NEW MODELS ACCOUNT FOR PAVEMENT ROUGHNESS IN ANALYSIS OF WATER FILM THICKNESS FOR ASSESSING HYDROPLANING RISK

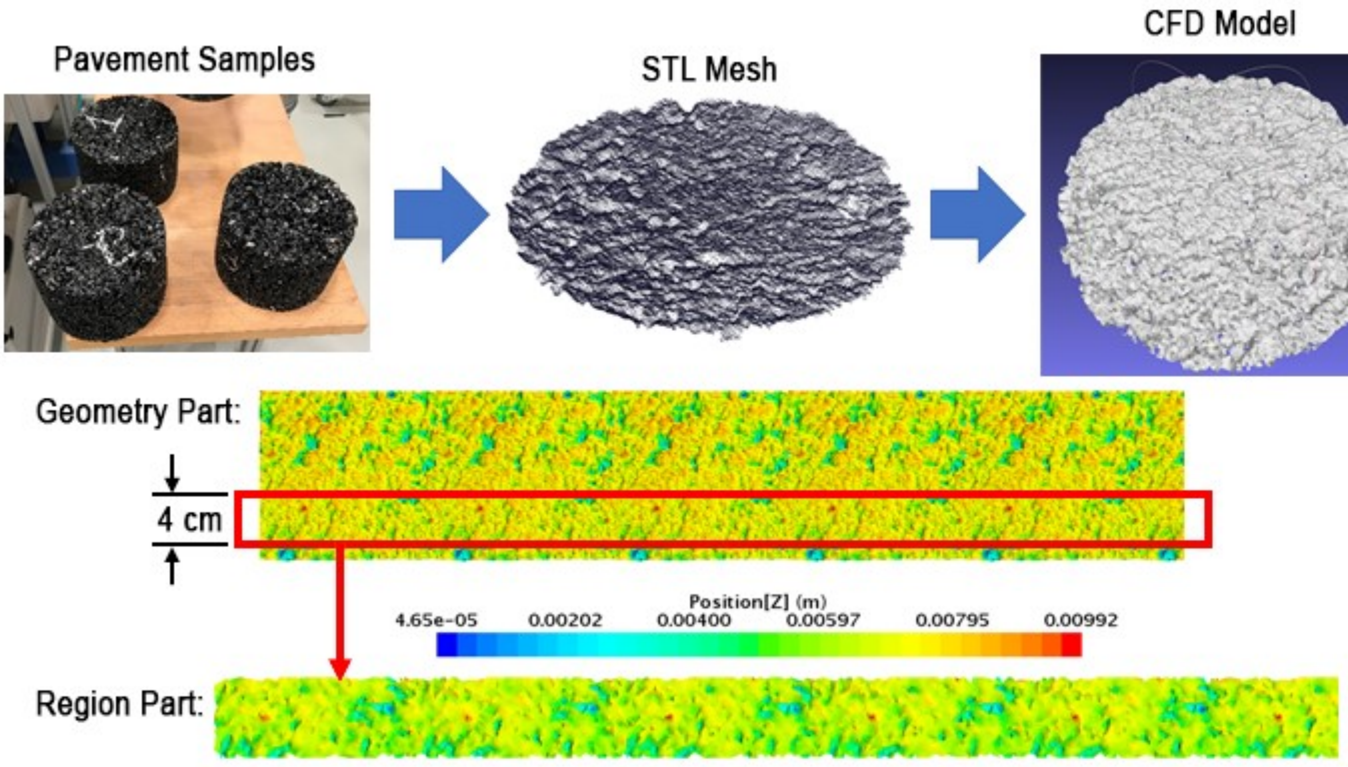
INTRODUCTION

In hydraulic engineering, the Manning's roughness coefficient is often used to characterize surface roughness, and its values are either derived from experiments or assumed from empirical tables. In most computational fluid dynamics (CFD) software, the user must specify a roughness height parameter, k_s, thus setting the equivalent sand–grain roughness height on a surface. The effective roughness height is limited to one half the height of the layer of computational cells adjacent to the road surface; beyond that, it has no effect. The height of cell layers in the analysis of water films is about 0.1 mm, limiting the roughness height to about 0.05 mm, which is far smaller than the range of roughness of road surfaces that may vary up to about 3.6 mm. Alternate approaches to treating roughness in the software are needed.

MODELING ROUGHNESS WITH THE MESHED-OUT GEOMETRY MODEL

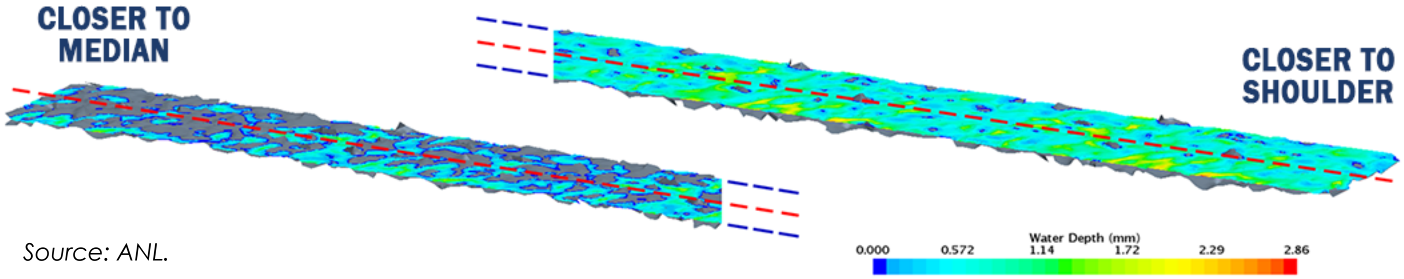
The most obvious way to capture the effects of significant roughness at the road surface (e.g., asphalt) where the water film height is, at most, a few times the roughness height, is to mesh out the roughness of the surface directly. Pavement samples are scanned into a stereolithographic (STL) file, and the sample surface is cut up, copied, and stitched together to construct a larger strip of pavement.

Converting an asphalt sample to a CFD road surface model.(1)



Source: Argonne National Laboratory (ANL). Modifications: Federal Highway Administration (FHWA).

CFD simulation of rainwater buildup and flow on a rough pavement strip across a two-lane highway is shown below, where the rainfall intensity equals 50 cm/hr, and the model has a cross slope of 2 percent.

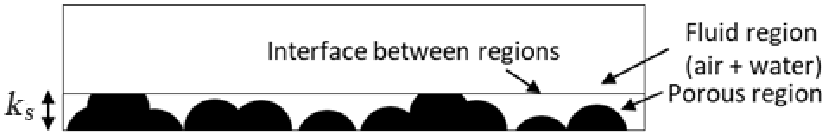


Source: ANL.

Rainwater buildup across a slice of highway.[1]

MODELING ROUGHNESS AS A POROUS REGION

CFD analysis with meshed-out roughness consumes prohibitively large computer resources for large sections of roads. A third approach to modeling roughness assumes that the pavement surface is approximated with a bed of spherical particles that represents the aggregate and uses a porous media model to analyze flow within the rough layer asperities. The parameters that characterize roughness in the model are aggregate size, texture depth, and porosity.

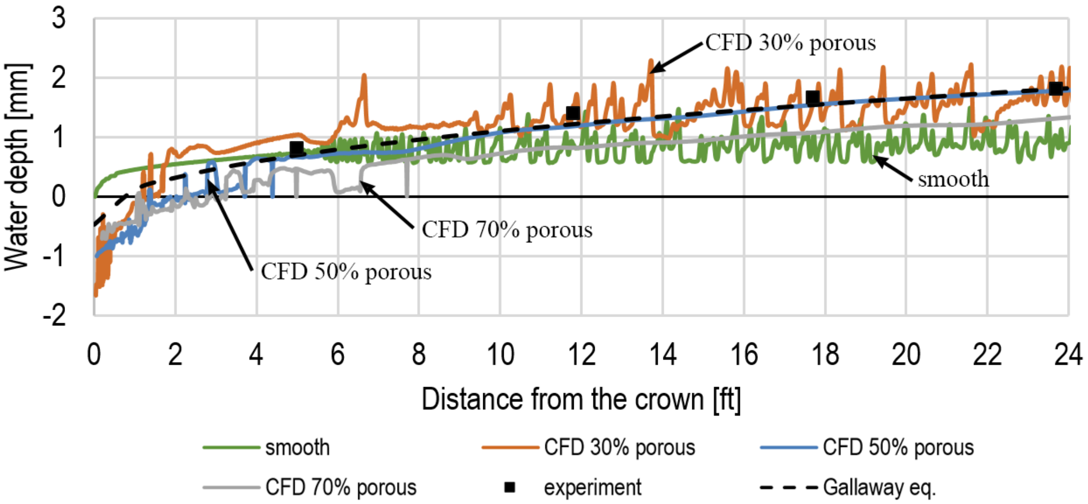


Source: ANL.

Pavement surface approximation with surface particles.[1]

Water film thickness on a two-lane-wide highway strip with a texture depth of 0.5 mm and cross slope of 4 percent at rain intensity of 14 cm/hr is shown below for several porosities. The 50-percent porosity appears to match the experimental data best. The porous media approach captures the effects of pavement roughness well, without using excessive computer resources.

Comparison of water film thickness.[1]



Source: ANL. Modifications: FHWA.

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1. Sitek, M.A. and Lottes, S.A. (2020). Computational Analysis of Water Film Thickness During Rain Events for Assessing Hydroplaning Risk Part 2: Rough Road Surfaces. Argonne National Laboratory, ANL-20/37. Lemont, IL.