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Size effect of axial compressive strength of circular concrete columns strengthened by GFRP: A meso-scale analysis

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Abstract: Wrapping concrete columns with Fiber Reinforced Polymer/Plastic (FRP) jackets is an efficient method to strengthen its ductility. At present, the studies on the axial compressive behavior of FRP confined concrete columns are mainly based on the tests of small-sized specimens. There is lack of studies on the failure of large-sized columns, leading to the fact that the studies on the failure mechanism and mechanical properties of large-sized FRP confined concrete members are still insufficient. In the present study, a three-dimensional numerical model is established for the simulation of the failure of GFRP-confined concrete cylinder having different structural sizes, considering the heterogeneity of concrete and the interaction between GFRP and concrete. The meso-scale numerical method was verified by comparing the simulation results with the available test ones. Moreover, the influences of structural size and constraint (described by volume allocation rate of GFRP) on the failure mechanism and failure modes of concrete columns were examined. Also, the effect of constraint on the nominal compressive strength and the corresponding size effect of the concrete columns was quantitatively studied. Finally, based on the classic size effect law (SEL), a semi empirical-semi theoretical formula that can describe the influence of constraint generated by GFRP on the size effect of GFRP-confined concrete columns under axial compression was developed. Relevant experiments and simulation results confirm the rationality of the formula.

Keywords: GFRP reinforced concrete column; volume allocation rate; lateral constraint; axial compressive strength; size effect

Uncertainty analysis of P-Ⅲ distribution population mean based on sampling distribution theory

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Abstract: In view of the uncertainty of P-Ⅲ distribution parameters, a method based on sampling distribution theory is proposed. Firstly, with the concept of sampling distribution and characteristic function, the sample mean distribution function is deduced. And then, an auxiliary random variable is constructed with its distribution function deduced. Then, the confidence interval of population mean is obtained by combining the upper and lower probability points in the case of the known variation coefficient and the known skewness coefficient. The method is applied to Shangyoujiang Basin, and the confidence interval of designed flood peak is reasonable. The theoretical deduction shows that the sample mean and the auxiliary random variables still obey the P-Ⅲ distribution, and the distribution parameters of the auxiliary random variables are only related to the variation coefficient and the skewness coefficient, and have nothing to do with the population mean of the whole. The application results show that it is feasible and effective to study the uncertainty of P-Ⅲ distribution population mean based on the sampling distribution theory.

Keywords: sampling distribution; P-Ⅲ distribution; uncertainty; sample mean; population mean

Experimental study on dam-break of a red mud reservoir with complex dam slopes

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Abstract: Red mud is a kind of waste slag with unique properties discharged from alumina production. Therefore, red mud reservoir has special dam-break characteristic because of its extremely fine tailings particles. In this paper, a red mud reservoir and its downstream channel were studied as a whole, and the development process and mechanism of the overflow dam break about the tailings reservoir were analyzed by physical model test. The test results show that the dam-break development law of the red mud reservoir is relatively complex, and the process can be divided into three stages, and each stage has a trend of approaching dynamic equilibrium. In addition, the large change of dam slope results in the different partition phenomenon on the dam surface space. Finally, the formula for calculating the maximum submergence height of red mud flow in the downstream channel is derived and verified by model test data.

Keywords: red mud reservoir; dam-break; model test; maximum submergence height; complex dam slopes

Study on optimization of water transfer process based on RBF surrogate model

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Abstract: In the water transfer process of the regulating and storage project through the pump station, the water level needs to be adjusted through reasonable control of the opening and closing time of the pump station, so as to constantly optimize the water transfer process. However, previous optimization methods are inefficient and difficult to obtain an optimal solution. In order to solve this problem, this paper takes the Lower Nansi Lake in Shandong reach of the eastern route of South-to-North Water Transfer Project as the research object, and establishes the optimization model of water transfer process based on RBF (Radial Basis Function) surrogate model to study the optimal water transfer process of the Lower Nansi Lake. The method is used to obtain the optimal scheme within the parameter range of the water transfer process, and the optimal scheme for the water transfer process under different starting water levels is obtained based on the actual water transfer situation. Firstly, 80 samples of the water transfer process are selected automatically according to the parameter interval of the water transfer process scheme, and the water level of each scheme is calculated using the 1D-2D coupled hydrodynamic model. Secondly, the RBF surrogate model is adopted to establish and verify the relationship between the water transfer process scheme and the response of the highest and lowest water levels. Finally, based on the RBF surrogate model, taking the shortest working time of the pump station as the objective, the optimization model was established considering water balance and water level constraints, and particle swarm optimization was adopted to solve the problem. The research results show that the absolute depth error is no more than 0.05m and the relative depth error is no more than 0.99% compared with the calculation results of the scheme water level and the coupled model in the optimized water transfer process, and the optimization model of water transfer process based on RBF surrogate model has high accuracy. Based on this model, the optimal solution within the parameter interval of the water transfer process is obtained, which solves the limitation of the traditional method to obtain the optimal solution within a limited number of artificially set schemes.

Keywords: hydrodynamics; optimization of water transfer process; RBF surrogate model; particle swarm optimization; storage engineering

A unified meso-scale simulation method for concrete under both tension and compression based on Cohesive Zone Model

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Abstract: The application of Cohesive Zone Model is extended to concrete compression fracture simulation at meso-scale. The unity of concrete tension and compression has been realized. Referring to the previous experimental study and the characteristic of Cohesive Zone Model, different fracture behavior under tension and shear, mixed fracture criterion is defined to cohesive elements, and global interaction behavior is defined to the model. Specimens with different mesh accuracy are modeled for mesh sensitivity study. The cause of mesh sensitivity in concrete tension and compression simulation are discussed. The whole deformation process of concrete under tension and compression is simulated. A parametric study of fracture energy, interface strength, aggregate shape and aggregate material properties is conducted. The influence of concrete fracture and interaction behavior on the whole mechanic properties are discussed based on the analysis of failure mode and mechanic performance. The study results show that the compression simulation of concrete is more sensitive to the mesh's precision compared with tension simulation, and for the coarse mesh would restrain the internal force redistribution of concrete. The mixed-mode fracture partial to mode I fracture is the main failure mode of concrete under uniaxial tension. The mixed-mode fracture energy caused by the difference of mode I and mode II fracture energy comprises 48.2% of the whole tension fracture energy of the specimen. The smoothness of aggregate has a positive effect on uniaxial tension strength, while it would reduce the mechanical occlusion between particles and lead to a higher strength degradation rate.

Keywords: concrete; meso-scale; simulation; Cohesive Zone Model

Seepage characteristic of marble fracture and effect of filling sands

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Abstract: Filled and unfilled fracture seepage tests were conducted on 9 marble samples with different morphology surfaces by self-made rock fracture seepage test system. The effects of loading and unloading process, feeding water head, fracture surface morphology, filled sand particle size and thickness on fracture seepage under different normal stress conditions were studied. The results show that when the fracture is not filled, in the normal loading stage, the seepage flow increases linearly with the increase of feeding water head, and decreases negatively exponentially with increase of normal stress. The relationship between seepage flowrate and normal stress was obtained by embedding a 3D morphology parameter S_q (slope root mean square). The flowrate per head increases exponentially with mechanical aperture and the average index is 3.01, thus a modified Cubic law is proposed and the modified parameters have exponential function relations with S_q of the rock fracture surfaces. In the unloading stage, the effect of normal stress on flowrate is greatly reduced and the flowrate almost keeps unchanged with the decrease of normal stress. Comparing with the unfilled marble fractures, the effects of fracture closure, fracture surface morphology and normal stress on fracture flowrate are reduced when the fracture is filled with sands. The flowrate per head increases when the filled sand size or the filled sand thickness is bigger on the whole.

Keywords: seepage test; normal stress; 3D morphology parameter; flowrate; filled fracture

Study on the real-time accurate model of pumped storage unit based on equivalent circuit

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Abstract: A real-time accurate equivalent circuit model (RAECM) of pumped storage unit(PSU) is proposed to solve the conundrums that the traditional linear model is difficult to accurately describe the hydraulic transient behavior of large fluctuating conditions, and the nonlinear model based on method of characteristic(MOC) cannot ensure the real-time of simulation and the existing models of PSU for control optimization match the actual operations in power station hardly. According to the layout of pipe system, the topological network of equivalent circuit is constructed. The interpolation model of pump turbine based on improved Suter transformation and BP neural network has been put forward to improve the accuracy in the S characteristic area. The formula of water head for compensating error is derived using the discrete analysis of variable-scale space-time. The implicit Radau ⅡA is introduced to solve implicit ordinary differential equations, which can improve the model stability owing to the wider stability domain. Finally, the time complexity and simulation efficiency of RAECM are analyzed. The simulations indicate that RAECM can not only satisfy the calculation precision of the overall performance, but also guarantee the real-time in operations, which can serve as the basis for the various engineering applications.

Keywords: equivalent circuit theory; pumped storage unit; the real-time simulation; transient process; complete characteristic curves

Optimization of nozzle structure and investigation on hydraulic performance of impact sprinkler

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Abstract: In order to reduce the operating cost of impact sprinkler in engineering application and improve the quality of sprinkler irrigation, this paper focused on the improvement of main and secondary nozzle structure of the 8034D impact sprinkler, and the effects of the improved nozzle structure on sprinkler flow rate, radial water distribution and the uniformity coefficient of combined sprinkler irrigation. The results showed that, conical angles of inner cavity had a significant effect on sprinkler flow rate, the larger the conical angles of inner cavity, the smaller the sprinkler flow rate. At the same working pressure, the improved secondary nozzle structure had little effect on the sprinkler flow rate. With the increasing of the horizontal distance between the measured point and the sprinkler, the radial water application rate at different conical angles of inner cavity and the cylinder lengths was decreasing. The uniformity of sprinkler irrigation of the combination 2 were better among the four combinations, the average uniformity coefficient of seven kinds of combined space in a square arrangement of sprinkler was 87.8%, and the peak of the uniformity coefficient reached 89.3% when the sprinkler spacing was 17m×17m. Taking the irrigation quality and cost into account, the main and secondary nozzles of the 8034D impact sprinkler choosing combination 2 at the sprinkler operating pressure of 250 kPa and the sprinkler spacing of 17m×17m.

Keywords: impact sprinkler; improvement of nozzle structure; sprinkler flow rate; radial water distribution; uniformity coefficient of combined sprinkler irrigation

Study on heat transfer across island riparian zone under Manwan reservoir operations in summer

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Abstract: In this study, water level and temperature in the riparian zone were in-situ monitored for 49 days in summer using automatic sensors on an island of Manwan reservoir in the Langcang River. Through the analysis of the lateral hyporheic exchanges and temperature spatial-temporal patterns in the riparian zone, the heat transfer quantities across the riparian zone were calculated, which is helpful to reveal the riparian heat transfer in summer under Manwan reservoir operations and the underlying mechanisms. The results demonstrate that due to the reservoir operation the frequent fluctuation of water level promotes the hyporheic exchanges between the island and reservoir with exchange volume per unit length across the island up to $-0.12 \sim 0.06$ m^2/d. Under the solar radiation, the island sediments is heating up faster because of its specific heat lower than water, that forms the difference in temperature of 0.26 ℃ ~ 4.80 ℃ higher than the water in reservoir. Driven by the hyporheic flow, heat is transferred from the island to the reservoir. The heat transfer quantity is following the order of upper layer > middle layer > bottom layer, with 1635.21 MJ, 730.68 MJ and 104.49 MJ per unit area, respectively. Sensitivity analyses show that the heat transfer is most affected by amplitude of water fluctuation, followed by the temperature difference and least affected by the fluctuation period. This study is beneficial to the studies of heat and water exchanges in riparian zones in dammed rivers.

Keywords: reservoir operation; riparian zone; hyporheic exchange; heat transfer; sensitivity analysis

Effect of lithium bromide on early hydration process of cement at low temperature

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Abstract: The traditional early strength components can not meet the requirements of green and high performance concrete, and the researches of early strength accelerators at low temperature (especially 5℃) were relatively few, and their effects were limited, and the mechanism was also not understood well. In this study, as an early strength component, the effect of LiBr on the compressive strengths and setting times at 5°C were investigated, and its effect on the early hydration process of cement was also discussed. The results show that with the addition of LiBr at low temperature of 5℃, both the initial setting and final setting time of cement paste are slightly shortened, which can significantly accelerate the development of the early strength of the mortar speciment, and thestrength is still greatly improved at 28d. Meanwhile, the compressive strengths of motars mixed with 0.5% LiBr can increased by 383%, 54%, 41% and 11% at 1d, 3d, 7d and 28d respectively, each of them is close to the strengths of the contrast sample cured at 20℃ at the same age. The presence of LiBr can promote the dissolution of C3S at low temperature, resulting in a significant increase in its dissolved amount. With the increased amount of $Ca(OH)_2$ dissolved and the solution pH value, it is beneficial to the precipitation reaction of hydration products. At low temperature, LiBr can promote hydration reaction of cement at the early stage, and shorten the induction period of cement hydration, advance the acceleration period, and increase the maximum heat release rate and the heat release rate. The presence of LiBr can make the cement hydration entered into the D stage earlier which is controlled by the diffusion factor. A large amount of $Ca(OH)_2$ is formed in the products after only 12 hours of hydration, and some calcium silicate hydrate and hydrated calcium bromoaluminate products are also produced.

Keywords: low temperature; early strength accelerator; lithium bromide; solution; hydration

Flow characteristics analysis of large-diameter flow and pressure regulating valve with piston sleeve

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Abstract: Various flow and pressure conditions of pipeline can be adjusted by the flow and pressure regulating valve whose hydraulic regulation performance and flow characteristics greatly influence the efficient operation of pipeline system. In this research, the large-diameter flow and pressure regulating valve with piston sleeve of 2400LT-41X-10Q type was investigated by the CFD code Fluent, combined with RNG k-ε turbulence model and dynamic mesh. And flow characteristics of the valve was analyzed by comparing the steady-state conditions in different valve openings as well as transient conditions of the opening and closing processes. The results indicate that the dynamic flow coefficients in opening and closing processes are both less than the corresponding static flow coefficients in steady-state conditions, while the dynamic resistance coefficients are larger than the static ones instead, which is caused by the flow obstruction from piston sleeve movement. Corresponding to the opening and closing processes respectively, opposite transient lateral forces will exert on the piston sleeve and the force component in axial direction is significantly greater than those in other two directions. Due to the vacant travel used for fixing the sleeve near full valve opening, the lateral forces in vertical and horizontal direction will get to their peak magnitudes, which may influence the operation of driving mechanism or make the piston sleeve get stuck in these directions. Moreover, flow field distributions of velocity, pressure, turbulent kinetic energy and turbulent dissipation rate in different openings were compared to illustrate operation and flow characteristics of the flow and pressure regulating valve. The analysis results provide a guidance for selection and utilization of the flow and pressure regulating valve with piston sleeve.

Keywords: flow and pressure regulating valve; flow coefficient; resistance coefficient; lateral force; flow characteristics

Experimental study on compression characteristics and deformation parameters of the rubble-bedding of gravity quays

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Abstract: The compression characteristics and deformation parameters of the rubble-bedding of gravity quays are investigated by prototype compression test. Stones of 10~80kg are randomly filled in a steel cylinder, and are imposed to varying levels of compression load. The load-deformation curves of the block stones and the circumferential strain of the steel cylinder are tested. The stress-strain curves and deformation parameters are finally obtained from combined experimental and finite element analysis. Five groups of samples with different initial void ratios and grading curves are studied by compression test of reciprocating loading and unloading. According to the test phenomena and data, the particle crushing characteristics, the compression characteristics and void ratios characteristics of the block stones are analyzed. The Poisson's ratio of the block stones can be assumed as a constant between 0.2 and 0.3. The compressive deformation moduli depend on the numbers of loading and unloading, which can be denoted as three compression modulus parameters of initial loading, secondary loading and multiple loading according to the value range. The stress-strain curve of the block stones in the rubble-bedding of gravity quays can be described piecewise by the corresponding modulus of compression according to the loading times of segmented load stress.

Keywords: rubble-bedding; block stones; compression test; deformation parameters; experimental study