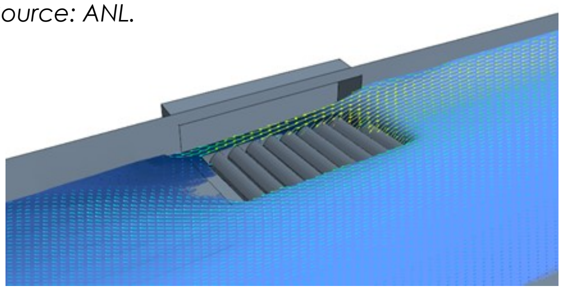
Improving Pavement Drainage in Extreme Weather Events and on Wider Roadways using Computational Fluid Dynamics (CFD)

Source: ANL.



Example result of flow over a drain in on grade location.

The required capacity of road drainage systems to handle higher volumes of runoff during rain events has increased over time. To accommodate growing traffic volumes, modern roads are built with additional lanes, while some older roads have been widened. The additional lanes and widened roads result in a larger pavement surface area and, therefore, a greater rainfall collection area. In addition, more frequent and extreme rain events can overwhelm existing drainage systems, and new systems should be designed to handle the higher rates of runoff. State departments of transportation (DOT) are developing new designs of drainage structures, including more accurate functions of efficiency under a variety of conditions. They are also assessing old designs to determine if they are sufficient to drain higher flow rates off the roads.

The Turner-Fairbank Highway Research Center's (TFHRC's) J. Sterling Jones Hydraulics Research Laboratory provided the technical assistance to several State DOTs to model these drainage structures using their partnership with Argonne National Laboratory's (ANL's) Transportation Research and Analysis Computing Center (TRACC). Three-dimensional CFD analysis can determine flow and efficiency through drains with complex geometry at field scale over a broad range of conditions. As participants of a pooled fund study, two State DOTs, South Carolina Department of Transportation (SCDOT) and Ohio Department of Transportation (ODOT), inquired about using these advanced computing capabilities to perform an evaluation of drainage. SCDOT catch basin types CB16 and CB17 are curb opening inlets, while inlets CB3 and CB3A are a combination of a grate inlet and curb opening.

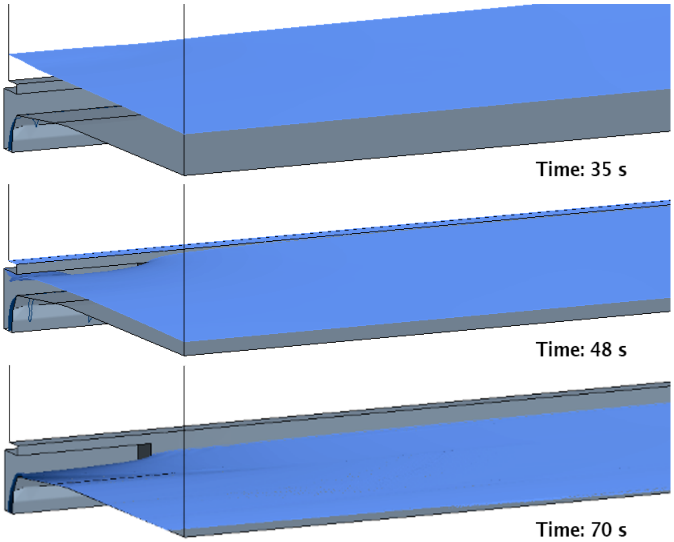
Geometric parameters include varying cross-slopes and longitudinal slopes of the road surface, shoulder/gutter width, and a range of flow rates. On grade and sump conditions are analyzed. The analysis yields the hydraulic efficiency of the inlets; the split of the flow rate between front, side, and backflow of the grate; flow through the curb opening when present; and the bypass flow.

Road surface roughness is accounted for in the models. Concrete roads and other smooth surfaces, including some asphalt, can be modeled as smooth. For rougher roads with texture depths of many millimeters, the effects of roughness can be captured by including the texture of the road surface as a porous media layer.

The computational domain covers the space right above the road and drain. In the model of the drainage in on grade conditions, water is introduced to the computational domain through a velocity inlet boundary condition with assigned depth and velocity of the flow. The flow rate through the drain and the bypass is computed during the simulation and compared to the inlet flow rate. As a result, the hydraulic capacity can be calculated.

To model sump conditions, the computational domain is initially filled with water up to about 3 ft above the road. During the simulation, water is free to flow out through the drain. The flow rate and water depth are monitored during the simulation to establish the hydraulic capacity. The transition between orifice flow and weir flow can be analyzed and studied.

Time snapshots of water draining through a curb opening.



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