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Study on dynamic evaluation of vibration quality of concrete dam based on real-time monitoring

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Abstract: The vibration quality evaluation of concrete dam is an important means for the quality control of the concrete dam construction. Traditional method combines artificial experience control with postmortem finite core sampling point detection to control the vibration quality of concrete dam; in addition, the existing vibration monitoring research on vibrator only uses a single rangefinder to range and lacks evaluation method of vibration quality. Taking into account the challenges and difficulties of real-time vibration quality dynamic evaluation and feedback control in concrete dam storehouse, this paper puts forward a real-time monitoring method of the vibration quality of concrete dam considering vibration quality acceptance management based on a ranging scheme with two rangefinders, and establishes a dynamic evaluation model for concrete dam vibration quality considering parameter uncertainty on the basis of this method. The model mainly includes the following contents: (1) conducting quantitative analysis of the uncertainty of concrete characteristic parameters by introducing the "information entropy" theory; (2) proposing the dynamic evaluation method of concrete compression strength based on random forest algorithm in the case of parameter uncertainty, and the evaluation results are applied to the whole dam storehouse surface vibration quality evaluation. The evaluation model are compared with the models built by multiple linear regression and artificial neural network algorithm, which verifies the consistency and superiority of the random forest model. The dynamic evaluation of the vibrating quality of the abnormal concrete area of a RCC dam project in southwest China is carried out by the evaluation method proposed in this paper. The results show that the method can accurately evaluate the vibration of concrete storehouse surface quality, and it also provides a theoretical basis for the vibration quality control of the concrete dam.

Keywords: concrete dam; vibration quality evaluation; vibration real-time monitoring method; uncertainty; random forest

Research and application of water-sediment co-scheduling model of reservoir based on reservoir-channels coupling relationships

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Abstract: In order to raise comprehensive benefit of reservoir on sediment-laden river, considering flood control, power generation, ecological remediation and discharge capacity maintenance of downstream channel, a mathematical model of multi-objective optimization of reservoir has been established by using dynamic programming method on the basis of reservoir-channels coupling relationships. It is composed of computation modules of sediment scour, power benefit and riverbed evolution in downstream channel. Among them, the riverbed evolution module is the focus of the whole mathematical model. The result of calculation is regarded as not only the critical state for the optimization dispatching, but also the boundary conditions for the next year. The model has been applied to the research of water-sand joint operation of Xiaolangdi reservoir. The results show that the model can effectively coordinate the benefits of flood control and power generation, and achieve comprehensive benefit on the basis of maintaining discharge capacity around 4000m^3/s. It is of great significance to solve the problem of water-sediment coordinative optimized dispatch in the reservoir of sediment-laden river.

Keywords: water and sediment regulation; optimal operation; coupled model; sediment movement; multi-objective decision-making

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Two-dimensional numerical simulation for surface runoff in catchments based on Godunov scheme

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Abstract: When the two-dimensional fully dynamic water equations (SWEs) are used to simulate the surface runoff propagation, the problem of drying and wetting conversion is encountered. To resolve this problem, a new numerical model has been developed using Godunov scheme based on the sheet flow concept. In this model, the corrected Roe's approximate Riemann solver for the calculation of fluxes in triangulated unstructured grid is used; the bottom slope terms are calculated directly by applying the Green's theorem, and the semi-implicit discretization method is adopted to deal with the highly nonlinear friction terms. The main advantage of this model is that the drying and wetting treatment becomes extremely simple, and no special reconstruction is required for the water surface and topography of the unit. The new model provides more comprehensive calculation capabilities, which are proved by four case studies. Finally, the model is applied in the Xiejiawan catchment for S curve calculation and rainfall runoff process simulation, and the result is reasonable and reliable. Therefore, the model has been proved that it has the ability to simulate surface runoff propagation in real-world catchments and it can provide a new way for the calculation of surface runoff in small watershed.

Keywords: surface runoff; two-dimensional numerical simulation; shallow water equations; unstructured grid; Godunov scheme

Size effect on frost heave damage for lining trapezoidal canal with arc-bottom in cold regions

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Abstract: In order to find out the influence of groundwater table, frozen depth and canal height on the frost heave damage for lining trapezoidal canal with arc-bottom on the frozen soil base, a classification system for frozen soil was described as closed system, semi-open system and open system in terms of the maximum capillary rise. Based on the thermal-moisture-mechanic coupled theory for frozen soil, 30 sets of lined canals with different sections were performed with the assistance of COMSOL Multiphysics software. The results of calculated displacement field and stress field show that within the range of the thickness of lining suggested by standard, the larger the scale of the canal with narrower and deeper section, and the larger the frozen depth and the more shallow the groundwater table are, the more serious damage of frost heave for lining canal will be. For the closed system, the small and medium size canals can be cracked at the center on the lower surface of the lining canal bed, while the large-size canals can be cracked both at the center on the lower lining surface of the canal bed and at the 2/3 height from the top of canal on the upper surface of the lining canal slope. For the semi-open system, small and medium size canals can be cracked at the center on the upper surface of the lining canal bed, while large-size canals will be cracked both at the center on the upper lining surface of the canal bed and on the lower surface of the lining canals slope foot. For the open system, small size canals can be cracked at the center on the upper surface of the lining canal bed, medium size canals can be cracked on the upper surface of the lining canal foot, while the large-size canals can be cracked both at the center on the lower lining surface of the canal bed and at the 2/3 height from the top of canal on the upper surface of the lining canal slope. The results revealed the size effect on frost heave damage for lining canals, providing a guiding significance and a quantitative reference for the anti-frost heave design and reasonable joints of lining construction for lining trapezoidal canal with arc-bottom.

Keywords: cold regions; lining trapezoidal canal with arc-bottom; thermal-moisture-mechanic coupling; frost heave damage; size effect

Fractal behaviors of microscope pore structure of soil reconstructed by quartet structure generation set

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Abstract: The microstructure model generated by a multi parameter random generation-growth algorithm, termed as the quartet structure generation set (QSGS), has been widely used to study the soil pore structure and predict the hydraulic properties of soil. However, there is still lack of experimental evidence and quantitative comparative analysis whether the model can truly reflect the soil pore structure characteristics. The samples of three soils different in porosity were scanned with a scanning electron microscope (SEM) producing SEM images for comparing quantitatively with the QSGS model. The morphological characteristics of pores and their distributions in the model and soil were analyzed using digital image technology. The mass fractal dimension D_m and the surface fractal dimension D_s of pores are estimated from the measured data. The results show that the microscopic pore structure generated by the QSGS algorithm is controlled by parameters such as porosity P, core distribution probability P_d, and directional growth probabilities P_i, among which P_d has more significant influence on the pore structure. The QSGS model generated when $P_d \leqslant 0.01$ has similar microscopic pore morphology and pore distribution with the soil, as well as the same fractal properties and close fractal dimension values. The lower the porosity is, and the larger the D_m is. The D_m displays a significant linear regression relationship with the porosity. The larger the D_s the more irregular the soil pore profile. The distribution of D_s is found in agreement with a total normal distribution in the pore. The research results reveal the influence of model parameters on the microstructure generated by QSGS algorithm and provide scientific basis for the rational selection of model parameters.

Keywords: quartet structure generation set(QSGS); reconstruction; microscopic pore structure; mass fractal dimension D_m; surface fractal dimension D_s

Parameters sensitivity analysis of successive dam break model for cascade reservoir based on the orthogonal test method

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Abstract: The construction of cascade reservoirs is the main way for hydropower development on the rivers. A reasonable selection of the parameters for the successive dam break analysis model is of great significance for the safe operation of the cascade hydropower projects. Taking a fictitious three-stage cascade reservoir system of "Xiazhuang (1)-Dali-Shuangtunzi" in a river basin in southwest China as an example, the orthogonal test method is adopted in this study to conduct the parameters sensitivity analysis of successive dam break model for cascade reservoir, considering major test indexes of the dam break flow Q of Xiazhuang (1), and the highest water level H_1 and H_2 in Dali and Shuangtunzi reservoirs respectively. The results show that among the parameters of successive dam break model for cascade reservoirs, the erosion rate b and the adjusting water level of Shuangtunzi reservoir have significant influence on the calculation results of each index, which are parameters with high sensitivity; while the flood frequency P has relatively small influence on each index. Therefore, in the inversion analysis of the dam break parameters for cascade reservoir, b and H_* should be selected as the key parameters of the inversion analysis. The research methods and results of this paper can provide a reference for the rational selection of parameters in the successive dam break model during the parameter inversion analysis of the cascade reservoirs.

Keywords: cascade reservoirs; successive dam break model; earth-rock dam; the orthogonal test method; sensitivity analysis

Experimental study on mode Ⅱ fracture of bonding interface between sprayable UHTCC and concrete

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Abstract: The use of sprayable Ultra High Toughness Cementitious Composites (UHTCC for short) to reinforce and repair hydraulic structure has broad prospects. In order to evaluate the effect of strengthening, an experimental study on shear-mode fracture has been carried out by using the composite specimens of double-edge unnotched and shear-mode. The existing concrete interfaces are treated respectively by high-pressure water washing, artificial chiseling and plastering interfacial agent, to study the impact of different factors on interface fracture toughness of bonding interface between sprayable UHTCC and concrete. Two construction technologies of spraying UHTCC and casting UHTCC are studied. The results of experiments show that the bonding properties between sprayable UHTCC and existing concrete is satisfactory; the interface roughness has no significant effect on interface fracture toughness; plastering interfacial agent can make the interface fracture toughness decreased significantly; the interface fracture toughness of composite specimens using sprayable UHTCC is better than using casted UHTCC. The sprayable UHTCC technique is suitable for the strengthening and repair of hydraulic concrete structures.

Keywords: sprayable; UHTCC; interface; shear-mode fracture toughness

Numerical modeling of soil water flow and solute transport based on Richards' Equation switching

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Abstract: The high non-linearity in the hydraulic retention curve introduces potential numerical instability and mass balance error in the traditional unsaturated-saturated flow models, which subsequently increases the difficulty for solute transport simulation. This paper proposed a generalized equation switching scheme, which implicitly solves different governing equations at adjacent vertices. The proposed method is applicable to all kinds of iterative solvers and fully considers the priorities in different forms of Richards' Equation. We successfully implemented the method into a one-dimensional unsaturated-saturated flow and solute transport model. A series of soil column experiments as well as numerical tests are conducted to validate the proposed model. Regarding the difficulties in simulating (1) the salt leaching process within a dry-sandy soil column, and (2) the salt accumulation in layered soils under rapidly drying-wetting atmospheric boundary, the proposed model shows significant improvement in numerical accuracy and computational cost compared with the conventional HYDRUS-1D model. The developed method is promising for the application to large-scale simulation of flow and solute transport.

Keywords: Richards' Equation; equation switching; unsaturated-saturated flow; solute transport; numerical modeling

Study on particle crush and deformation characteristics considering rockfill gradation effect

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Abstract: The relative density test of six graded rockfill materials and the conventional large-scale triaxial test were carried out. The relationship between the grading of the rockfill and the shear strength, the dilatancy, the compressibility and particle fragmentation was analyzed. The relationship between the Generalized Plastic Constitutive model parameters and the fractal dimension of the sample is selected, and the result of the triaxial test with different gradation is used to verify the rationality of the relationship between the model parameters and the hierarchical fractal dimension function. The results show that the physical and mechanical properties of the rockfill are closely related to the gradation, and the quadratic function of the fractal dimension of the sample can better reflect the influence of the gradation on its physical and mechanical properties. The conclusion can provide the basis for the calculation of stress and deformation of rockfill dam considering gradation effect.

Keywords: fractal theory; rockfill; gradation; particle fragmentation; constitutive model

Deformation of flood wave during ice river period in the Ningxia–Inner Mongolian Reach of the Yellow River

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Abstract: The existence of ice cover in northern river courses may affect flood rooting and the deformation of flood wave propagation. Taking the Ningxia–Inner Mongolia Reach of the Yellow River as the research object, the Muskingum method is applied to calculate the flood rooting during ice period, analyzing the relationship between the Muskingum parameters and the roughness, and comparing the difference of the impacts of ice cover thickening and thawing processes on the flood wave deformation. The results indicate that it is feasible to apply the Muskingum method to calculate flood during ice river period, the greater the section roughness, the longer the flood wave propagation and the greater the degree of deformation will be. During the ice cover thickening process, the deformation of flood wave increases at first, then decreases, and afterward increases again. During the ice cover thawing process, the deformation of flood wave increases. In the case of same ice thickness, there is an intersection of flood wave deformation during two processes of ice thickness development. Before the intersection point of ice thickness range, the deformation of flood wave is greater when ice cover melts and thins. After that, the deformation of flood wave is greater when ice cover freezes and thickens.

Keywords: Muskingum method; ice river flood; flood wave deformation; ice cover thickening; ice cover thawing

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Investigation on the clocking effect of a double–entry two–stage double suction centrifugal pump with high head

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Abstract: The clocking effect caused by the relative position between impeller and diffuser vane has great effect on the performance of a pump. The clocking effect of a double–entry two–stage double suction centrifugal pump which is often used in the Yellow River Diversion Project is investigated. Four schemes with relative installation angle 0°, 15°, 30°and 45° between the two stage impellers which have six blades are designed. The influence of clocking effect on the unsteady pressure fluctuation in the pump and on the radial force of impeller at three typical conditions is investigated. The results show that the clocking effect has little influence on the head and efficiency whose discrepancy is less than 2%. The clocking effect has great influence on both the pressure fluctuation and the unsteady radial force imposed on the impeller. For the 30° scheme, the pressure fluctuation amplitude of inter–stage flow channel tongue is reduced by 70%, 38% and 40% respectively compared with 0°, 15° and 45° schemes at design condition, and the pressure pulsation amplitude of the volute tongue is reduced by 31%, 18% and 22%. The radial force of the impeller varies periodically at three typical conditions. The radial force of the impeller is the smallest for the 30° scheme. Thus, it is suggested that the relative position between the impellers of two–stage double suction centrifugal pump should be installed circumferential symmetric staggered to obtain better performance. The research results provide a scientific basis for the optimal design and stable operation for the high head multi–stage centrifugal pumps.

Keywords: high head; two–stage double–suction centrifugal pump; clocking effect; pressure fluctuation; radial force

Comparative analysis of the elastic buckling solutions for ring-stiffened steel pipes under uniform external pressure

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Abstract: Ring-stiffened pipes are widely applied in water conservancy, hydroelectric and other engineering and their stability under external pressure is the key issue of concern. The estimation for the elastic buckling pressure of a ring-stiffened pipe subjected to uniform lateral external pressure was discussed, and solving the critical pressure was formulated as a nonlinear integer programming problem. The equations for analytically evaluating the buckling pressure, including exact one and simplified ones, were compared in detail, which proved that the simplified equation adopted in the current steel pipe design gives lower critical external pressure and is very conservative. Based on the exact equation and the design adopted equation for buckling pressure, the critical spacing between stiffening rings was deduced to clarify the applicable range of these equations. The critical spacing is much more reasonable in comparison with the existing counterparts because of the incorporation of the ratio of thickness to radius. The finite element analysis was carried out for the elastic buckling of the steel pipes with different spacing and different constraints of stiffening rings. By using the critical pressures obtained, the applicability and precision of the equations for buckling pressure were examinde comprehensively. The comparisons show that both the analytical solution and the design used solution for buckling pressure are conservative and overly safe, and that the critical pressure of actual ring-stiffened pipes increases to some extent in comparison with ideal ring-stiffened pipes.

Keywords: penstock; stiffening ring; cylindrical shell; elastic buckling; critical pressure

Crack resistance of loaded flexural TRC-strengthened beams under chloride erosion

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Abstract: Further study on the flexural beams strengthened with textile reinforced concrete (TRC) is conducted, considering the influence of dry-wet cycle and its coupling with bending stress on the crack resistance of the loaded TRC-strengthened RC beams. Four-point bending loading method was used for graded loading to analyze the influence of the above factors on the distribution and development of the crack. The results show that with the increase of dry-wet cycle times, the crack resistance of TRC was weakened, the crack developed faster, and the maximum crack width enlarged; With the increase of bending stress, the ductility of beam was weakened, the crack developed faster, and the maximum crack width enlarged; The load-bearing reinforcement had greater influence on the beam in the condition of higher bending stress, and the greater the bending stress, the greater the influence on the interfacial performance between TRC and old concrete, affecting the crack resistance of TRC.

Keywords: textile reinforced concrete; dry-wet cycle; bending stress; crack development; crack width

Experimental study on bond behavior between UHTCC and corroded reinforcement using beam members

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Abstract: The use of ultra-high toughness cementitious composite (UHTCC) can improve the corrosion resistance of hydraulic structures effectively. However, the rebar in structural members may be subjected to corrosion to a certain extent under long-term chloride environment attack, possibly resulting in deteriorated bond performance of UHTCC and rebar. In the present paper, the effect of corrosion on bond behavior of UHTCC and rebar is investigated through bond tests using beam members. The experimental results indicated that compared with concrete specimens, UHTCC specimens all presented ductile pull-out failure mode and full bond-slip curves. UHTCC samples all had no corrosion cracks in the range of corrosion level obtained in this test, and the rebar corrosion was relatively uniform. The bond strength of UHTCC specimens first increased and then decreased with increasing corrosion ratio. In detail, bond strength scarcely reduced at corrosion ratio below about 14%, and decreased by 5% at about 16% corrosion ratio. Meanwhile, the bond toughness merely reduced by about 5% within tested corrosion level of 16%.

Keywords: UHTCC; corrosion; bond; beam test; toughness