US Army Corps of Engineers®
Engineer Research and Development Center

Navigation Systems Research Program Hydrodynamic Design of Inland Structures

Problem

Designers are often faced with difficult challenges at hydraulic structures. Many times the problems they are designing for involve fluid/structure interactions. Problems that fall into this category are deployment of bulkheads under flowing water, vessel response to flow conditions, and the momentum of floating objects (e.g. tows, debris, ice) prior to impacting a structure.

The winter of 2004-2005 saw relatively high flows on the Ohio River. These large discharges produced swift currents that were difficult for towboat pilots to handle. A result of the high flows was that several barge trains struck the spillways of Ohio River locks and dams. Emergency devices to deflect runaway barges from the spillways could prevent barges from striking spillways. Other emergency devices to stop flows in the event of mechanical failure at a hydraulic structure are also needed.

Research Approach

The overall technical objective of this work unit is to integrate the Discrete Element Model (DEM) structural modules into the 2D Shallow-water and 3D Navier-Stokes modules of the Adaptive Hydraulics (ADH) numerical flow model. This will provide a modeling system that can estimate forces on the structures and the hydraulic influence of various components of hydraulic structures. More specific objectives are to develop a full suite of discrete element based tools for simulation of materials and structures that impact the Corps of Engineers navigation mission including ice, debris, riprap, bulkheads and vessels.

Currently the ice/debris DEM has been developed and run on ADH water velocity and surface elevation fields. We have developed full ellipsoidal rock simulations that can be similarly integrated with ADH to model underwater deposition of rock for bed protection. We have also begun prototype development of discrete element based barge and mooring models. The discrete element based barge model will be compatible with the DEM used to model rocks, ice, and debris as well as the elements used to construct the model guard walls, piers, lock walls, and gates. This will allow simulation of impacts, forces and mooring dynamics caused by lock filling and emptying as well as ice and debris effects.

Labs/others involved

Coastal and Hydraulics Laboratory, Cold Regions Research and Engineering Laboratory.

Final Products

Previous efforts have resulted in the integration of a 2D flow model and the DEM producing a river ice/debris model. Demonstration applications were made for ice accumulation at the Soo Lock approach and woody debris passage at the Harland Diversion project. Also, demonstration of the ability to compute vessel/fluid interaction was made in a prototype design of a boom that would deflect a runaway barge from striking a spillway. The demo was applied at the Greenup Lock and Dam on the Ohio River. Vessel movement and the loads generated in the boom were computed. The loads are those generated from the momentum of a drafted barge being carried by the Ohio River current. These simulations and the novel modeling system have been submitted for peer review in a paper to be published in ASCE's *Journal of Hydraulic Engineering*.

The computer models developed in this work unit will not be trivial to run successfully. Generally, the coupled ADH/DEM model will be run to generate data sets from which hydraulic and structural design guidance can be established. The primary technical transfer will be in terms of papers, technical notes, and data sets that can be honed into design guidance.

Ultimately, multiple workshops are planned to provide District staff interested in using these models to address problems such as improved methods for preventing debris and ice from entering lock chambers.

Point of Contact

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Discrete Element Model examples can be found at:
http://www.crrel.usace.army.mil/sid/hopkins_files/Riverice/river_ice.htm