

MOUNTAIN-PLAINS CONSORTIUM

RESEARCH BRIEF | MPC 24-526 (project 596) | May 2024

Laboratory Measurements of Bed Shear Stress and Soil Erosion Rate in Cohesive Soils



the **ISSUE**

As engineers design bridges, they must consider the impact of flowing water. Discharge, rate, soil properties and site characteristics are all factors. Soil scoured from around bridge abutments and piers may weaken the structure, reducing the bridge's life span or making it unsafe. The relationship between soil erosion rate and bed shear stress is an important problem in sediment transport and scour. However, obtaining reliable measurements of soil erodibility is challenging, both in the field and in the laboratory. Cohesive soil may erode in blocks, chunks, or non-uniformly. Many studies have been conducted to investigate the erosion processes of cohesive soils, but the understanding is still far from complete.

the **RESEARCH**

The velocity distribution over a clay sample in a soil erosion testing facility was measured. The experimental data were used to study the effect of soil erosion depth on bed shear stress. The relationship between unconfined compressive strength, bed shear stress and soil erosion rate were also investigated.

Soil erosion rate testing was conducted in a 0.15-m-wide, 0.3-m-deep and 1.825-m-long open-channel flume installed with a gravel bed and a 70-mm-diameter sediment recess. Test samples with a range of unconfined compressive strength values were prepared using Nora Moody clay by varying the water content. The tests were performed under steady, uniform flow conditions. The flow rate was kept constant, and the bed shear stress was varied by changing the channel slope and determined using the measured flow depth and channel slope. The soil erosion rate was found from the difference



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Project Title

Measurement of Turbulent
Flow Characteristics and Bed
Shear Stress in Laboratory
Soil Erosion Tests

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the **RESEARCH** continued

in the mass of the test sample measured before and after the test. The measured erosion rate was related to the soil's unconfined compressive strength and applied bed shear stress. The velocity distribution over the soil sample was then measured using the particle image velocimetry technique. The instrument employed a camera to capture the displacement of fluid tracers between straddled frames. The images were processed to obtain the velocity distributions at different soil erosion depths. The bed shear stress over the soil sample was determined from the measured velocity profile using the logarithmic law and compared with the bed shear stress found on the surrounding gravel.

the **FINDINGS**

A new method was developed to determine the bed shear stress on a rough bed using the logarithmic law. The method assumes that the equivalent roughness of the rough bed is a function of the flow depth and grain size and has the same value in uniform and non-uniform flows. The new method reduces the uncertainty in bed shear stress measurements by determining the equivalent roughness experimentally instead of treating it as a fitting parameter in the traditional method. When the new method was applied to a clay sample embedded in a gravel bed, the results showed that the bed shear stress determined from the measured velocity profile did not change significantly from the gravel to the clay when the equivalent roughness was held at the same value, which suggests that an open-channel flume with a rough bed may be a practical way to perform laboratory soil erosion rate testing.

the **IMPACT**

This project has developed an improved method for finding the bed shear stress on a rough bed using the logarithmic law. The logarithmic law is widely used in research and engineering practices to obtain the bed shear stress from a measured velocity profile and is an important tool for predicting soil erosion and scour. The new method can reduce measurement uncertainties where the logarithmic layer is very thin, such as after a sudden change in bed roughness. This common problem is often encountered in laboratory testing of soil erosion and scour.

For more information on this project, download the Main report at <https://www.ugpti.org/resources/reports/details.php?id=1260>

For more information or additional copies, visit the Web site at www.mountain-plains.org, call (701) 231-7767 or write to Mountain-Plains Consortium, Upper Great Plains Transportation Institute, North Dakota State University, Dept. 2880, PO Box 6050, Fargo, ND 58108-6050.



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