Reservoir Routing in Successive Rockfill Detention Dams using Two-Dimensional Mathematical Model for through and Overtop Flow

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Abstract

Rockfill dams can be considered as effective and economical tools in flood control. As such, employing successive dams is expected to cause an effective mitigation to flood hydrograph. Since flow in coarse media of rockfill dam is turbulent, flow analysis must be based on non-Darcy equations. Flow effects interaction of successive rockfill dams, overtopping flow condition, which maybe experienced by the first dam, in addition to through seepage flow lead to high complexity of hydraulics of such dams. In this paper, by introducing the inflow hydrograph to the first reservoir, employing a two-dimensional model for through and overtop dam flow and also employing hydrologic reservoir routing method, it is demonstrated that obtaining the final outflow hydrograph is possible. The mathematical model accuracy was evaluated by comparing its results to experimental data. The model results show good agreement with this experimental data. Finally, sensitivity analysis demonstrated that the model results is much more sensitive to the average particle size of rockfill media compared to other parameters such as dam's length and upstream and downstream angles.

Key words: Flood Control, Successive Rockfill Dams, Through and Overtop Flow, Non-Darcy's Flow.

The Efficacy of a Convex Corner at a Bend Inlet for the Control of Supercritical Oblique Waves

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Abstract

A novel method for the control of supercritical waves is introduced by the installation of a convex corner at a bend inlet. In this method the negative waves emitted from the convex corner are superimposed on the positive waves caused by the outer wall of the bend. Thereby, the heights of the positive waves are decreased. In the first part of the article, the existing analytical relationships for the supercritical flow in straight transitions and bends are reviewed and the interactions of waves in them are examined. Then, using the Roe-TVD finite volume method, the supercritical flow in transitions and bends is simulated numerically. The precision and accuracy of the numerical results in comparison with analytical, numerical and experimental solutions of the other researchers are satisfactory. Next, for the reduction of wave height at the outer wall of a curved channel, a small convex corner is located at the inner wall of the bend inlet. The interaction of positive and negative waves transforms the original single-hump wave at the outer wall to a smaller double-hump wave. The optimum expansion angle of the convex corner (α) is a function of the offset breadth to the bend width, d/b, radius of curvature to the bend width, r_c/b, and the inlet Froude number, Fr_0. The numerical studies carried out for dimensionless widths (d/b=4%, 8%, 12%), in the range of $2.5<Fr_0<4.5$ for three bends with (r_c/b= 10, 15, 20) indicated that using an optimum convex corner the wave height may be decreased between 10 to 45%.

Key words: Supercritical flow, Bends, Oblique waves, Transitions, Convex corner, Roe-TVD method

Construction and Evaluation of PID Control System for Irrigation Canals in Laboratory Scale

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Abstract

Automation is one of the main options for improving operations and increasing flexibility in irrigation canals. Construction and testing of related technology is one of initial and main attempts in reaching this goal.. In this research PID classical control system was constructed, and tested at a laboratory flume. The hardware of the system includes the depth and gate opening sensors, motor, slide gate, electronic boards and computer. The software part of the system is the PID control system, which is developed and connected with equipments using LABVIEW software. To study the performance of the constructed control system, different scenarios of sudden changes of upstream and downstream flow were tested. Maximum Absolute Error (*MAE*), Integral of Absolute magnitude of Error (*IAE*) and System Response Time (*SRT*) indicators are used for evaluating the performance of the system. The results showed that the performance of the developed upstream and downstream control system is appropriate, However, downstream PID control system showed better performance when compared to the upstream PID control system. The developed PID automatic control system and experiences gained from constructed facilities could be implemented in irrigation canals.

Key words*:* Technology Development, Automation, Control Systems, Irrigation Canals, Labview, PID Logic

Optimal Dimensions of Protective Spur Dike for Mitigation of Scour Depth around Main Spur Dikes within a Straight Reach for Incipient Motion for Bed Sediment Movement

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Abstract

Maximum scour depth around a series of spur dikes is one of the important problems in their design. In this paper, the mitigation of scour depth around a series of consecutive spur dikes within a straight reach was investigated by using a protective spur dike located upstream of the first main spur dike. Effect of different parameters of protective spur dike is experimentally investigated including 4 ratios of protective spur dike length to the first main spur dike length (L_p/L_f) equal to 0.2, 0.4, 0.6 and 0.8, three angles of protective spur dike (θ) of 45, 90 and 135 degree and 4 ratios of protective spur dike distance to the first main spur dike length (X/L_f) equal to 1, 1.5, 2 and 2.5. The experiments were conducted for the velocity of incipient motion for bed sediment movement and bed size diameter of 0.91 mm (D_{50}) and standard deviation of 1.38. The effect of protective spur dike on the flow pattern around the spur dikes was investigated in a rigid bed too. The experiments showed that the proper design of protective spur dike can significantly mitigate maximum scour depth around the main spur dikes. In particular, the protective spur dike with L_p/L_f =0.8, X/L_f=2, θ=45° decreased an average of 76.6 percent of scour depth around the spur dikes. The maximum decrease of scour depth around the first spur dike (74.7 percent) was obtained by applying the protective spur dike with L_p/L_f=0.8, X/L_f=2.5, θ=90°.

Key words*:* River training, Protective spur dike, Scouring, scour mitigation, 3D flow.

Flood Propagation Forecasting Based on Non-linear Diffusive Wave Equation

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Abstract

Existence of a quick and accurate flood routing model is of great importance for river training as well as flood forecasting and warning systems in order to prevent or mitigate flood casualties and damages. Diffusive wave is one of the channel routing methods in which acceleration terms have been neglected in momentum equation. Among different types of diffusive wave models, Cappelaere equation, considering its unique features, was applied in present research. This model is an advection-diffusion equation, including non-linear parameters, with main advantage of no need for topographic and hydraulic characteristics of the river. In this paper, Leapfrog-Dufort Frankel finite difference numerical scheme was used for discretization and numerical solution of the Cappelaere equation which increases computational speed of flood routing. Furthermore, a novel method of estimating celerity(C) and diffusivity (D) parameters was proposed which is superior to previous methods. In this method, C and D parameters can be calibrated just by observed hydrographs in a reach and are applicable for future flood forecasting in the same reach. By this method, absolute independency of parameter estimation in diffusive wave routing method from river geometry, manning roughness and bed slope is obtained. To validate the model and the proposed method of parameter estimation, the routed hydrographs were compared with the dynamic Saint-Venant equations in a synthetic prismatic channel. Furthermore, the model was calibrated in a 80 km reach, Yasavol-Gharegooni, of Ghezel-Ozan river and results were tested against the observed hydrographs. Using the model, duration of routing in the channel and river were found to be 15.7 and 59 seconds respectively. Maximum error in peak discharge in the channel and river does not exceed 0.04% and 0.24% respectively. Concerning time to peak, the maximum error in the channel and river were 0.87% and 1.57% respectively. Results in the channel and the river showed that the proposed model is not only accurate in predicting peak discharge and time of peak, but also is successful in Conserving mass of flood.

Key words*:* Flood Routing, Diffusive Wave, Cappelaere Equation, Celerity and Diffusivity Parameters..

Flood Control by Optimization of Spillway Gate Operation using Fuzzy Logic

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Abstract

At present appropriate utilization of water resources is vital. Development and establishment of communities along rivers have made the safety against floods very significant. Therefore, dam operation management becomes vital and maneuvering of gates is the most important issue in this regard.

Spillway gate operation policies to reduce flood losses and preservation of storage and safety of the dam are studied in this paper. In this regard, multi-stage operation methods are studied and analyzed. The fuzzy logic principles are used to optimize gate operation and overcome weak points of multi-stage operation method. Karun III dam is considered as a case study and the five stage flood routing policy followed by the fuzzy logic based operation of spillway gates of the reservoir during floods has been applied. The fuzzy logic results in smooth routed hydrographs rather than stepped ones. Eventually, verification of the proposed method has been done by a comparison with the results obtained by using the genetic algorithm to optimize gate operation assuming known inflow hydrographs. Results indicate that the proposed method is quite satisfactory.

Key words*:* Spillway Gate Operation, Five-Stage Operation Policy, Fuzzy Logic, Genetic algorithm.

Scour of Cohesive Material Downstream of an Apron due to Submerged Horizontal Jets

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Abstract

In this paper, the effect of clay content on the local scouring downstream of a rigid apron due to a submerged horizontal jet has been studied experimentally. Seven different mixtures of cohesive sediments with clay content equal to 0, 10, 15, 20, 25, 30 and 40 % were used. Results showed that the clay content has an important effect in the scouring process. It shows that with clay content equal to 40%, the maximum depth of scour may be reduced up to 80% of the non-cohesive materials. Using dimensional analysis, a new non-dimensional parameter is introduced which includes the effect of both the grain densimetric Froude number and clay content. It was also found that there is a critical value for the mentioned dimensionless parameter, where no erosion occurs below that value. Also, dimensionless equations and graphs are presented to determine the characteristic lengths of the scour hole including the maximum scour depth, the maximum longitudinal extension of the hole and the sand wave height.

Key words: Local Scour, Cohesive Sediments, Clay Content, Dimensional Analysis.