JOURNAL OF HYDRAULIC ENGINEERING

Vol. 50 No. 2, 2019

(Monthly)

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水 利 学 报

SHUILI XUEBAO

第50卷　　2019年　　第2期(月刊)

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[**期刊基本参数**]CN11－1882/TV＊1956＊m＊A4＊128＊zh＊P＊￥30.00＊1000＊14＊2019-02

EDITORIAL BOARD

《水利学报》第九届编辑委员会组成名单

Deformation characteristics and shear strength failure criteria of CC-RCC materials in combined dam structures

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Abstract: In the form of combined damming, many parts of the dam body are jointly poured by large volume conventional and roller compacted concrete. The diversity of the distribution positions of the two materials and the difference of the mechanical properties are the main causes of deformation coordination problem of the dam body. In order to analyze the deformation coordination characteristics of dam materials, mesoscopic mechanical numerical models of CC (Conventional Concrete)-RCC (Roller Compacted Concrete) composite specimens were established. Based on the actual performance of concretes in the dam body, the mesoscopic strength of composite specimen was calculated and analyzed by non-homogeneous finite element method. The effects of fly ash content and material interface slant angle on the mechanical properties of composite materials were evaluated. The results show that the strength of concrete composite specimens is determined by the strength of weaker concrete materials and it decreases with the increase of fly ash content. The lateral compressive stress increases the strength of composite specimens greatly. According to the numerical test data, the failure criterion of composite specimens in the form of combined damming is proposed. Then, the mechanism of slant shear failure of composite specimens is analyzed and the validity and reliability of shear failure criterion are verified. The research results can provide a reference for the design of the material in combined dam structures.

Keywords: combined dam structure; CC-RCC; composite specimens; shear failure criterion; numerical simulation

Intelligent grouting control method and system for hydropower engineering

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Abstract: Cement grouting is an important measure for foundation reinforcement and anti-seepage in hydropower projects. Based on the intelligent closed-loop control theory of "full perception, real analysis and real-time control", this study proposed a 3-zone, 5-stage and *P-Q-C-t* coordinated real-time control method. Through real-time coordinated intelligent control of the grouting pressure *P*, the absorption rate *Q*, the slurry density *C*, the rock mass uplifting value ΔH, slurry temperature *T* and grouting duration t, the integration intelligent identification and control of grouting under normal and special circumstances are realized. This study also developed an intelligent grouting system composed of intelligent grouting cell (iGC) and intelligent grouting management cloud platform iGM, which realized one-key closed-loop intelligent control on cement grouting process. The system has been fully applied in the consolidation and high-pressure curtain grouting at the Wudongde and Baihetan hydropower stations. The application ensured the construction quality of cement grouting at dam site, and have high popularization and application value in similar projects.

Keywords: cement grouting; intelligent grouting method; intelligent control system; intelligent grouting units

Influence of roughness and backwater of bridge piers on flood carrying capacity in a wide-shallow river

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Abstract: The roughness and backwater of bridge piers are the key parameters, which effect on the flood carrying capacity in a wide-shallow river. In this study, these two parameters are analyzed by physical model test, numerical simulation and empirical formula. The slope protection is simulated by four kinds of materials, namely, no vegetation, sparse vegetation, sparse vegetation and shrub, and dense vegetation. The average water level difference is 0.03m under the condition of no vegetation and dense vegetation. The results show that the impact on the flood carrying capacity is not significant with the obvious roughness changes in the wide-shallow river. The simulation on the backwater of bridge piers shows the results of the two-dimensional mathematical models, which can reflect the boundary conditions of the river and characteristics of the bridge more really than the empirical formula and one-dimensional mathematical model, are close to the physical model experiments. This study provides a reliable basis for the evaluation of the roughness and the calculation of the pier backwater in the wide-shallow river.

Keywords: wide-shallow river; roughness; backwater; bridge pier; physical model; numerical simulation

Experimental study on the influence of density and stress level on particle breakage of coral sand

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Abstract: During the shearing process, coral sand is prone to particle breakage, which is related to stress level, initial density and stress path. In order to study the effect of density and stress level on the particles breakage of coral sand, triaxial compression tests and one-dimensional compression tests were carried out. In this paper, the quantitative relationship between the relative breakage of particles and the confining pressure and the initial void ratio of the specimen under triaxial compression is established, as well as the relationship between the relative breakage and the average particle size of the sample. The results show that, under triaxial compression and one-dimensional compression, the relative breakage increases with the increase of stress level (confining pressure or vertical stress) and sample density, but the degree of particle breakage under the two stress paths is significantly different.

Keywords: coral sand; particle breakage; triaxial test; one-dimensional compression

Optimality conditions for operating rule of parallel reservoir system Ⅱ. Algorithm design and case study

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Abstract: Following the assumption that multi-period reservoir optimal operation problem can be formulated by multiple two-period optimal operation problems, this paper designs a new algorithm to solve the multi-period operation model on the basis of K-T conditions presented in companion paper. Further, to verify the effectiveness of the new algorithm, a real-world parallel reservoir supply system in Liaoning Province, i.e., Biliu River reservoir and Yingna River reservoir, is used as a case study. The numerical results show that less water shortage and higher supply reliability are obtained from the new algorithm with comparison of the performances of the commonly used operation rule.

Keywords: parallel reservoir system; two-period model; optimality conditions; K-T conditions; algorithm design

Water resources comprehensive allocation and simulation model (WAS), part Ⅱ. Application

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Abstract: Aiming at the characteristics of the natural-social water cycle system, a multi-dimension index model verification method for cross-section flow process, cross-section feature runoff volume, regional water allocation was established, and Qingyang City in Gansu Province is taken as an example to use the WAS model(Water Allocation and Simulation Model). The correlation coefficient R^2 of runoff simulation in calibration period 1967-1985 of the Yuluoping cross-section was 0.89, and the Nash coefficient was 0.79. The correlation coefficient R^2 of runoff simulation in validation period 1986-2000 was 0.88, and the Nash coefficient was 0.76. The average annual error of the simulation and measurement of regional water resources was 4.1%, and the errors at frequency of 25%, 50%, 75% and 90% were 5.0%, 1.1%, 5.9% and 4.2%, respectively. The average error of the water allocation and measurement of Qingyang City was 0.35%. Based on the result, the water resources allocation plan for water supply of 284 million m^3 and water consumption of 211 million m^3 in the current year was put forward, and the decomposition map of regional water balance was given. The results show that WAS model can describe the dynamic feedback relationship between natural and social water circulation systems, and the model can also meet the accuracy requirements of water resources assessment and management.

Keywords: water resources; simulation; allocation; verification; water resources assessment; water resources management

Unsteady change of water and sediment processes downstream of cascade reservoirs in the Lower Jinsha River and its influence on navigation conditions

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Abstract: With the construction and application of cascade reservoirs in the Lower Jinsha River, the water and sediment processes downstream of the reservoirs are obviously changing and affecting navigation conditions. The analysis method of water and sediment unsteady process is proposed, and the unsteady characteristics of water level, discharge and sediment concentration downstream of Xiangjiaba reservoir and its influence on navigation conditions are analyzed. The results show that the variation coefficient of water level can reach 0.10~0.12, and the variation coefficient of discharge can be 0.20~0.40. Although the sediment concentration decreased significantly, the variation coefficient of sediment concentration could reach about 1.0. The annual average normalized water level and discharge in Xiangjiaba hydrologic station is about 1.0, and the navigation conditions of the montanic river channel downstream of Xiangjiaba reservoir are generally stable. It is beneficial to reduce the flood peak and increase low discharge to the navigation conditions of the river channel downstream the dam, but the daily regulation of the hydropower station, the reservoir water storage and the flood discharge increase the inconstancy of the flow and water level, which have some adverse effects on the navigable conditions.

Keywords: Lower Jinsha River; cascade reservoirs; water and sediment process; unsteady change; navigation conditions

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Real-time flood control risk estimation of reservoir and analysis on the interoperability of storage capacity of multi-reservoir regulation

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Abstract: The risk analysis of reservoir flood operation is an important link and basis for real-time flood control decision-making. In order to evaluate the real-time flood control risk of the reservoir, a method for calculating the frequency curve of reservoir capacity based on a long series of measured historical runoff data was presented in this paper. Based on this proposed method, the risk analysis model of real-time flood control operation was established. Furthermore, according to the actual flood control operation demand of the Three Gorges Reservoir, the flood control risk of reservoir in different periods of flood season was further analyzed. Meanwhile, the variation of the frequency curve of flood control capacity and the interoperability of storage capacity of multi-reservoirs were studied when the upstream cascade reservoirs cooperate with the Three Gorges Reservoir for joint operation. The study shows that the calculated frequency curve of reservoir flood control can be used to judge the current flood situation and effectively reduce the flood control risk of the Three Gorges Reservoir by using the interoperable performance of reservoir flood control reasonably.

Keywords: flood control storage capacity; risk analysis; frequency curve; joint flood control operation; flood storage capacity distribution and interoperability

Influence of water content on dynamic compressive properties of concrete subjected to seismic strain rate

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Abstract: To clarify the influence of water contents on the mechanical properties of concrete subjected to seismic strain rate, a vacuum water-saturated equipment was used to prepare concrete specimens with different water contents rapidly. The effect of cement secondary hydration on the rest results can be minimized by this method. Uniaxial compression tests were carried out at strain rates of 10^{-5}, 10^{-4} and 10^{-3} s^{-1}. The effects of strain rate and water content on the stress-strain curves, compressive strength, elastic modulus and critical strain of concrete are analyzed. The obtained results show that the compressive strength and elastic modulus increase with the increase of strain rate, while the critical strain of concrete decreases. At a same strain rate, increasing water content lowers the compressive strength, but increase the dynamic increase factor under dynamic loading. Critical strain decreases more significantly with the increase of water content especially at higher strain rates. Empirical formula for the mechanical properties of concrete are proposed in this study considering the effect of strain rate as well as the water content, which has a good agreement with the test results.

Keywords: concrete; water content; strain rate; multi-parameter analysis; mechanical properties

Entropy production analysis for vortex rope of a turbine model

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Abstract: In order to study the causes and pressure pulsation characteristics of the vortex rope under the partial load condition of the pump turbine, the model pump turbine was set as the research object in this paper. Both the steady and unsteady three-dimensional numerical simulation was carried out to simulate the internal flow, which was analyzed by the entropy production theory further. The results show that the numerical simulation is in good agreement with the experimental data. The entropy production in the scroll and stay vane is very small, while it is greater in the runner and draft. The flow separation produced on the pressure surface in the small discharge condition and it leads to the appearance of the high entropy production rate distribution area. And the area will expand as the discharge is further reduced. There are two kinds of vortex ropes with strong and fine shape at partial load, which are all spiral. The formation of the vortex rope has a great relationship with the circulation of the blade outlet n deviating from the zero. The appearance of the vortex rope will form a vortex in the draft tube, blocking the draft tube passage. The vortex rope will rotate in the same direction with the runner, but the rotation speed is lower, resulting in low frequency pressure pulsation with large amplitude in the draft tube.

Keywords: pump turbine; entropy production; vortex rope; pressure fluctuation; flow field

Calculation of crop coefficient and evapotranspiration based on temperature effect

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Abstract: It is of great significance to accurately estimate the crop evapotranspiration, for developing sound irrigation plans and improving water use efficiency. To explore the dynamic change of daily water demand, and temperature effect on crop growth, the three-point temperature (optimal temperature, upper limit temperature, lower limit temperature) were applied to calculate crop coefficient and evapotranspiration. The calculation models of evapotranspiration for winter wheat and summer maize were established based on the data of large-scale weighing lysimeters and weather monitoring station in Wudaogou Hydrological Experimental Station. The results show that crop coefficients of wheat and maize simulated through temperature had a high degree of fitness with the measured data. Both correlation coefficients are greater than 0.80 and both average absolute errors are about 0.10. The evapotranspiration model has reliable forecasting ability on different time scales, of 1 d, 3 d and 5 d. The correlation coefficients of wheat are 0.95, 0.98, and 0.98, respectively. With the time scale increasing from 1 d to 5 d, the absolute error decreased from 0.67 $mm \cdot d^{-1}$ to 0.41 $mm \cdot d^{-1}$, the forecast accuracy rate (<1 $mm \cdot d^{-1}$) increased from 73% to 90%, and the forecast accuracy improved. Simultaneously, maize showed the same law.

Keywords: temperature effect; crop coefficient; actual evapotranspiration; reference crop evapotranspiration; time scale; forecast model

Ecological thresholds for the dominated wetland plants of Poyang Lake along the gradient of flooding duration

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Abstract: After 2003, the "river-lake" relation between Poyang Lake and Yangtze River has been changed significantly. The flooding duration for the wetlands is obviously shorter than that before 2003, and it is hard to guarantee the ecological demands of wetland plants. The trend of wetland degradation has emerged gradually. In order to illustrate the ecological demands of wetland plants for flooding duration, the response curve has been established by the coupling between hydrodynamic model and statistical model, and the ecological thresholds of the six dominant wetland plants of Poyang Lake are quantified, respectively. The results demonstrate that the relation between area of wetland plants and flooding duration can be depicted through Gaussian curve, and the optimal, suitable and inhibited thresholds can be estimated along the gradient of flooding duration. Besides, there are obvious differences for the ecological thresholds among the six species of wetland plants. For instance, Carex has the strongest adaptability to flooding, and the suitable and the optimal thresholds for the Carex are 60~240 days and 120~180 days, respectively, while its growth would be inhibited if the duration of flooding is longer than 300 days. Among the six species of wetland plants, Cynodon dactylon shows weakest adaptability to flooding, its suitable and optimal thresholds are 30~60 days and 30~90 days, respectively, and it is not found in area where the flooding duration is longer than 120 days. Different survival strategies, such as dormancy and morphological plasticity, are the main reason for the different ecological threshold. The findings of this study can be used for guiding the eco-hydrological process regulation and wetland restoration.

Keywords: Poyang Lake; wetland plants; flooding duration; gradient; ecological threshold

Application of overall matrix method in operation stability analysis for frequency regulation mode of hydropower stations

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Abstract: The operation stability is a key problem in design and operation of hydropower stations. In the past, theoretical analysis based on transfer function method and numerical simulation were mostly used to analyze the operation stability of hydropower stations. However, when the pipeline system is more complex, such as a system with multiple generating units sharing a same pipeline, it is difficult to deduce the system transfer function, and it is not easy to establish the simulation model and get a more accurate stability region. The aim of this paper is to study the above problems. First, the expression of the impedance of hydropower generating units is derived. Then, based on the analysis method of oscillation characteristics of hydraulic system, an overall matrix of the hydropower generation system is established, and the stability criterion is applied based on whether the maximum damping ratio is smaller than zero. In order to verify the method, two engineering examples are given in this paper. For a hydropower station with one generating unit, the proposed overall matrix method is compared with transfer function method and numerical simulation based on MATLAB/Simulink; for a hydropower station with four generating units sharing the same conduit, the proposed overall matrix method is compared with the numerical simulation based on MATLAB/Simulink. The results show that the overall matrix method can accurately solve the stability region of the complex system and can be adapted to various layout forms of hydropower stations by modifying the order of the corresponding matrix arrangement of the system, which greatly facilitates the calculation and analysis of the stability of hydropower stations.

Keywords: hydropower station; overall matrix; complex pipeline system; stability

Characteristic analysis and uncertainty assessment of joint distribution of flow and sand in Jinghe River basin

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Abstract: The flow and sediment are non-independent two-dimensional random variables, so it is very necessary to carry out joint probability analysis of flow and sediment in order to realize the scientific management scheme of flow and sediment. In the joint probability analysis, the limited flow and sediment sample size would induce quantile estimation uncertainty in bivariate probability analysis. Based on Monte Carlo method, this paper presents the quantitative uncertainty evaluation method of bivariate quantile estimation in the Jinghe River basin. The flow and sediment joint distribution model is established based on Copulas function and the most likely realizations of bivariate quantile estimation are derived. The Monte Carlo sampling method is used to analyze the influence of sample uncertainty of bivariate quantile estimation, and the confidence region of bivariate quantile estimation is calculated. The results demonstrate that when the OR return period is 20 years, the 95% confidence region of bivariate quantile estimation shows greater uncertainty. It is a great challenge to determine the quantile estimation of river basin engineering design. The uncertainty of bivariate quantile estimation increases with the increase of the joint return period level.

Keywords: Copula function; Joint return period; Monte Carlo; Most likely combination; Jinghe River basin