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Study on pattern and mechanism of river section topography adjustment in the downstream of the Three Gorges project

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Abstract: After the use of the Three Gorges Reservoir in 2003, the adaptive adjustment of the middle and lower reaches of the Yangtze River is very complicated because of the variation of incoming flow and sediment. The analysis shows that in the influence of sand reduction, the change of the section form can be divided into three modes: the whole undercutting, the translational adjustment and the compound adjustment. For the middle and lower reaches of the Yangtze River are mostly controlled channels, the relative depth of cross section centroid is presented as a useful index of section topography to reveal the mechanism of river cross section adjustment. Through quantitative analysis, it is found that during the bed making process the sectional topography has not only the sharpening phenomenon due to deep groove scouring, but also the attenuation phenomenon due to beach scouring. Both directions are closely related to the strong scouring effect of the main flow region caused by the new flow and sediment conditions, and also up to bed-forming function of normal water has been strengthened and bed-forming function of flood water has been significantly weakened. So, in the channel where the direction of the thalweg is far different from the mainflow position of the dominant flow level, the cross sections show translational adjustment mode firstly, and in the straight channel, the cross sections mainly show compound adjustment mode, accompanied by making the sectional topography more sharp.

Keywords: river bed evolution; bed-forming function; the Three Gorges project; section topography; flow and sediment conditions

Water Resources Comprehensive Allocation and Simulation Model (WAS), part Ⅰ. Theory and development

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Abstract: Aiming at the scientific problems of complex mutual feedback mechanism of natural-social water resources system, as well as the application requirements of water management, a conceptual semi-distributed Water Resources Comprehensive Allocation and Simulation Model (WAS) was constructed by combining hydrological numerical simulation and adaptive allocation of water resources. The related theoretical methods such as WAS model framework, unit division, dynamic mutual feedback simulation, calculation principle and operation strategy are proposed to provide support for the simulation and scientific deployment of natural-social water resources composite system.

Keywords: water resources; simulation and allocation; conceptual; semi-distributed; model

Design method for optimal hydraulic cross-section and practically economic cross-section of horizontal-bottomed power-law shaped canals with general exponent parameter

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Abstract: As to large and medium-sized canals, they are often designed in the form of horizontal-bottomed Power-Law shaped canals. But there is no analytical solution for all of the wetted-perimeter of horizontal-bottomed power-law shaped canals with general exponent parameter. Therefore, its optimal hydraulic cross-section and practically economic cross-section with general exponent parameter is very complicated. In addition, in the literature the optimum hydraulic horizontal-bottomed power-law shaped canals has been developed for only specific exponent m of the power-law formula. In this article, by using Gauss-hypergeometric function, an analytical solution for the integral formula of the wetted-perimeter of horizontal-bottomed power-law section with general exponent parameter is obtained. Taking ratio of water surface width of power-law shaped side to water depth, and ratio of bed width to water depth as variables, hydraulic optimal section parameter can be obtained by using Lagrange multiplier method. The parameter equation of optimal hydraulic cross-section is obtained. According to the relationship between optimal hydraulic cross-section and practically economic cross-section, the parameter equation of practically economic cross-section of any horizontal-bottomed power-law section with general exponent parameter is also obtained. This article not only presents the uniform design method of optimal hydraulic cross-section and practically economic cross-section about these shaped canals with general exponent parameter, but also gives a super-optimal hydraulic horizontal-bottomed power-law shaped canals' s exponent parameter m=3, where the discharge is largest. This super-optimal hydraulic section presents a new discovery as it provides the global maximum discharge among all possible section shapes. It can be used as reference in the planning and design of large and medium-sized canals.

Keywords: horizontal-bottomed power-law shaped canals; Gaussian hypergeometric function; optimal hydraulic cross-section; practically economic cross-section; open channel hydraulics

Study on the mechanism of water-sediment interaction in the scouring process around a pile

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Abstract: Aimed at exploration of the sediment transport behavior in local scouring process around a structure, 3D turbulent flow equations coupled with bedload and suspended load transport, as well as bed deformation were used to numerically simulate the local scour and investigate the contribution of the two kinds of sediment transportation, horse-shoe vortex, and the correlation of suspended load with the sediment suspension index under clear water and livebed conditions. It was found that under the clear water scour condition, the transport of suspended load contributes a relatively small proportion, and the scouring process is dominated by bed load transport which contributes approximately up 95 percent. Under the live bed scour condition, suspended load transport increases rapidly with the decrease of the particle suspension index. In the scouring process, the variation of sediment transport rate for suspended load and bed load is consistent with the trend of the local shear stress around the structure. Further, the variation of the bed shear stress is positively controlled by the horseshoe vortex.

Keywords: local scouring; bed shear stress; horseshoe vortex; sediment transport; suspended load; bed load

Optimality conditions for operating rule of parallel reservoir system, part Ⅰ. Theoretical analysis

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Abstract: The optimality conditions of operation rule are essential for the coordinated operation of multi-reservoir system. The purpose of this paper is to derive the optimality conditions of operation rule for parallel reservoir system, which is defined in terms of system-wide release rules and individual reservoir storage balancing functions, by using the K-T conditions to solve a two-period model. Specially, the applicable water availability of both parallel system and individual reservoir for the optimality conditions are given, and the main factors to determine the water supply priority of individual reservoir are specified. The theoretical results show that both the total system water availability and individual reservoir water availability have to be restricted within a certain range, in order to guarantee the optimal operation of parallel reservoir system.

Keywords: parallel reservoir system; two-period model; operation rule; optimality conditions; K-T conditions

Effect of low impact development measures on inundation reduction ——Taking Jinan pilot area as example

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Abstract: Flood Simulation Numerical Model and Flood Risk Analysis Software (FRAS) developed independently by IWHR are used in this study to evaluate the effect of individual and combined low impact development (LID) measures on inundation reduction. In addition, the SCS method is added to the original rainfall-runoff model, which is coupled with the 2D surface hydraulic model in real-time. Therefore, the software can reflect the runoff and confluence process more accurately. The simulation results indicate: (1) Combined LID measures can decrease the flooding area at pilot area, small watershed and block scale under all the 24h design storm with 5-year, 10-year and 20-year return period. Besides, the total runoff volume and peak discharge are also reduced at watershed scale after implementing these measures. The effects are most significant under the 5-year return period storm, where the total runoff and peak discharge are cut respectively by 6.5% and 9.7% and the inundation area is cut by 48.96% in the measure-intensive block. (2) Individual LID measures have different effects under the 24h design storm with 10-year return period at basin scale. All measures can reduce inundation volume but it tends to increase at first and then decrease during the rainfall procedure. The effects of different individual LID measures on inundation area reduction are ranked as: sunken lawn, permeable pavement, green roof. (3) Inundation reduction effect of LID measure is also closely related to the measure type and scale, terrain, underlying surface condition and setting location. It is necessary to have multi-scheme simulation as well as analysis through hydrological-hydraulic model when design the LID measures.

Keywords: low impact development; urban inundation; effect assessment; sponge city; Jinan

Coupled swash zone hydrodynamics and beach morphodynamics modeling Ⅱ. Model establishment & validation

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Abstract: Based on the one-dimensional nonlinear shallow water equations and the bed deformation equation, this study considers two types (a total of six) of different sediment transport rate formulas, and implants the bed shear stress and seepage source terms to the equations, and finally a more complete model of swash zone hydrodynamics and beach morphodynamics is proposed, in which a coupled solution was realized. The model reliability is numerically verified based on the classical benchmark. The verification results show that the TVD-WAF format and the segmental sand transport rate formula used in the proposed coupling model have achieved good solutions in numerical accuracy and morphological changes, which are better than previous research results. On this basis, this model is used to carry out numerical investigation of smash zone hydrodynamics and beach profile evolution. The results of depth, shoreline trajectory and shoreline profile are in good agreement with the experimental results, and then the study focused on the effects of different friction coefficients and the presence of seepage on beach morphologies. The results indicate that the segmental sediment transport rate formula proposed in this study is suitable for the study of sediment transport in the swash zone, and the effects of bed friction and seepage should not be ignored during established the beach morphodynamics model of swash zone.

Key words: swash zone; morphodynamics; nonlinear shallow water equation; bed friction; seepage

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Research on slip-stick vibration of emergency gate induced by high dam flood discharge

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Abstract: The emergency gate is employed for emergency closure in flowing water to prevent the accident propagation. However, the frequent occurrence of emergency gate incomplete closure accompanying slip-stick vibration may cause serious loss, and lead to strong load on hydraulic structures. Based on control theory, the nonlinear friction characteristics induced by static/dynamic friction conversion are separated from the gate closing process, and is regarded as an independent element in systematic structure diagram. Furthermore, by reasonably selecting the controlled variable and reference input, a negative feedback control system model is established to describe the aforementioned engineering problem. The rationality and effectiveness of the presented theoretical model is validated by comparing the theoretical results and actual conditions, simulating slip-stick vibration displacement, and reversely deducing the holding force. According to the theory analysis, the generative mechanism of the engineering problem is clarified and the theoretical guidance is provided for the gate optimization scheme.

Keywords: control theory; emergency gate; incomplete closure of emergency gate; slip-stick vibration; nonlinear friction characteristic; phase plane

Study on preparation of high dense and toughened hydraulic concrete and its properties

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Abstract: Aiming to obtain the concrete with satisfactory volume stability and anti-permeability, the micro-performance of cement-based materials were analyzed to design the rheological property of slurry by mixing appropriate chemical admixtures. The effect of the dispersion, air entrainment, coagulation of chemical admixtures and curing system on filling capacity of slurry and rate of setting were investigated to optimize the particle packing and workability of slurry by particle accumulation algorithm. The toughness and shrinkage strain were improved by adding steel fiber. Meanwhile, a series of experimental tests were carried out to estimate the basic mechanical characteristic, durability and volume stability on the high-dense and toughened hydraulic concrete(HDTHC). The results show that the compressive strength and splitting tensile strength of HDTHC reached 109.66MPa and 17.60MPa respectively. Its electric flux of 6h was not exceeding 130C, the carbonation depth of 28d was 2mm, the loss rate of freeze-thaw quality was no more than 0.2%, the strength loss rate was no more than 2%, as well as the dry shrinkage deformation of 42d was no more than 0.17‰. HDTHC showed good mechanical properties, excellent durability and volume stability.

Keywords: hydraulic concrete; high dense; toughened; preparation; performance test

Research on the displacement direction coordination parameter of colluvial landslide induced by reservoir and its warning destabilized criterion

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Abstract: The displacement of colluvial landslide in reservoir area is affected by the circulating fluctuation of reservoir water level and rainfall and has the characteristics of fluctuation and oscillation. However, the change and mutation of the displacement are mostly caused by the fluctuation of reservoir water level and rainfall, which are not necessarily due to the decrease of slope stability. Therefore, using the traditional single-dimension displacement prediction parameters and criteria to analyze the stability of landslides often causes misjudgment. For this problem, this paper proposes the vertical displacement direction rate as an effective displacement direction coordination parameter for the analysis and evaluation of slope stability evolution according to the basic principle of holographic theory of landslide. Meanwhile, the quantitative relationship between surface vertical displacement direction rate and the evolution of stability in the compression stage and the plastic deformation stage of slope are deeply analyzed and determined. Based on the analysis results above, this paper establishes the monitoring and warning criteria of the vertical displacement direction rate of the colluvial landslide induced by reservoir through the basic trend displacement analysis principle of mathematical statistics. According to the vertical displacement direction rate parameter and the criterion, the stability of Xintan landslide is calculated and discriminated by the data of F series monitoring points. The prediction coincide with actual deformation of slope in different instability stage, it reveals that the vertical displacement direction rate parameter is effective in the stability evaluation and warning of colluvial landslide induced by reservoir.

Keywords: colluvial landslide induced by reservoir; vertical displacement direction rate; trend displacement criterion; Xintan landslide

Unsteady flow and pressure pulse analysis of a Francis pump-turbine on reverse pump zone with small guide vane opening

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Abstract: The S-curve characteristic is widespread in pump-turbine. When the unit starts running under turbine-mode, the operating condition usually cannot be changed from no-load to full-load directly, which inevitably make the unit to enter reverse pump zone. This phenomenon brings difficulties for grid connections. In this paper, a model pump-turbine was chosen for analysis. The three-dimensional numerical calculation of the overall flow channel was carried out for the reverse pump mode under an extreme small guide vane opening. The simulations were performed with the SAS SST-CC turbulence model. The steady simulated external characteristic parameter curves were in good agreement with the model test data for five operating points. The operating point where the flow rate is relatively small was chosen for long-term unsteady flow calculations, where eight different points on nine runner blade to blade flow channel were chosen to monitor the pressure fluctuations. The results show that there exists a noteworthy difference of pressure peak-to-peak amplitudes and pulsation frequencies in each rotating flow passage. The largest peak-to-peak difference is up to 4.2%, which means that the flow distribution in the runners is not uniform for this condition. From points rva to rvh with those points closer to the guide vane, the main frequency of the pulsation in the low frequency region is gradually increased from $0.19f_n$ to $1.07f_n$; the pulsation amplitude caused by rotate and static interference (RSI) will gradually increase, but not for points rvg. The flow pattern shows that this points was located on outflow and the inflow transition zone of the runner blade outflow channels. Flow pattern analysis indicates that the runner flow fields are asymmetrical in different blade passages under this revise pump condition, with significant flow separation and vortexes.

Keywords: Pump-turbine; reverse pump; unsteady flow; pressure pulse; rotate and state interaction

Confirmation failure test of 2D Geomechanical model for dam foundation stability of right #1 dam section in Danba Hydropower Station

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Abstract: Danba Hydropower Station will be the first gate dam project in China with a dam height of more than 40m on the deep overburden. The dam site area is dominated by deep Quaternary overburden layer with a maximum thickness of 127.66m. The foundation of the retaining right #1 dam section is divided into 5 cover layers with low deformation modulus and large compressibility. Such geological conditions could result in uneven settlement on the dam and foundation, which has a direct impact on the stability and safety of dam foundation. Therefore, further study on the stability of dam foundation is needed. For the above geological problems, this paper selected the right #1 dam section with weak geological conditions as the research object, and the geomechanical model test method was adopted. In the test, the deep overburden in the dam site was fully simulated. Through the failure test, the deformation distribution characteristics of the dam and the foundation are obtained, the maximum vertical displacement of the dam is 7.60cm under the normal water level, which meets the requirements of the specification. The destruction mechanism and the failure mode are revealed. And the dam foundation stability of overloading method test safety coefficients are determined as follows: crack initiation overload safety coefficient K_1=1.2, nonlinear deformation safety coefficient K_2=1.6 ~ 1.8, ultimate overload safety coefficient K_3=2.0 ~ 2.4. The test results can provide reference for the design, construction and reinforcement design of the project.

Keywords: Danba Hydropower Station; thick overburden layer; stability of dam foundation; geomechanical model; failure test; safety coefficient