Report as of FY2007 for 2006VT25B: "Evaluating Quantitative Models of Riverbank Stability "

Publications

Project 2006VT25B has resulted in no reported publications as of FY2007.

Report Follows

Progress Report: Evaluating Quantitative Models of Riverbank Stability

PIs: Mandar Dewoolkar and Paul Bierman

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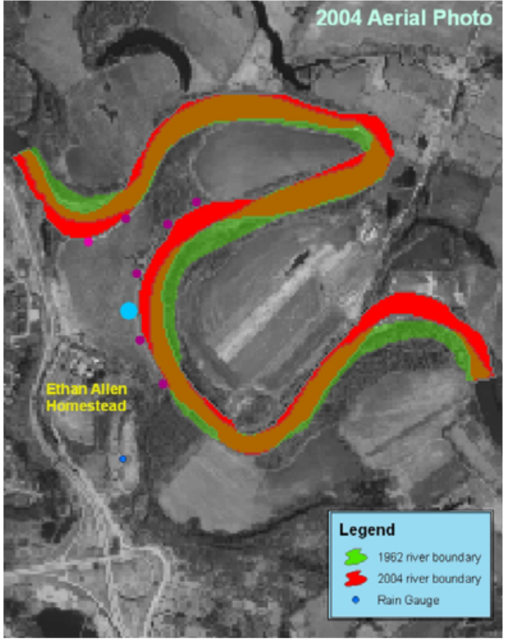
Preliminaries

A kick-off meeting was held between the interested personnel from Vermont ANR and the project team, where ANR's relevant on-going projects and research priorities were discussed. We also reviewed relevant stream-related past and ongoing research projects on-campus so as to optimize research efforts. Based on these interactions, we decided that three types of streams/rivers will be studied, i.e. large low-gradient, smaller low-gradient, and smaller higher gradient. As described earlier, the research methods involve a variety of in-situ soil testing methods, laboratory experiments, multiple types of sensors, and analysis methods. We focused our effort during the 2006 field season on one river to ensure that all in-situ testing methods, sensors and laboratory methods would work satisfactorily and provide a consistent framework for analysis, before investing resources and efforts in instrumenting all sites at once. We chose a stretch of Winooski River (Figure 1) near Ethan Allen Homestead because of its vicinity to UVM. Here, the Winooski River is considered large low-gradient alluvial river. Eight sampling locations along the banks of the river were chosen (Figure 1b – larger blue circle indicates the instrumented site and purple circles indicate other seven sites). All locations were chosen along the outer bank of a meander bend in the river because this is where we expect bank failure is most likely to occur. Of these eight locations, four appeared to be unstable and four appeared to be marginally stable. Figure 1b shows how the banks of the river have changed between 1962 and 2004 from aerial photographs.

(a) Bank of Winooski River



(b) Site locations

Figure 1 Selected site locations along Winooski River and analysis of aerial photos

Subsurface Investigations and In-situ Testing

At each of the selected locations, 3-inch diameter boreholes were advanced using a hand-operated auger (Figure 2a). Because of accessibility and safety issues, it was not possible to use a drill rig. We were able to auger to a depth of up to 16 feet using a hand operated auger above groundwater table. At each of the eight sites, multiple boreholes were augured and bulk soil samples were obtained in each soil layer (Figure 2b). In several locations, 10-inch long Shelby tubes (Figure 2c) were used to retrieve "undisturbed" soil samples. These "undisturbed" soil samples were needed for conducting the direct shear and triaxial tests in the laboratory for verifying in-situ shear strength parameters obtained using borehole shear tests (BST). The BST device (Figure 2d) was acquired for this project. Once the sample was removed from the hole, a BST was conducted to measure the shear strength of the same soil in-situ (Figure 2e).

(b) Bulk soil sample

(a) Hand auger *(c) Shelby tube sample* *(d) BST* *(e) Field operation of BST*

Figure 2: Subsurface investigations and in situ testing

The data collection for the four locations where the bank was on the verge of failure was fairly straight forward. At other four locations, hand auger and BST were a bit difficult to operate because of the presence of some gravel in soils. Soil samples were analyzed in the laboratory. Mechanical sieve and hydrometer analyses were used to determine grain size distributions of soil samples. Results were similar for the soil samples from multiple depths for the above sites. Atterberg limit tests were also conducted on these soil samples. The results from these tests in conjunction with the soil gradation indicate that soils retrieved from the sites can be classified as either silty sand or silt according to the Unified Soil Classification System (USCS).

The Shelby tube samples that were taken in the field were also used to obtain the angle of internal friction and cohesion in the laboratory and compare to those found in the field. The results from the laboratory direct shear tests provided on average higher angles of internal friction, 2 to 5 degrees, with greater variability than were determined using the BST. It is suspected that hand-operated sampling method caused significant compaction of the sample, and the laboratory strength values are not reliable. Presently we are exploring other methods of soil sampling for successful retrieval of soil samples with minimal disturbance. Another alternative is to verify the results of BST at very shallow locations where soil samples for laboratory testing can be retrieved with lesser disturbance.

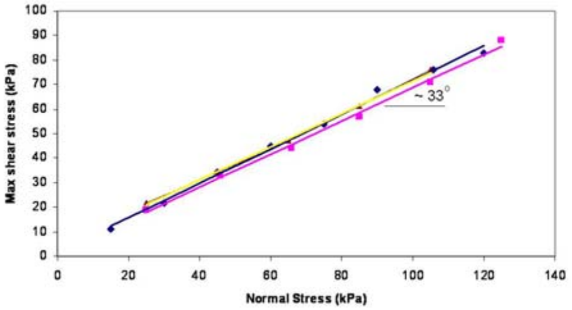
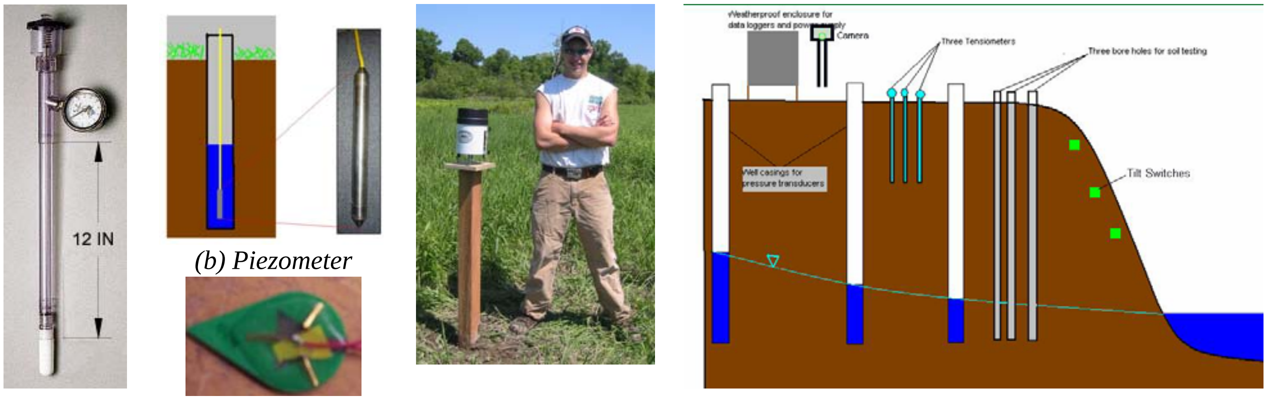


Figure 3: Shear stress versus normal stress data from BST tests conducted in silty sand at the selected sites

An example of BST shear stress versus normal stress data is shown in Figure 3. The data were taken in the silty sand layer at several locations. As seen, the results were repeatable. The data indicates soil cohesion to be close to zero (y-intercept) and effective friction angle of about 33 degrees, as expected for medium dense sand.

Instrumentation

At the locations of BST measurements, we attempted to obtain soil suction measurements using tensiometers (Figure 4a). Of the six tensiometers installed, three were installed with dial gages and three were installed with pressure transducers attached to a datalogger. These tensiometers worked quite well when tested dry to moist soils in our laboratory. However, they did not record suction in the field. We believe the reason for this is that the soil moisture content in the field was consistently high all summer long. This conclusion was also supported by measuring moisture content, which was generally high indicating that the soils were near full saturation. Continuous measurements of in-situ pore pressures are needed for analysis. This required installing electronic pore pressure transducers in groundwater wells. All summer near bank water table was too high to install wells by hand far enough below seasonal mean elevations. The monitoring wells and pore pressure transducers (Figure 4b) were therefore installed at the instrumented cross-section in September 2006, when the groundwater table was lower. There were also twelve tilt switches (Figure 4c) installed along this section of failing bank. A data logging rain gauge was also installed (Figure 4d) in the beginning of Summer 2006. General instrumentation plan at the site is depicted in Figure 4e.



(b) Piezometer

(a)Tensiometer *(c) Tilt switch* *(d) Rain gauge* *(e) Schematic of instrumentation plan*

Figure 4:Various Sensors installed at the instrumented site

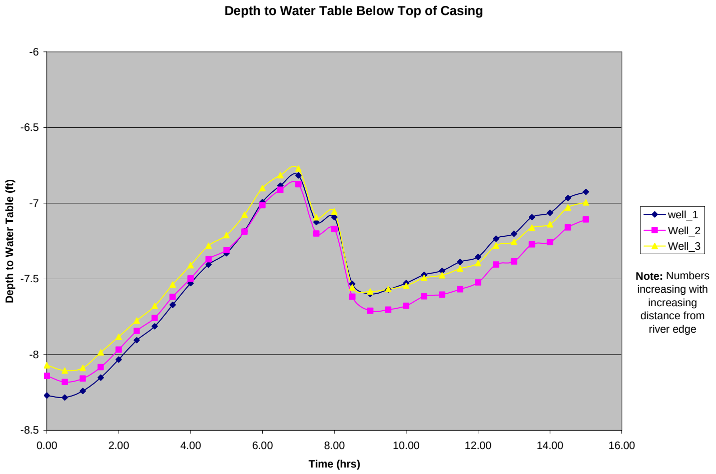


Figure 5: Example of groundwater table measurements

A snapshot of data from water pressure transducers for the on instrumented site is shown in Figure 5, which displays the ground water table during 16 hrs of a storm event.

Signals from the tilt switches are being recorded by an onsite data logger in a weatherproof box (Figure 6a), which is wirelessly connected to a computer in the Winooski Valley Park District Office, which is about 200 meters from the instrumented site. The initial plan was to embed accelerometers in the bank and obtain time history of movement using sophisticated hardware and software packages. However, the costs associated with such a system prohibited its use. Also, we realized that timing of bank failure is sufficient to relate the bank failure to precipitation (measured by the rain gage), river water level (inferred from USGS data), and pore pressures in soils (measured using piezometers installed in groundwater wells). The specifics of failure surface geometry were not needed through electronic measurements. They can be obtained by surveying the cross-section once the tilt switches indicate bank movement. A tilt switch creates a signal when its orientation changes by more than 10 degrees. In the field we noticed that large discrete blocks of soil fail from the bank rather than a progressive failure taking place over a number of days. Therefore, a sudden response from a tilt switch in the form of a binary signal will be sufficient to confirm that the soil around the tilt switch has failed.


(a) Weatherproof box *(b) Survey*

Figure 6: Weatherproof box with data loggers and surveying

These switches were embedded in custom designed caddies to be put into the edge of the bank. These switches were then connected to “CricketSats”, which were developed specifically for this purpose. They can be disposable, but are expected to work reliably in the wireless node, and each assembly costs roughly $15 in hardware. Each CricketSat was given a specific tone to broadcast, all in the audible spectrum, to identify it. Since this is a planned network, the location of each node is known and by knowing which node is broadcasting its tone we know where the event occurred. CricketSat broadcasts its tone when the orientation of the tilt switch changes because of soil movement. The signal is received by a decoder board on a computer located in the Winooski Valley Park District office. We are presently evaluating the success of these tilt switches.

At each testing site, GPS coordinates were taken as well as several photographs. We also developed procedures for obtaining detailed surveys of bank cross-sections (Figure 6b), which will be required as input geometry for seepage and slope stability analyses.

Student Training

So far, two graduate (Andrea Pearce and Jaron Borg from Civil and Environmental Engineering) and four undergraduate students (Ryan Foster and Nathan Shaffer from Civil and Environmental Engineering, Christopher Palombini from Electrical Engineering and Jian Xin Yu from Environmental Sciences) worked on this project. Pearce, Foster and Borg are supported through this grant in addition to other sources. Shaffer and Palombini were supported through the Richard Barrett Scholarships. Yu is supported through an on-campus Math-Bio Scholarship supported by the National Science Foundations. Jaron Borg recently finished his B.S. and has decided to undertake this research as his thesis topic for his M.S.

The BST and some of the drilling and sampling equipment acquired through this project was used extensively in obtaining soil samples and conducting in-situ shear strength testing in “service-learning” term projects conducted in Dewoolkar’s Geotechnical Design course and also a field course offered by Bierman in Summer 07 impacting a total of about 30 students.