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Research on parallel dynamic programming based on feasible region search mapping

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Abstract: To overcome the difficulties in selection of the constraint processing mechanism and long calcnlation time by using the traditional dynamic programming for optimizing reservoir group operation, a mapping model for feasible region search is developed based on knowledge of the set and mapping theory. A parallel dynamic programming algorithm is put forward on the basis of feasible region search mapping. Through construction of the feasible solution search space and a parallel computing mode, this algorithm can avoid the calculation of invalid state combinations and give full play to the power of multi-core computers, thus improving computational efficiency. As an example, the joint scheduling of three reservoirs in Lixianjiang river basin is taken for case study. In terms of annual generated energy, calculation time and other criteria, detailed comparative analysis is conducted over the improved algorithm, the traditional dynamic programming and also progressive optimization algorithm. The results show that the proposed algorithm can reduce computation time while ensuring global convergence of the solutions, which provides scientific reference for making the optimal scheduling strategy of cascade reservoirs.

Keywords: mapping; feasible region; parallel computing; dynamic programming; joint operation

Experimental study on uniaxial compressive strength features of ice from Wuliangsuhai Lake

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Abstract: In order to accumulate the actual data concerning uniaxial compressive strength of thermal growth fresh water columnar ice, we chose the columnar ice in Wuliangsuhai Lake where is a kind of furiotile lake beside the Yellow River as samples in the experiment. We loaded the samples in the directions vertical to the ice surface and parallel to the ice surface under different displacement speeds at −2℃, −5℃, −7℃, −10℃ and −15℃ by electronic universal experiment machine with strict temperature control and displacement speed control. The influence of strain rate, loading direction and temperature on the uniaxial compressive strength were studied. It was found that the uniaxial compressive strengths vary with the strain rates and temperatures. At a certain temperature, the strength feature increased to a peak value firstly, and then reduced, and finally was tending toward smooth with the increase of strain rate, The ice samples include three destruction forms: bulging failure, shear failure and splitting failure. In the range of the test temperature, the ice strength decreases with the increase of experiment temperature. The uniaxial compressive strength can be fitted into a surface with the influence of temperature and strain rate. The strength loaded in the direction vertical to the ice surface is larger than that parallel to the ice surface. For the columnar ice in Wuliangsuhai Lake, the peak uniaxial compressive strength loaded in the direction vertical to the ice surface is 2.1 times as large as the strength loaded in the direction parallel to the ice surface firstly, the strain rate at the peak strength increases with ice temperature increasing secondly and logarithmic function can be used to express the variation of peak strength with ice temperature at last.

Keywords: fresh water ice; compressive strength; temperature; strain rate; experiment

Effect of nano-modification on double-K fracture parameters of recycled concrete

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Abstract: Compared with natural aggregate, recycled aggregate has lower apparent density, higher water absorption and larger crushing index. Therefore, there are some defects in the performance of recycled aggregate concrete (RAC). In this paper, nano-SiO_2 solution was used to strengthen RAC. Three-point bending beam method was adopted to conduct fracture experiment of specimens with varying recycled aggregate replacement rates (0, 50%, 70%, 100%) and specimens with varying replacement rates (50% and 100%) and varying SiO_2 addition, 12 groups of 60 specimens in all. Double-K fracture parameters were used to assess the fracture property of recycled concrete and to investigate the effect of recycled aggregate replacement rates and addition of SiO_2 on the fracture property of recycled concrete. The results show that the initial cracking toughness and the unstable fracture toughness of RAC decreased with the increase of RAC rate. Appropriate amount of nano-SiO_2 can improve the fracture toughness of RAC, when the replacement rates of recycled aggregate were 50% and 100% respectively, and the content of nano-SiO_2 was 1.0%, the enhancement for initial cracking toughness and unstable fracture toughness of recycled concrete was the highest, reaching 0.6929 MPa·$m^{1/2}$ and 1.3073 MPa·$m^{1/2}$ respectively for recycled concrete with 50% recycled aggregate and 0.5552MPa·$m^{1/2}$ and 1.2410MPa·$m^{1/2}$ respectively for recycled concrete with 100% recycled aggregate.

Keywords: recycled concrete; nano-SiO_2; fracture property; three-point bending beam method; double-K fracture parameters

Study on unsteady flow field of butterfly valve in startup process of pressure-driven water diversion system in pumping station

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Abstract: Butterfly valves are widely used in pressure-driven water diversion systems. The opening process of the valve is a necessary stage for the system operation. In this process, the valve disc rotates in the flow field according to prescribed law, which will induce the variable-pressure and variable-section transient flow. In this study, based on the quasi-constant assumptions and Bernoulli equation for the pipe sections upstream and downstream of the butterfly valve, and the dynamic grid strategy for the 3D fluid domain, a numerical method for simulating the butterfly valve opening process is presented. This method combines the one dimensional and three dimensional calculations. The dynamic boundary conditions and data updating scheme used for simulation are proposed. The three dimensional numerical simulations of unsteady characteristics of butterfly valve opening process are carried out. The results show that the flow rate increases rapidly and runs up to 90 % of the rated flow with the valve disc angle varying from 0° to 45°, and then increases slowly with the disc angle increasing from 45° to 90°. The hydraulic torque of the valve disc increases rapidly and then decreases slowly, and the maximum value of hydraulic torque appears when the disc angle is 20°. It can be found that the downstream flow field of the valve disc has specific evolution characteristics, which show the transformation from two main vortices to smooth streamline. This study reveals the mechanism of hydraulic transient change during the opening of butterfly valve. The results could be used to direct optimization design of butterfly valve and stable operation of water supply system.

Keywords: pumping station; pressure-driven water diversion system; opening process of butterfly valve; evolution of flow field

Probability distribution calculation of the sum of hydrological random variables based on Copula function approach

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Abstract: The distribution probability calculation of the sum of hydrological random variables is a key content for the design flood in regional composition and the design flood in downstream area of cascade reservoirs. It is also important for planning, designing and management of water resources projects in downstream area of cascade reservoirs, and evaluating urban flood risk. But probability distribution of the sum of random is derived by two dimensional random function distribution, its marginal distributions must have the same type probability distribution, and the applications are limited in practical. In this study, based on the probability distribution definition of the sum of two dimensional random variables, a probability distribution calculation model of the sum of two dimensional dependent random variables was proposed by using of Copula function and mathematical transformation. This model was also extended to calculate probability distribution for the sum of two dimensional dependent random variables with Gamma and P-Ⅲ marginal distribution, respectively. The proposed model, which expressed as an integral of one dimensional conditional Copula, can overcome shortcomings of information distortion in data transformation process of probability combination discrete summation method, and the same type marginal distributions. Taking the 3h flood volumes of downstream area of the Qingjiang cascade reservoirs as an example, the proposed model calculation method and procedures were given. It also indicates that the model in this paper can provide some basic theories for the design flood region composition and design flood of downstream area of cascade reservoirs.

Keywords: dependent; sum of random variables; probability calculation; Copula function; Qingjiang watershed

Discussion on the application conditions of diffusion equations of suspended sediment transport

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Abstract: The transport of suspended sediment is one of the important issues in the field of river dynamics, which has been studied by using kinds of theories and methods. In this paper, the application conditions of diffusion equations based on these different theories were discussed. The results show that the traditional diffusion equation and the modified ones is valid when the sediment concentration is low and the particle inertia is small enough; the diffusion equations based on two-phase theory are also applied to the same conditions as the traditional diffusion equation because the inertial effect is not considered. Recently, a diffusion equation proposed by Snehasis Kundu1 and Koeli Ghoshal based on the relation for the drift velocity takes account of effects of lift force, particle turbulence, and particle inertia, which makes this equation suitable for high concentration and large inertia condition. However, the empirical constant is still adapted to determine the sediment diffusion coefficient, which has become the limitation of this model; the diffusion equation derived from the PDF equation and the dispersion equation, both of which are based on the kinetic theory, take account of effects of lift, particle turbulence, particle inertia and other factors on the sediment suspension except the gravitation and the turbulence. Therefore, these two equations can be used in the condition of high concentration and large inertia. Especially, the dispersion equation contains the effects of sediment concentration, the interaction between liquid and solid phase, the particle turbulence and collisions among particles on the sediment suspension, which can illustrate the underlying mechanisms of suspended sediment transport.

Keywords: suspended sediment; diffusion equation; concentration; particle inertia

Construction and application of a new comprehensive drought index based on Copula function

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Abstract: Drought index is an important tool for the study of drought, and the construction of comprehensive drought index is the frontier and trend of drought monitoring and risk assessment. Based on Archimedes's Copula function, combined rainfall (Meteorology) and runoff (Hydrology), we constructed a new comprehensive drought index (*MSDI*p) that can comprehensively characterize the meteorology drought and hydrology drought. It is used to characterize the characteristics of drought evolution in the Weihe River basin. The results indicate that: (1) the *MSDI*p index can not only capture the occurrence of drought as well as the standardized precipitation index (*SPI*), but also describe the duration and termination of drought as well as the standardized runoff index (*SRI*). It possesses the advantages of both meteorological index and hydrological drought index in characterizing drought, which can comprehensively characterize the characteristics of drought evolution. (2) Influenced by climate changing and human activities, the comprehensive drought in the Weihe basin has increased significantly over the past 50 years. (3) There is a change point in the comprehensive drought index sequence of the Weihe basin (1994), and in the future, the risk of drought is increasing. (4) Sunspot and atmospheric circulation anomaly factors have great influence on the occurrence of comprehensive drought in the Weihe basin, of which sunspot activity is the strongest. In addition to the direct influence, sunspot can also influence the occurrence of comprehensive drought by affecting the atmospheric circulation anomaly factors.

Keywords: drought; comprehensive drought index; Copula function; sunspot activity; Weihe River basin

Uncertainty of bivariate design flood estimation and its impact on reservoir flood prevention

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Abstract: The limited sample size would induce quantile estimation uncertainty in bivariate hydrological frequency analysis. A copula-based parametric bootstrap uncertainty (C-PBU) model considering the most likely realization to characterize the uncertainty of bivariate design flood estimation is proposed, and the quantitative uncertainty evaluation indexes are presented. The impacts of joint quantile estimation uncertainty on reservoir operation are explored and such uncertainty of highest reservoir water level derived from different typical flood hydrograph (TFH) schemes were compared. The 95% confidence regions of bivariate quantile estimation in the Geheyan reservoir are derived, and the influences of different sample sizes on uncertainty are investigated. The results demonstrate that the bivariate quantile estimation and TFH selection have large uncertainty. It is suggested to consider the uncertainty of reservoir flood prevention in practice by using of the C-PBU model.

Keywords: design flood; reservoir operation; uncertainty; copula function; bootstrap; C-PBU model

Application of unsteady phreatic flow model and its solution under the boundary control of complicated function

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Abstract: Based on the Fourier transformation, a method independent on the transformation process is proposed to solve the phreatic unsteady flow model controlled by the complex canal-water-level boundary. The theoretical solution of the model is given by using the convolution definition and the differential property of the convolution. Lagrange linear interpolation is applied to the actual water level process, and the interpolation function is substituted into the theoretical solution, and the actual solution of the problem can be obtained easily. The results show that: (1) The method is relatively simple and the solution is composed of common functions with simpler forms; (2) The wiring method for calculating the parameters of the model based on the time course of the fluctuating speed of phreatic level is simple and convenient; (3) The boundary water level change process has a cumulative effect of two times the amplitude of the boundary water level in the exchange of water between the canal and phreatic water.

Keywords: transient phreatic flow; Lagrange interpolation; Fourier transform; convolution differential property; cumulative effects

Vibration transfer path identification of the hydropower house based on transfer entropy

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Abstract: The hydropower house is a sophisticated spatial structure, and its vibration testing signals are often mixed with various noises, which makes it more difficult to analyze the vibration source transmission path. In this paper, a new method was presented, which is combined the adaptive wavelet threshold denoising method based on EMD and the transfer entropy method. The method can accurately identify the vertical vibration transmission path of hydropower house. First, in order to denoise the vibration test signal, EMD decomposition and wavelet entropy method were adopted to adaptively determine the denoising threshold of the corresponding scale according to the energy characteristics of the signals. Then, the transfer entropy method was used to identify the transmission path of structural vibration source. The validity of the method was proved by the numerical simulation of the harmonic signals. Based on the field experiments vibration signals of a large scale hydropower house structure, the transfer direction and vertical transfer path of vortex belt were identified, the rate of information transmission between measuring points was also calculated. The results show that the main vertical vibration transfer path caused by vortex belt is as follows: draft tube → turbine pier (the foundation of stator and the foundation of lower bracket) → superstructure of the powerhouse (generator floor slab).

Keywords: hydropower house; empirical mode decomposition; wavelet entropy; transfer entropy; transfer path

Experimental and numerical simulation on bond behavior between polymer anchorage body and soil

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Abstract: In view of insufficient recognition of the mechanism of interaction between polymer anchorage body and soil as well as imperfect bond strength parameters, the bonding behavior between the low density (0.11~0.13 g/cm^3) polymer anchorage body and different status soil was studied by the large-scale model of concentric pull-out tests, and the load-displacement curve of loading end, the distribution of axial force and cohesive stress were obtained as well as the empirical value of the cohesive strength was put forward. From the view of micromechanics, the numerical model of anchor bolt-polymer anchorage body-soil systems was established by Particle Flow Code in 2 dimensions (PFC2D) software, and the anchoring mechanism of polymer anchorage body under pull-out load was analyzed. In addition, the rationality of the numerical model was verified by comparing with the model test results, and the variation law of stress and the porosity of soil were discussed emphatically. The experimental results provide the parametric basis for the design and application of polymer anchorage grouting, and the particle flow model provides a feasible tool for micro-scale study of the polymer anchorage mechanism.

keywords: polymer; anchorage body; particle flow code; micro-parameters; bonding strength

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A global optimization algorithm of upper bound method with inclined interface blocks for slope stability

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Abstract: Using the upper bound method with inclined interface blocks, the optimization methods should be adopted to search for critical sliding mode with the global minimize factor of safety. Because the optimization variables include slip surface positions and inclined interface angles, the freedom and nonlinearity are increasing significantly and searching for the global minimize factor of safety becomes more difficult. In this paper, a mathematical model of sliding mode optimization is provided, considering the slip surface sliding along the weak interlayer or not. In order to generate proper sliding modes during the random search process, some geometrical constraints are introduced, finally the optimization problem is converted to the minimize problem with multi-degree of freedom and bound constraints. Combined with genetic algorithm and particle swarm algorithm, some typical examples are analyzed. The result shows that the mathematical model proposed in this paper can avoid generating the unreasonable sliding modes during the random search process, with the result that the optimization efficiency is improved significantly and the non-convergence of numerical calculation is avoided. Combined the mathematical model with the global optimization algorithms, the solution obtained is reasonable and very close to the limit equilibrium solution.

Keywords: slope stability; critical sliding mode; upper bound method with inclined interface blocks; global optimization model

Study of staged drought-limited water level of the main reservoir in the large-scale irrigation district

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Abstract: As a common water conservancy project, especially in dry season with reduced rainfall and runoff, the reservoir plays an important role in water resources carrying capacity (WRCC), including water quantity, water quality, water ecology and water-flowing renewal. The drought limited water level is a controlled characteristic water line of reservoir when it is running at low water level. In this study, based on the characteristics of water inflow of Meishan reservoir in Pishihang Irrigation District and the characteristics of water demand from different users, the Hausdorff dimension fractal method is used to divide the inflow process of Meishan reservoir into several periods firstly, then the initial drought limited water level (subdivided into drought warning water level and dry water level) is calculated by water inflow and water supply in early-warning periods of different typical years. Based on the long series of simulation model and optimization model of water resources system in reservoir and irrigation district, the paper optimizes and determines the drought limited water level of Meishan reservoir in different early-warning periods. Finally, the rationality of drought limited water level is evaluated from several aspects such as reservoir operation, irrigation, production and living water consumption, ecological water supply and hydropower generation, which provides technical reference for the water conservancy department to guide drought relief operation in reservoir irrigation area and formulate corresponding drought relief plan.

Keywords: large-scale irrigation district; drought limited water level of reservoir; drought warning water level; dry water level; optimal

On the mechanism of drag reduction of wall microstructure flow control technique

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Abstract: In the present work drag reduction and its causes of wall microstructure flow control technique have been investigated experimentally. Pressure drop tests were carried out on a closed rectangular duct and particle image velocimetry was used to measure inner structure and corresponding flow parameters of boundary layer. Plates with micro-grooves or micro-riblets were fixed as the floor of the duck pipe. The result shows that a notable decrease in drag reduction for microstructure surfaces can be seen at a certain range of s^+. The dag reduction rate increased first then decreased with the increase of s^+, and a maximum rag-reduction of nearly 9.9 percent was acquired over the micro-grooves surface B. Microstructure can thicken the boundary layer and weaken turbulent fluctuation intensity. What's more, Reynolds shear stress, and root-mean-square velocity both decreased.

Keywords: flow control; wall microstructure; drag reduction rate; Reynolds shear stress; turbulent fluctuation intensity