Transportation Pooled Fund Program TPF-5(446) Quarterly Progress Report

Quarter 4, October - December 2021

prepared by
M. Sitek, S. Lottes, H. Ley

Nuclear Science & Engineering Division, Argonne National Laboratory

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TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): _FHWA_____________________________________

INSTRUCTIONS:

Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e., SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* *TPF-5(446)*		**Transportation Pooled Fund Program - Report Period:** ☐Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☒Quarter 4 (October 1 – December 31)
Project Title: **High Performance Computational Fluid Dynamics (CFD) Modeling Services for Highway Hydraulics**		
Name of Project Manager(s): *Kornel Kerenyi*	**Phone Number:** *(202) 493-3142*	**E-Mail** *kornel.kerenyi@fhwa.dot.gov*
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**

Project schedule status:

☒ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date

Project Description:

The Federal Highway Administration established an Inter-Agency Agreement (IAA) with the Department of Energy's (DOE) Argonne National Laboratory (ANL) Transportation Analysis Research Computing Center (TRACC) to get access and support for High Performance Computational Fluid Dynamics (CFD) modeling for highway hydraulics research conducted at the Turner-Fairbank Highway Research Center (TFHRC) Hydraulics Laboratory. TRACC was established in October 2006 to serve as a high-performance computing center for use by U.S. Department of Transportation (USDOT) research teams, including those from Argonne and their university partners. The objective of this cooperative project is to:

- Provide research and analysis for a variety of highway hydraulics projects managed or coordinated by State DOTs.
- Provide and maintain a high-performance Computational Fluid Dynamics (CFD) computing environment for application to highway hydraulics infrastructure and related projects.
- Support and seek to broaden the use of CFD among State Department of Transportation employees.

The work includes:

- Computational Mechanics Research on a Variety of Projects: The TRACC scientific staff in the computational mechanics focus area will perform research, analysis, and parametric computations as required for projects managed or coordinated by State DOTs.
- Computational Mechanics Research Support: The TRACC support team consisting of highly qualified engineers in the CFD focus areas will provide guidance to users of CFD software on an as needed or periodic basis determined by the State DOTs.
- Computing Support: The TRACC team will use the TRACC clusters for work done on projects; The TRACC system administrator will maintain the clusters and work closely with the Argonne system administrator's community; The TRACC system administrator will also install the latest versions of the STAR-CCM+ and OpenFOAM CFD software and other software that may be required for accomplishing projects.

Progress this Quarter:

(Includes meetings, work plan status, contract status, significant progress, etc.)

1: Computational Mechanics Research on a Variety of Projects

1.1: Comparison of experimental and computational hydraulic efficiency of grate inlets

Physical tests of a set of grate inlets presented in HEC-22 were performed at the Hydraulics Research Laboratory at Turner-Fairbank Highway Research Center. A force balance flume was used for this purpose, see Figure 1. The grates selected for testing are: a P50 with straight bars, a 45-deg-tilt bar grate and a curved-vane grate. Models of ½ of the grates' geometry in 1:10 scale were 3D printed at the laboratory. Because the force balance flume is relatively long, as compared to the models of the grates, the downstream-most section of the flume was separated from the rest to decrease the time needed for each test. The models of the grates were installed in one of the corners, next to the downstream wall of the flume. Additionally, two honeycombs were used to eliminate the turbulence and straighten the flow entering the flume. During the tests, the water level was measured with a sensor located on the centerline, ~0.5 m away from the grate. The experimental setup is presented in Figure 2.

Two methods of testing were used, transient and steady. All tests were initialized with a blocked grate, and the flume filled with water. In the transient tests, after the blockage was removed, the water was allowed to drain through the grate. The water level was continuously measured during the test, and the flow rate was calculated from the loss of water level in the flume in time. In the steady tests, after removing the blockage from the grate, the water surface was kept stable by adjusting the flow rate through the pump. The test was repeated for multiple water levels for each of the grates and the correlation between the water level and pump flow rate was recorded.

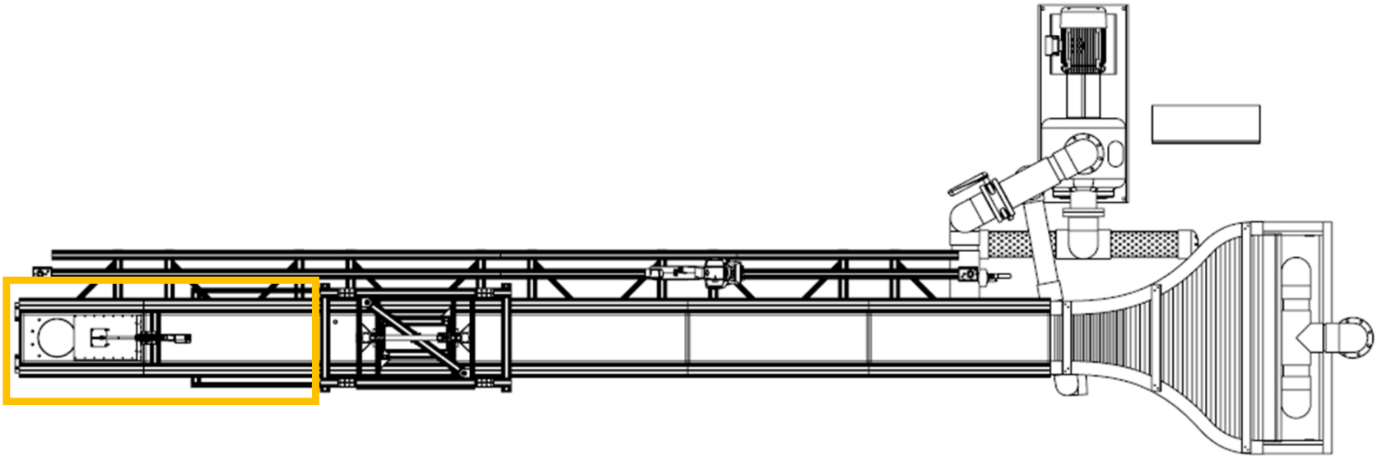

Figure 1. Force balance flume. The section of the flume used to perform the physical modeling is marked with a yellow rectangle.

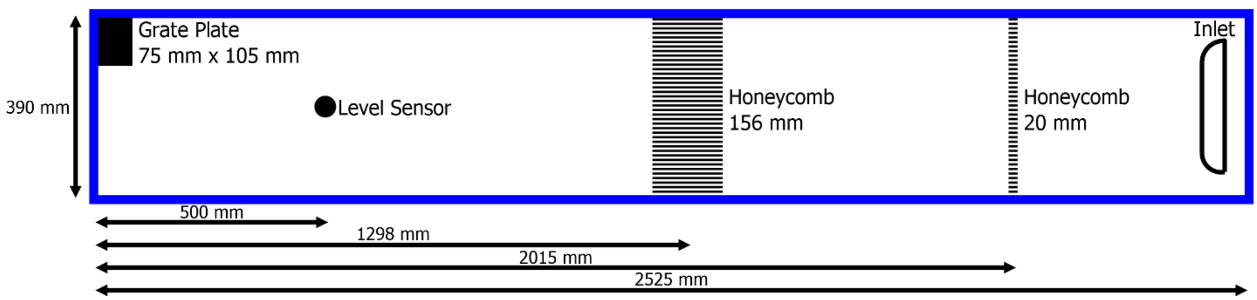

Figure 2. Dimensions and the configuration of the force balance flume section.

The computational model was built in STAR-CCM+ CFD software to resemble the geometry of the physical model of a flume with a grate inlet. The honeycombs were not included in the model. Simulations of the transient tests were performed for the three grates. Each computational simulation was initialized with the domain filled with water. During a simulation, as the water drained through the grate, the water level at the location of the sensor and the flow rate through the grate were recorded.

Example screenshots of a flow through a grate in a CFD simulation and a physical test are presented in Figure 3. The computational result shows the water surface colored with its vertical position from yellow to red.

Figure 3. Flow through a P50 grate in CFD simulation (left) and physical test (right).

The measurements of the flow rates and corresponding water levels, collected during the physical and computational experiments, were plotted in Figure 4 for the 45-deg-tilt grate and the curved-vane grate. Colorful solid lines present the results of the transient physical tests, the green solid lines with markers present the results of the steady physical tests, and the black solid lines present the computational results. Overall, the computational results compare well with the experimental measurements. For a given flow rate, the transient physical model gives the lowest water depth than the steady test. The computational model gives on average greater water depths, which makes it more conservative.

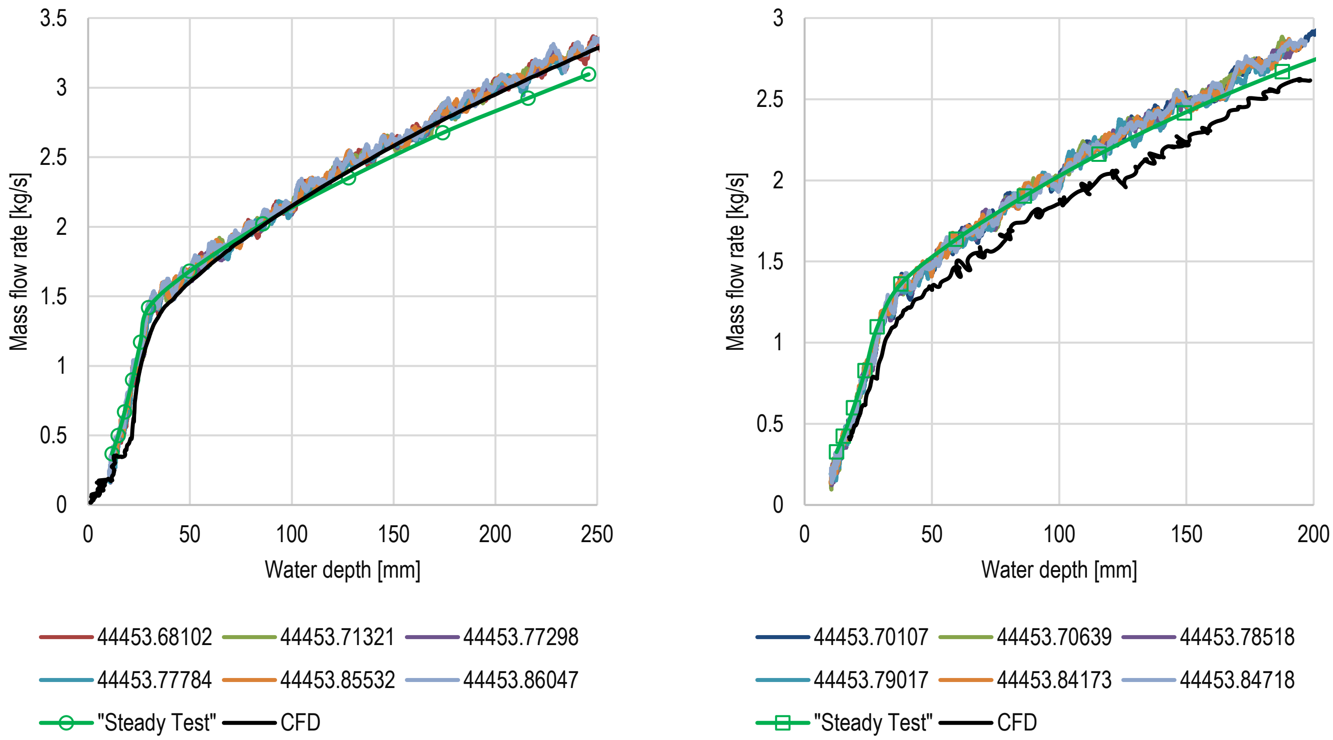

Figure 4. Correlations of the mass flow rate and water depth for a 45-deg-tilt bar grate (left), and a curved-vane grate (right).

Anticipated work next quarter:

1: Computational Mechanics Research on a Variety of Projects

- hydraulic analysis of catch basins on grade and in sump
- analysis of water film thickness on pavements (hydroplaning water film thickness and speed)

2: Computational Mechanics Research Support

This work will continue.

Task 3: Computing Support

This work will continue.

Circumstance affecting project or budget.

(Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.