, several 3D numerical simulations of five hub ratios were carried out with three different working conditions through widely used ANSYS CFX software. The steady and unsteady calculation results were analyzed and the optimum hub ratio of the turbine was determined. The one-way fluid and structure interaction calculation was carried out based on the ANSYS Workbench platform, and the hydraulic characteristics and the static stress of the partial structure of the runner before and after the hub ratio optimization were compared and analyzed. The results showed that, after the reduction from the original hub ratio 0.35 to the optimal hub ratio 0.31, the passage flow area increases as well as the flow rate, which lead to the improvement of the operating efficiency and the unit output. Besides, the pressure difference at back of the blade decreases, and the flow velocity becomes more uniform. Furthermore, the maximum amplitude of pressure pulsation reduces from 6.60% to 0.46%, and the displacement deformation and static stress distribution of the runner are basically the same. Both the maximum displacement and the maximum static stress increase slightly and still meet the structural strength requirements. The research results in this paper could provide a reference for solving the problem of insufficient output of this type of turbine, which have a guiding significance for the optimal design and manufacture of the hydraulic turbine.

Keywords: bulb tubular turbine; hub ratio; hydraulic performance; structural strength; numerical simulation