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Research progress and frontiers on flood discharge atomization of Chinese high dam projects

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Abstract: The flood discharge security and protection of high dam projects is a hot issue in the field of hydraulic engineering. For high dam projects with characteristics of high water head, large discharge and narrow canyon in China, the problem of flood discharge atomization is very serious. With Chinese hydropower projects construction extending to high altitude area with low pressure, the atomization mechanism under complex environment, forecasting methods with higher precision and scientific hazard prevention technologies are in urgent need of breakthrough. The article constructed the field source characteristics and protection system of atomized rainfall on the basis of research achievements and engineering applications of flood discharge atomization at home and abroad. Moreover, the article abstracted the development achievements and technical bottleneck in this field, and expounded the methods to break through key scientific and technical issues. Series studies and results are intended to promote flood discharge atomization research from experience to science and provide theoretical and technical supports for structural design and long-term safe operation of large water resources and hydropower engineering.

Keywords: high dam atomization; field source characteristics; complex discharge environment; prototype telemetry; microscopic test; refined prediction; hazard prevention and control

Research and practice on intelligent construction technology system of Jinsha River hydropower projects

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Abstract: Facing the challenges of complex environment, condition changes, resource flow, structural transformation and behavior adjustment of large hydropower projects in the lower reaches of the Jinsha River, an intelligent construction technology system has been established to focus on the whole life cycle safety of large-scale hydropower projects from the engineering planning, construction, and operation. This intelligent system adopts the principle of intelligent closed-loop control of "comprehensive perception, real analysis and real-time control", takes digital and intelligent technologies of resource elements digital management, digital control of business procedures, intelligent control of process flow, accurate analysis of physical costs, structural safety, coupled simulation analysis, and linkage control as its core, the hydropower engineering data model like dam panoramic information model DIM as its foundation, and the intelligent construction management platform iDam as its main body. Hence, this paper analyzes the key technologies, including engineering data structure decomposition and coding system, engineering data aware-transmission-sharing technology, the systemic architecture and business architecture of iDam platform, and the performance of intelligent construction engineering. Relying on the unified engineering data structure and coding system, the platform iDam is capable to integrate all basis data, environment data, process data, and monitoring data throughout the whole engineering process of the construction. As a result, the analysis function, based on engineering technology and management data, can be applied to different parties including owners, construction, supervision, design, R&D and operation side. This early practice of intelligent construction shows that the technical system established by this paper is scientific and feasible, which makes it a good reference for the study and application of intelligent construction technology and management system in terms of infrastructure.

Keywords: intelligent construction; management platform; intelligent technology; data model; coding system; hydropower engineering

Water distribution system simulation and fault detection platform by means of transient analysis

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Abstract: To overcome the deficiency such as check error of the traditional model for fault detection and steady flow model itself, this paper tries to design and develop a Smart Water Distribution System (WDS) simulation and fault detection platform including leaks and blockage by means of transient analysis. Besides, the corresponding fault identification method is presented. The platform includes the conventional water supply tank, water distribution system, experimental control system, variable-speed pump, fault simulation device, low intensity transient exciter and so on. Based on the RSView configuration software, a Supervisory Control and Data Acquisition (SCADA) system for the WDS was developed and thus, the pressure and flow conditions in the WDS can be monitored. The newly controllable and low intensity transient exciter was developed and it can replace the traditional valve and produce the similar effect of transient fluctuation excited by the valve closure. The experimental platform expands the idea of control, simulation, fault detection and response determination for WDS in the laboratory, and provides a reference for supporting and popularizing the practical smart WDS and fault detection analysis.

Keywords: water distribution system; smart water resource; fault detection; SCADA system; transient flow exciter

Critical water level of abrupt loess landslides: a case study in Heifangtai, Gansu Province

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Abstract: The field investigation of Heifangtai loess landslides in Gansu Province shows that the rise of groundwater level may lead to abrupt loess landslides. Based on the synchronous monitoring of water level and deformation of typical landslide, it is confirmed that when the groundwater level rises to a certain extent, it will cause deformation and failure of landslides. In order to further reveal the influence of water level on soil failure, the failure process of soil in the process of gradual increase of pore water pressure is studied by triaxial normal deviatoric stress drainage shear test. The results show that the pore water pressure can cause the sudden increase and destruction of the soil deformation when the axial stress is 26%, which is verified by the field investigation of the landslide water level and the thickness of the Loess by the ground water level of Heifangtai which accounts for the thickness ratio of 0.4 of the loess. Combined with the test and investigation, the identification method of such landslide is established based on the water level ratio.

Keywords: Heifangtai; sudden loess landslide; ground water table; triaxial test; water level recognition

Theoretical analysis and the classification of pollutant mixing zone considering variation of flow velocity and lateral diffusion coefficient in rivers

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Abstract: Average velocity and lateral diffusion coefficient of the river section can not well reflect on the characteristics of the pollutant advection-diffusion near the discharge bank, because the middle deep slot and the far-shore topographic changes of the wide shallow river have little effect on the pollutant mixing zone near the discharge bank. Based on the analysis of the synchronous observation data of the sewage mixing zone at Huangshaxi in the Yangtze River during a flat water period, the lateral exponential distribution of depth-averaged flow velocity and the two-dimensional transformation formula of the lateral diffusion coefficient are proposed. Under the condition of stable point source on the straight bank of the wide river, the analytical solution of the concentration distribution of the two-dimensional advection-diffusion equation with variable coefficient was solved, and the concentration distribution characteristics were analyzed. On this basis, the theoretical formulas of the maximum length, maximum width, and corresponding longitudinal coordinates and area of the pollutant mixing zone were derived, and the boundary normalized (equal concentration) curve equation of the pollutant mixing zone was given. The influence of the distribution characteristic parameters (m, n and α) of the depth-averaged flow velocity and the lateral diffusion coefficient on the morphology of the pollutant mixing zone was discussed. The classification, shape characteristics, classification conditions, and variable lateral diffusion coefficients estimation methods of the pollution mixing zone on the river bank were proposed. The example shows that the α-I type pollutant mixing zone, boundary curve equation, and geometrical characteristic parameters can characterize the isoline shape of the COD_{Cr} field observation of the sewage mixing zone at Huangshaxi in the Yangtze River during a flat water period.

Keywords: river shore discharge source; exponential law of the flow velocity; variable lateral diffusion coefficient; concentration distribution; pollutant mixing zone; geometric characteristics; classification conditions

Seismic fragility analysis of arch dam based on vector-valued intensity measure

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Abstract: Based on vector-valued intensity measure (VIM), seismic fragility surface of arch dam is established with three performance indexes, namely arch crown displacement, transverse joint opening and damage volume ratio. Taking the Baihetan arch dam as the research object and considering the uncertainty of ground motion and material, incremental dynamic analysis (IDA) of the arch dam is carried out. After the IDA results are taken into logarithm, the binary linear regression is performed to obtain probabilistic seismic demand model and then the seismic vulnerability surface is calculated. The efficiency of VIM and scalar-valued intensity measure (SIM) is compared. The research results show that VIM can significantly reduce the dispersion of seismic demand prediction about arch dam because of containing more seismic intensity information. It is more efficient than SIM. The seismic vulnerability surface based on VIM is more reliable than the seismic vulnerability curve based on SIM.

Keywords: arch dam; ground motion; vector-valued intensity measure; fragility; uncertainties

Effects of salt in irrigation water on soil structural properties and water flow characteristics

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Abstract: Non-conventional irrigation water (e.g. reclaimed water and brackish water) for irrigation alleviates the shortage of agricultural water resources and increases the crop yield. However, salt in irrigation water modifies the irrigated soil structure and properties and changes the soil water flow characteristics, increasing the difficulty of irrigation and fertilization management and enhancing the contamination risk for groundwater system. In this research, laboratory irrigation experiments carried on manually filled soil columns were conducted to study the effects of salinity of irrigation water (i.e. 0, 1.0, 3.0 and 5.0g/L), irrigation frequency (irrigated every day, once every two days, and once every four days), and saline water and freshwater alternative irrigation schedule (irrigated with freshwater only, irrigated with saline water only, and irrigated with saline water and freshwater alternatively) on soil bulk density, soil aggregate stability, soil porosity and pore-size distributions, soil surface infiltrability and soil water flow heterogeneity. The results illustrated that, moderate salinity of irrigation water, lower irrigation frequency with higher irrigation quota, and saline water and freshwater alternative irrigation schedule all enhanced the soil aggregate stability when wetting, prevented soil clogging, improved soil surface infiltrability, and decreased soil water flow heterogeneity. This research has certain reference value for reclaimed and brackish water irrigation scheduling design.

Keywords: salinity; soil aggregates stability; soil pore size distribution; soil surface infiltrability; heterogeneous soil water flow

Research on collaborative emergency dispatch of the excessive flood of cascade reservoirs

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Abstract: Due to the impact of global climate changing, the frequency of extreme weather events has increased significantly. The suddenness, harmfulness and unpredictability of the excessive floods are more prominent, posing a great challenge to the collaborative emergency dispatch and the safety of cascade reservoirs. And the dam break or even continuous collapse is the biggest threat to the cascade reservoir. In response to the excessive flooding, it is one of the effective means to realize the comprehensive utilization efficiency of reservoirs to carry out emergency dispatch of cascade reservoirs. In this paper, the maximum water level minimization criteria is selected as the objective function of the collaborative emergency dispatching model for excessive flood, and the Progress Optimality Algorithm method is used to solve the model. Taking the Pubugou Reservoir, the Shenxigou Reservoir and the Zhentouba-I Reservoir in the Dadu River Basin as an example, an emergency dispatching plan for the excessive flood of the cascaded reservoirs in this basin is proposed, the process of its exceeding flood control is calculated. The rationality and reliability of the above model are verified. The results indicate that through the collaborative emergency dispatching of cascade reservoirs, each reservoir will pre-discharge the water in the pre-flood stage, freeing up more reservoir storage capacity, facilitate to meet the possible flood in the later stage, reduce the water level of each reservoir as much as possible, and effectively ensure the flood control safety of cascade reservoirs. The research results have important theoretical significance and engineering practical value for the establishment of emergency dispatch mechanism for the excessive flood of cascade reservoirs in major river basins.

Keywords: cascade reservoirs; excessive flood; maximum water level minimization criteria; collaborative emergency dispatching

Modeling and research of stochastic differential equations for hydraulic geometry relationship

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Abstract: Uncertainty in flow-sediment input and channel boundary of restriction caused by environmental change (such as clclimatic events) pose difficulties for the accurate acquisition of information on river morphology dynamics. In this study, a set of stable stochastic differential equations (SDEs) are developed to simulate the dynamic probability distributions of typical hydraulic geometry variables represented by slope, width, depth and velocity with varying bankfull discharge at certain moment in river system. The random parts of each equation are modeled based on single Gaussian white noise and further on compound Gaussian/ Fractional white noise plus Poisson noise. Consistent estimate of the SDEs parameters are conducted using a composite nonparametric MLE method. The stochastic models are examined with Monte Carlo simulation in a lower Yellow River case, and results successfully reveal the potential responses of hydraulic geometries to stochastic disturbance, and especially, the average trends mainly run to synchronize with the measured values. Comparisons among the three models confirm the advantage of Fractional jump-diffusion model, and through further discussion, stream power on the basis of such model is concluded as the better systematic measure of river dynamics. The proposed stochastic approach is new to the field of fluvial relationships, and its application could help to design and monitor river system with the specified accuracy requirements.

Keywords: hydraulic geometry; stochastic differential equation; environmental change; river management

Research of water resources multi-dimensional equilibrium allocation based on eco-hydrological threshold regulation in inland arid region

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Abstract: To tackle the strong conflict between urban development and ecological environment protection in inland arid regions, a multi-dimensional equilibrium allocation model of water resources based on eco-hydrological threshold regulation was constructed, after identifying the coupling mechanism between water cycle and ecological evolution. The model is divided into three layers; the first layer manages the total consumption of the water resources system and regulates the balance between groundwater exploitation and supplement in the basin; the second layer regulates the balance between water supply and demand and the balance between water resources and irrigation area from the economic and societal system in the administrative division; the third layer regulates the balance between water resources and ecological environment and the balance between water and salt of the environmental system in the key control channel sections and irrigation areas, as well as providing the corresponding multiple loop iteration algorithm. Applying the model to the Tarim River Basin located in China's inland arid region, the results show that, in the normal and dry years (occurrence no greater than 50% comparing to the long-term climatology), with an increased water-saving irrigation area of 0.85 million hectares, a reduced agricultural irrigation area of 0.41 million hectares, as well as a reduced water usage of national economy by 7.5 billion m^3, it is possible for the orderly benign evolution and efficient as well as balanced development of composite system integrated with the water resources, economic society and ecosystem, and the results also verify the feasibility of the method.

Keywords: ecosystem; water cycle; ecological hydrology index threshold; water resource multi-dimensional equilibrium allocation; Tarim River

High efficient and accurate simulation of pollutant transport in torrential flow based on adaptive grid method

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Abstract: A Godunov-type scheme finite volume model based on adaptive structured grid method is proposed for accurately simulating pollutant transport in sudden water pollution accidents with torrential flow conditions. In the model, two-dimensional shallow water governing equations are discretized by adaptive structured grids. The structured grids with high gradients of water level or pollutant concentration are subdivided to improve grid resolution. In addition, the grids near wet /dry fronts are also subdivided. The model has spatial-temporal second-order precision through solving shallow water governing equations by MUSCL-Hancock method. HLLC's approximate Riemann solution is used to compute the interface flux based on non-negative reconstruction and local modification of bed slope, it can maintain the stability and well-balanced condition of the model . The test results indicate that adaptive gird method can automatically identify and subdivide the grids with high gradients of water level or pollutant concentration as well as the girds near wet/dry fronts. It can improve model computational efficiency without compromising solution accuracy. The model can efficiently and accurately simulate pollutant transport in sudden water pollution accidents with torrential flow conditions and is applicable for assessment, early warning and emergency management of sudden water pollution accidents.

Keywords: sudden water pollution; torrential flow; pollutant transport; adaptive structured grids; finite volume

Joint state and parameter estimation of two-dimensional soil water flow model based on Ensemble Kalman Filter method

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Abstract: The Ensemble Kalman Filter method (EnKF) explicitly considers the uncertainties such as input, output and model structure, and has been widely used in the parameter estimation problem in hydrology. The objective of this study was to extend the use of EnKF to state and parameters estimation of two-dimensional soil water flow model. Numerical experiments were conducted to assess the performance of EnKF on soil hydraulic parameters estimation and pressure head assimilation under the condition of line source infiltration for silt loam, loam and sandy loam. The influence of the arrangement of observation points and the number of observation points on assimilation results was further analyzed. The results show that the vertical arrangement of observation points can obtain better parameter estimation in comparison with that of horizontal arrangement for silt loam. The saturated hydraulic conductivity and shape parameter can be well estimated when the observation points are arranged horizontally in 0-30cm deep soil for loam and sandy loam. The observation points should be arranged as close as possible to the soil surface, so that the assimilation system can update the state as soon as possible and the parameters converge to the true value more quickly. However the assimilation effect on the pressure head is limited to a certain depth of soil. The prediction errors of soil pressure head in the areas with observation points are smaller than that of areas without observation points. Increasing the number of observation points can improve the prediction of soil pressure head and the estimation of soil hydraulic parameters. The result of this study indicates that the EnKF is an effective method for parameter estimation in two-dimensional soil water flow model.

Keywords: Ensemble Kalman Filter; two-dimensional soil water flow; parameter estimation