10TH Annual Technical Forum

GEOHAZARDS IN TRANSPORTATION IN THE APPALACHIAN REGION

August 3 – 5, 2010
Columbus, OH

Hosted by:

The Ohio Department of Transportation
Office of Geotechnical Engineering

Sponsored by:

CENTER FOR ENVIRONMENTAL, GEOTECHNICAL, AND APPLIED SCIENCES

10TH Annual Technical Forum
GEOHAZARDS IN TRANSPORTATION IN THE APPALACHIAN REGION
Crown Plaza North, Columbus, OH, August 3 – 5, 2010

TECHNICAL PROGRAM

DAY 1: August 3, 2010

FIELD TRIP (8:00 a.m. – 5:00 p.m.)

5:00 – 7:00 p.m.	Exhibitor Set Up	***Foyer***
7:00 – 9:00 p.m.	Reception and Registration	***Lobby Foyer and Cardinal Room***

DAY 2: August 4, 2010

7:00 a.m.	Registration	***Lobby Foyer***
8:00 a.m.	Welcome: Tony Szwilski (CEGAS) Opening Session: Surface and Underground Mines Chair: Kirk Beach (ODOT)	***Ballrooms 1 & 2***
10:00 a.m.	Coffee Break	***Foyer***
10:30 a.m.	Session 2 Slope Management Systems Chair: Ben Rivers (FHWA)	***Ballrooms 1 & 2***
12:00	Lunch: Speaker Pat Gallagher, CTL Engineering	***Cardinal Room***
1:30 p.m.	Session 3: (CONCURRENT SESSION) Flood Hazards in Appalachia Chair: Hugh Bevans (USGS)	***Ballroom 1***
1:30 p.m.	Session 4: (CONCURRENT SESSIONS) Karst Issues Chair: John Stanton (USCE Nashville)	***Ballroom 2***

4:00 p.m.	Session 5: (CONCURRENT SESSIONS) Rock Mechanics Aspects Chair: Steve Brewster (USCE Huntington)	***Ballroom 1***
4:00 p.m.	Session 6: (CONCURRENT SESSIONS) Structures Chair: Wael Zatar (MU)	***Ballroom 2***

DAY 3: August 5, 2010

7:30 a.m.	Registration	***Foyer***
8:00 a.m.	Session 7 (CONCURRENT SESSION) Rockfall Mitigation Measures Chair: Brian Bruckno (VDOT)	***Ballroom 1***
8:00 a.m.	Session 8 (CONCURRENT SESSION) The Kettle Chair: Vanessa Bateman (TNDOT)	***Ballroom 2***
10:00 a.m.	Coffee Break	***Foyer***
10:30 a.m.	Session 9 Landslides Chair: Matt Crawford (KGS)	***Ballrooms 1 & 2***
12:30	Closing Remarks and Adjourn	

Opening Session

1. Surface and Underground Mines

a. Chair: Kirk Beach

i. Presentation 1

The Influence of Softening on the Mine Floor Bearing Capacity; A Case History

Gennaro G. Marino, Ph.D., P.E., M. ASCE; Abdolreza Osouli, Ph.D., M. ASCE

ABSTRACT: This paper introduces a new approach to more accurately calculate floor-bearing capacities where difficult mine conditions were present considering the effect of softening. Due to softening and changes in confining pressures from under the mine room to pillar, the geotechnical properties of immediate fine-grained rock vary in the mine floor. Therefore, when floor softening is present, the conventional equations used to determine the floor bearing capacity are not very accurate. The developed methodology is based on analysis of a case study located in central Illinois utilizing FEM analysis and rock mechanics laboratory data. For this case study extensive geological mapping and laboratory tests including rock classification, rock swell properties and triaxial compression tests were conducted on samples of fine-grained rocks that predominantly consisted of mudstone. The results of laboratory tests are presented and discussed in detail. Aerial and cross-sectional analyses of the floor lithology and stratigraphy were performed in order to evaluate the important bearing conditions across the project site. From the analyses, the immediate floor thickness and type of the non-durable, weak rock as well as the thickness and type of the underlying durable, bearing resistant zone across the site were determined. Considering a certain pillar to room width ratios, 2D FEM analyses were performed on both softened and unsoftened floor conditions. Consequently, the bearing capacity ratio or the correction for softening effect was determined.

ii. Presentation 2

Abandoned Underground Mine Inventory and Risk Assessment (AUMIRA)

Stantec Consulting Services Inc.
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513-842-8200

Jim Swindler, Project Engineer, James.Swindler@stantec.com
Eric Kistner, Project Manager, Eric.Kistner@stantec.com

ABSTRACT: The Ohio Department of Transportation (ODOT) Office of Geotechnical Engineering (OGE) developed the Abandoned Underground Mine Inventory and Risk Assessment (AUMIRA) process to provide a means to inventory and perform risk assessment of sites along state-maintained highways underlain by abandoned underground mines. The process prioritizes the sites with regard to the potential threat to public safety for consideration to a more detailed investigation, monitoring, and/or remediation. A planning level remediation cost estimate is assigned to high priority sites.

After some initial population of the database by ODOT personnel, Stantec was contracted to complete the database. Background of why the AUMIRA process was developed will be

discussed. The primary phases of the AUMIRA process will be explained, including site identification, document and map research, site visits, site evaluation and database population, and remediation cost estimating. The application of Geographic Information Systems (GIS) and Global Positioning System (GPS) will be presented. Photographs of significant mine features observed during the site visits will be shown. Criteria used to evaluate the sites will be identified and results of the site evaluations will be summarized by statistics, maps, charts, and tables.

The results of remediation cost estimating using the web-enabled program developed by The Ohio State University, the *Remediation Cost Database and Web-Based Application for Geologic Hazards* (RCDA), will be summarized. The presentation will conclude with a summary of the limitations of the process and intent of use of the database. Planned future modifications, such as streamlining the evaluation process and inclusion of other underground voids (tunnels, auger mines, quarries, etc) will be discussed.

iii. Presentation 3

MINE REMEDIATION OPTIONS FOR A NEW HIGHWAY CORRIDOR

BEACH, Kirk, D., kirk.beach@dot.state.oh.us, Ohio Department of Transportation
CRAIG, P.E., Alan, L., alan.craig@dot.state.oh.us, Ohio Department of Transportation

ABSTRACT: The City of Nelsonville in southeastern Ohio is surrounded by rugged Appalachian foothills where coal and clay were previously mined. Planning for a Nelsonville bypass started in the mid 1990's and Construction of the four-lane highway began in 2007 with a projected completion date of 2014. The planning process evaluated multiple corridors through or around the town. Eventually, two corridors remained as possible alignment alternatives. At this point, preliminary drilling of the corridors was conducted to help characterize the limits of major geologic hazards (e.g., underground mines) which would help in the selection of a preferred alignment. Subsequently, the upper end of the estimated cost for remediation of underground mines along the new alignment rose to an estimated $50M to $75M. During the detailed design phase, the cost to stabilize nearly 8.5 miles of the main line was reduced to $30M through a detailed risk assessment. The mine remediation costs, which involved drilling into and grouting the mine voids, remained high initiating additional efforts to reduce costs. One of the principle components of the high costs was the use of cementation grout. An alternative solution was proposed utilizing barrier grouting and foam sand infilling. Although this method had merit, it was rejected. Eventually, the project moved into the bidding phase and another opportunity for alternative solutions arose. The bidding process allows contractors the option to submit Value Engineering solutions as alternatives to the proposed methods and materials. As such, ODOT received several alternative solutions with recommendations to: 1) excavate enough of the mine's overburden to utilize an implosion and, dynamic compaction procedure and 2) completely dig out and backfill an abandoned mine location. The first proposal was rejected when the Wayne National Forest which owns much of the land the bypass is located on raised the concern of the imploded material causing an increase in acid mine drainage. The second proposal has received preliminary approval. This project resulted in a significant impact to ODOT's business processes involving geotechnical issues. When dealing with underground mines, priority is given to avoidance followed by minimizing exposure, and, lastly, mitigation of the potential threat to the traveling public.

iv. Presentation 4

REAL TIME MONITORING OF SUBSIDENCE ALONG INTERSTATE I-70, MUSKINGUM COUNTY, OHIO

Kevin O'Connor, P.E., Ph.D.	*GeoTDR, Westerville, OH* *720 Greencrest Dr. Westerville, OH 43081*
Nikunj Kadakia, PE	*Ohio DOT, District 5* *Jacksontown, OH*
Kirk Beach	*Ohio DOT – Office of Geotechnical Engineering* *Columbus, OH*
Charles Dowding, PE., Ph.D.	*Dept. of Civil Engineering, Northwestern University* *Evanston, IL*

ABSTRACT: The Ohio Department of Transportation (Ohio DOT) encountered several subsidence features around or adjacent to the I-70 right-of-way which could be associated with abandoned mapped or unmapped underground mines in Muskingum County. East of Route 93 and west of Jackson Road, the westernmost portion of the roadway was over excavated and backfilled. The remaining portion has not been stabilized, but measures have been taken to investigate subsurface conditions in more detail, and monitor the overburden for movement associated with subsidence. Remote, automated monitoring of ground deformation is being accomplished using time domain reflectometry (TDR) to interrogate coaxial cables installed within the subgrade below each lane of the roadway. The cables were installed by a directional drilling contractor in horizontal holes drilled 5 feet or more beneath each lane over the entire section of highway. Information logged during the drilling and installation provided more details about existing subsurface conditions to supplement information obtained from vertical boreholes in the west portion of the project area and provides a basis for future borings in the eastern portion. The cables are connected to a central remote data acquisition system (DAS) that automatically interrogates the cables and stores measurements. The TDR reflection signatures are being employed for both surveillance and research. Surveillance is provided by the DAS which compares the initial or baseline signature of each cable and the current signature. When the magnitude of any TDR reflection differs from the baseline value by a specified amount, the DAS records the activity and notifies assigned personnel. If it is determined that actual movement of overburden has occurred, Ohio DOT personnel are alerted to intensify visual reconnaissance and determine if lane closures are necessary. Independently, research on different forms of comparative display and additional methods of signature comparison is being conducted by downloading signatures to a separate password-protected server.

2. Slope Management Systems

a. Chair: Ben Rivers

i. Presentation 1

Dendrogeomorphology – A Means to Assess Past, Present, and Future Landslide Activity

William M. Kappel, Hydrogeologist, USGS-New York Water Science Center. 30 Brown Road, Ithaca, NY, 14850, 607-266-0217 x-3013, wkappel@usgs.gov

ABSTRACT: Dendrogeomorphic techniques were used to assess soil movement during the last century within the Rattlesnake Gulf landslide in the Tully Valley, south of Syracuse, New York. This landslide and one across the valley along Rainbow Creek, just below U.S. Interstate 81, are postglacial, slow-moving, earth slides that each cover tens-of-acres and consist primarily of rotated, laminated, glaciolacustrine silt and clay. Sixty-two increment cores were obtained from thirty hemlock (*Tsuga canadensis)* trees across the active part of the Rattlesnake landslide and

from trees at three control sites to interpret the soil-displacement history. Annual growth rings were measured and reaction wood was identified to indicate years in which ring growth patterns changed from concentric to eccentric, on the premise that soil movement caused trees to tip and triggered eccentric ring growth in the displaced trees. These data provided a basis for an “event index” to identify years of landslide activity over the 108 years of record represented by the oldest trees.

Multiple-regression and residual-values analyses indicated a casual relation between precipitation and movement within the landslide and a cyclic (decades-long) tree-ring response to displacement within the Rattlesnake landslide area. The soil movement is triggered by factors that include (1) periods of below-average precipitation followed by persistent above-average precipitation, (2) an increase in streamflow following increased precipitation, which erodes the landslide toe and results in an upslope propagation of slumping, and (3) the harvesting of trees within the landslide. The Rainbow Creek landslide has a different slide history. It is caused by the failure of a shale promontory (waterfall) in Rainbow Creek, which previously retained glacial sediments that are now being eroded. This process has resulted in knickpoint migration toward Interstate 81, about 1,500 feet upstream, and streambed aggradation on the floor of the Tully Valley.

ii. Presentation 2

Integrated Geologic Hazard Management System

BEACH, Kirk D., Geology Program Manager, Office of Geotechnical Engineering, Ohio Department of Transportation, Columbus, OH 43223

ABSTRACT: During the past decade, the Ohio Department of Transportation has advanced its efforts to understand and manage its geologic hazards, such as landslides, rockfalls, underground mine and karst subsidence across the state. Working in cooperation with several universities, research projects have evolved to produce several risk assessment and inventory programs involving each of the major geologic hazards impacting our state highway systems. The management system allows field data collection with PC tablets while utilizing Bluetooth capable cameras, laser range finders, profilers, and GPS units. Uploading data directly to an enterprise database by way of a web connection is relatively painless. Access to all site information and risk scores is available through a web-based, GIS application. On the back side of the inventory application, a user can seamlessly access the remediation cost database application to develop planning level cost estimates. Cost/benefit ratios can then be computed for different remediation scenarios for optimizing remediation strategies. Once complete, the final cost estimate for remediation is transferred back to the inventory program. The final step allows District ODOT offices to submit their annual funding request for remediation of geologic hazards. The integration of these systems has produced a complete application allowing geologic hazardous sites to be inventoried, scored, and ranked followed by development of cost estimates and submission of sites by a simple click of a mouse. This system is a powerful management tool which has improved our diligence in the expenditure of limited funds while reducing our labor and costs in management of geologic hazards across the state.

iii. Presentation 3

GeoLIMS: A LABORATORY DATA MANAGEMENT SYSTEM FOR SOIL, ROCK AND WATER

BEACH, Kirk D., Geology Program Manager, Office of Geotechnical Engineering, Ohio Department of Transportation, Columbus, OH 43223
MULLIGAN, Sean, P.E., Geotechnical Lab Manager, Ohio Department of Transportation, Columbus, OH43223
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FENG, Frank, President, Acetek Ltd., 3568 Farnham St, North Canton, OH44720

ABSTRACT: In the environmental or geo-environmental fields, Laboratory Information Management Systems (LIMS) have been in place for decades in most state operated laboratories. A quest was undertaken to find a suitable LIMS application that would handle test data for soil, rock and water samples. Although a few systems were found, none matched the requirements for integration with a drilling request system, field data collection application and the transfer of test data and results into an enterprise database application. The Ohio Department of Transportation initiated a contract to study the laboratory business processes and develop an implementation plan for establishment of a GeoLIMS. As part of this effort, a work station was developed for soil moisture testing as a Proof-of-Concept in which a bar code scanner, electronic scales, and a PC workstation were integrated. Following the success of this pilot study, a detailed assessment was implemented to further define the business processes, current and future testing analyses, existing equipment and hardware, and interfacing requirements and data transfer from field PC tablets and field samples. One major dilemma involved the identification of data fields, schema, and data dictionary specific for the LIMS application and those required for the enterprise database. Although seemingly simple, a significant amount of time was spent defining data organization. Implementation of the GeoLIMS is justified by the beneficial returns provided by immediate validation of data entry, elimination of human error with recording of data or with the interpretation of written characters, quick determination of testing status on any sample within the log, and easy access for data retrieval, sorting, synthesis, and analysis for future applications. The main focus of the paper will present the high-level view of the integrated GeoLIMS, the work station design, lab tasks tracking methodology, and database structures. Integration with field drilling operation and interagency water testing data transfer will be discussed as well.

iv. Presentation 4

GEOTECHNICAL RISKS AND SLOPE MANAGEMENT SYSTEMS: AN FHWA PERSPECTIVE

Silas C. Nichols,, P.E., Senior Bridge Engineer – Geotechnical, Federal Highway Administration, Office of Bridge Technology, Washington, DC, 202-366-1554, silas.nichols@dot.gov
Benjamin S. Rivers, P.E., Geotechnical Engineer, Federal Highway Administration, Resource Center, Atlanta, GA, 404-562-3926, benjamin.rivers@dot.gov

ABSTRACT: Existing state highway agency slope management systems vary from state-to-state, reflecting the relative scale of associated problems for different agencies, and their associated policies, priorities and funding mechanisms. In addition to providing a means of inventorying the condition of slopes and related appurtenances, slope management systems provide an opportunity to establish designated funding means and prioritization based on accepted management strategies. Examples of management strategies include maximizing safety, minimizing risks, maximizing cost-benefit, integrating life-cycle analysis/performance considerations, and various combinations. With ever-decreasing budgets and increasing emphases on asset and risk management, the Federal Highway Administration (FHWA) is experiencing renewed interest in slope management and other geotechnical related management systems. This presentation provides an FHWA perspective on fundamental elements and considerations for effective slope management systems, and on how slope- and other geotechnical management systems relate to national initiatives and emerging policy direction.

3. Flood Hazards in Appalachia

b. Chair: Hugh Bevans

i. Presentation 1

An Overview of Appalachian Flooding

Dr. Kevin Law, West Virginia State Climatologist, Department of Geography, Marshall University.

ABSTRACT: Flooding events are the number one weather related disasters in the Appalachian Region. Due to a variety of factors including slope, land use, soil and vegetation type, not to mention the relatively high amount of intense precipitation, the region has some of the most devastating floods and highest frequency of floods in the entire United States.

This presentation looks at some of the historical flash floods and widespread floods over the last 100 years that have affected the region and investigates some of the meteorological/climatological and geographical factors that have led to these events. The economic and societal impacts will also be discussed along with mitigation efforts that have been attempted to prevent and minimize the damage from widespread and flash flooding.

ii. Presentation 2

Determining and Predicting Flood Magnitudes and Frequencies

Jeff Wiley, USGS West Virginia Water Science Center, Surface Water Specialist

ABSTRACT: This presentation will discuss the classic methods of determining magnitudes and frequencies of floods, variables that typically are correlated to flooding and their use in developing regional regression equations, and present most current flood equations publications available for Forum states.

iii. Presentation 3

A New USGS Flood Inundation Mapping Initiative

Dr. William Guertal, Director, USGS Indiana and Kentucky Water Science Centers

ABSTRACT: A powerful new tool for flood response and mitigation is digital geospatial flood-inundation maps that show flood water extent and depth on the land surface. Flood-inundation maps that are tied to U.S. Geological Survey (USGS) real-time stream gage data and National Weather Service (NWS) flood forecasts enable officials to make timely operational and public safety decisions during floods. The USGS has started a new National Flood Inundation Mapping Science Initiative – the purpose of this Initiative is to develop a comprehensive and partner-based National USGS Flood Inundation Mapping Science Program designed to meet USGS science strategy goals related to natural hazards and stakeholder needs. The USGS is working in the following focus areas for flood inundation mapping science: flood documentation studies; static flood-inundation map libraries; and, real-time dynamic flood inundation mapping. Working with partners including the National Weather Service (NWS), U.S. Army Corps of Engineers (USACE), the Federal Emergency Management Agency (FEMA), state agencies, cities, and universities, the USGS is providing flood inundation mapping science resources to help build more resilient communities.

iv. Presentation 4

Flood Alerts and Warnings

John Sikora, National Weather Service, Charleston Forecast Office, Senior Service Hydrologist

ABSTRACT: My presentation will delve into all the networks and data that the NWS uses to formulate and issue flood watches and warnings. The networks range from automated rain and met stations (IFLOWS, STORMS, etc) , NWS radar data, Cooperative observer networks (NWS.COOP, CoCoRAHs, Weather Underground, etc), Stream gaging networks, Social networks (Twitter, Facebook, etc), Phone networks, Internet networks to all the tools that the NWS uses to put all the data together to issue warnings.

4. Karst Issues

c. Chair: John Stanton

i. Presentation 1

Augmented Karst Mapping in Ohio

SHRAKE, Douglas L. and Donovan M. Powers
Ohio Department of Natural Resources, Division of Geological Survey
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ABSTRACT: Although aware of karst's geohazard potential, the Ohio Geological Survey did not actively incorporate karst feature documentation into its mapping program until 2008, when the karst system underlying the greater Bellevue, Ohio, region flooded. A period of significantly above-average rainfall occurred in the spring of 2008. The volume of precipitation overwhelmed the karst aquifer's ability to drain, and the conduits and surface depressions (sinkholes) flooded; similar events occurred in 1937 and 1969. The 2008 event significantly impacted transportation routes and caused structure damage in the region. During analyses of the Bellevue flood data, the Survey realized that a comprehensive karst mapping program needed to be incorporated into it's mapping and research agenda.

Largely due to interagency cooperation with local stakeholders, the first area selected for karst identification was a block of six 7.5-minute quadrangles—Powell, Shawnee Hills, Delaware, Ostrander, Waldo and Prospect—covering a rapidly developing area that includes the western third of Delaware County and adjacent portions of Franklin, Union, and Marion counties. Mapping was conducted by a combination of LiDAR processing, evaluation of high-resolution aerial photography, and fieldwork. The field area was organized into 255 2000-m × 2000-m map tiles. Field verification of the LiDAR and photo-indicated potential karst points has demonstrated that LiDAR processing did an adequate job of automated identification. However, based on photo- and field-identified features, the automation missed the process and needs some refinement. The necessity of field verification of LiDAR and aerial-photo-interpreted points is supported by (1) the misidentification of potential points (i.e., sewers, culverts, walled streams, and utilities) by both methods and (2) the documentation of karst features not identified by either method. The Survey seeks to use the information from this area to better refine the automation of karst feature identification.

ii. Presentation 2

Mapping of Karst Hazards Using Remote Sensor Technology

Ronald Green[1,3], Institute Scientist, Ben Abbott[2] Institute Engineer, Greg Willden[2], Senior Research Engineer, and Donald Poole[2] Research Engineer

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ABSTRACT: Downhole sensors were developed to map the dimensions and morphology of karst solution cavities as part of a US Army Corps of Engineers grout curtain project at the Center Hill Dam near Nashville, Tennessee. Drilling activities associated with the grout curtain project have indicated the presence of large cavities in limestone near the dam. The features are believed to be subvertical, vary in width from 10-30 ft, and extend from the ground surface to the depth of excavation with no indication of pinching out. Significant bit drops encountered during drilling are consistent with sub-vertical solution cavities whose infill sediments have been eroded and removed by groundwater.

Borehole sensors were developed to assist in cavity characterization because the full extent and dimensions of the cavities cannot be characterized solely based on borehole logs and bit drops. The sensors are equipped with sonar and magnetometer instrumentation to measure karst cavity morphology and orientation. The sensors can operate in either a water- or air-filled environment. A tether is attached to the sensors to allow real-time data collection. Immediate post-processing of the data allows for the generation of geo-referenced, three-dimensional maps of the cavities.

Preliminary field work at Center Hill Dam indicated that the dimensions and morphology of the cavities can be characterized using the sensor measurements. The only borehole to penetrate a karst cavity during the current grout curtain project was characterized using the sensor. The smooth wall of the borehole casing was detected to a depth of approximately 43 ft. Below the casing, the void opens up to a maximum width of slightly less than 10 ft and a height of approximately 4.5 ft. Cavity characterization is anticipated to be completed using the sensors as soon as site rockfall safety issues are resolved.

iii. Presentation 3

Center Hill Seepage and Remediation

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ABSTRACT: Since construction in the 1940's, seepage through limestone in a well developed Karst system has been synonymous with operation of the US Army Corps of Engineers' Center Hill Dam in central Tennessee. Original designers acknowledged the cave scattered region would require future grouting to control seepage through the well-developed bedrock joint system. Despite several localized grouting efforts over the years, total seepage has continually increased under normal reservoir conditions. Foundation conditions are deteriorating the clay-filled rock joints within the rims, the abutments and the dam's foundation. This erosion jeopardizes the 246-ft high earthen embankment of a main dam and an adjacent 125-ft high earthen saddle dam. The seepage, however, is most advanced in the rims, where sinkholes align open cavities. The first of three major construction contracts is now underway to increase the long-term safety of the dam. This first contract is placing grout in the most critical areas, the main dam embankment foundation and the left rim. The total rehabilitation effort is a multi-contract endeavor consisting primarily of grouting, constructing a concrete cut-off wall and possible placement of an RCC dam.

iv. Presentation 4

Follow-up on the Morristown, TN "Land-Bridge" at milepost 96.1-A

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ABSTRACT: Norfolk Southern Railway Company, in response to a persistent sinkhole outside of Morristown, TN, constructed a "Land-Bridge" over the problem area. Using exploratory drilling and ground penetrating RADAR to locate and map the limestone caverns below, the bridge pillars were constructed on stable ground. Over the years, the unstable

areas gradually subsided and have left a bridge over a sinkhole. After 10 years of use, the structure and sinkhole was re-evaluated to gauge continued effectiveness.

5. Rock Mechanics

a. Chair: Steve Brewster

i. Presentation 1

Tunneling in the Pine Mountain Overthrust, Harlan, Kentucky

Stanton, John L., Chief Geology Section, Nashville District Corps of Engineers
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ABSTRACT: Devastating flooding in April 1977 resulted in legislation authorizing construction of Local Flood Protection projects in the Appalachian sections of Kentucky and West Virginia. One of the hardest hit communities was Harlan, Kentucky. Numerous options were investigated for providing protection for Harlan. One component of the plan was a tunnel diversion of Clover Fork, one of the tributaries of the Cumberland River. Flat lying Pennsylvanian siltstones and shale of remarkable quality made tunneling a viable and more environmentally friendly option for diverting the flood waters around the central business district of Harlan. This presentation covers the initial design and the construction of these tunnels. Some of the unusual exploration, modeling, and testing programs will be discussed. An interesting case history on comparative production rates for two European manufactured road headers that were used for the excavation is included. In addition, a brief outline of alignment control, infrastructure, and stability measures that were necessary to complete the tunnels safely and to the lines and grades required, will be presented.

ii. Presentation 2

"Layer Cake Geology" not that simple in Central Ohio for OARS Tunnel

A. James Siebert

ABSTRACT: Thorough geotechnical investigations offer a unique insight into the subsurface conditions and the complexity that can exist, even within areas that are believed to be devoid of any interesting geologic structure. DLZ has had an opportunity to investigate the subsurface conditions for a proposed large diameter tunnel. The tunnel is to be mined through the bedrock nearly 200-feet beneath central Franklin County, Ohio. As with most of the region, a blanket of glacial materials and alluvium covers its bedrock and the bedrock features and structure. The generally accepted convention is that the sedimentary bedrock conditions in the region are relatively flat and that the rock strata are simply stacked one on top of the other. This is sometimes referred to as Layer Cake Geology. Initial investigations indicated that this simple "layer cake" was also present along the proposed project alignment. However as the subsurface investigation progressed, the supposed lackluster geology of Central Ohio offered up some interesting and sometimes surprising features including unknown structural features; fracturing and jointing; karst conditions; petroliferous rock; and hydrogeologic interconnections. These features ultimately altered the project approach and design, and changed our understanding of the not so simple geology of central Ohio

iii. Presentation 3

Assessing the Slaking Behavior of Clay-Bearing Rocks

*SHAKOOR, Abdul (**ashakor kent.edu**) and GAUTAM, Tej P. (tgautam1@kent.edu) and Department of Geology, Kent State University, Kent, OH 44240*

ABSTRACT: Clay-bearing rocks (shales, claystones, mudstones, siltstones) are the most abundant of all sedimentary rocks and are widely encountered in engineering construction. These rocks exhibit varying degrees of disintegration or slaking when subjected to changes in moisture content and this non-durable behavior is responsible for numerous problems in engineering construction. The slake durability test, standardized by the American Society of Testing and Materials (ASTM), is the most frequently used test to evaluate durability of clay-bearing rocks. In this test, the ratio of the weight of the sample retained in a 2-mm mesh drum, after rotating the drum in water for 10 minutes, to the initial weight (~500 g) of sample is used as a measure of durability. However, the test does not simulate natural conditions nor does it quantify the nature of slaked material. The objective of this study is to assess the slaking behavior of clay-bearing rocks under natural atmospheric conditions and to quantify the nature of slaked material in terms of grain size distribution.

Twenty samples of clay-bearing rocks, containing 5 shales, 5 claystones, 5 mudstones, and 5 siltstones, were selected for the study. For each of the 20 rocks, 12 replicate samples were prepared resulting in a total of 240 samples. Each sample consisted of 10-12 pieces, with a total weight of approximately 500 g. The samples were placed on the roof of McGilvrey Hall of Kent State University in September 2009 to expose them to varying atmospheric conditions for a period of one year. The slaking behavior of the samples was observed, described, and photographed regularly. Each month, one sample of each of the 20 clay-bearing rocks was removed, oven dried, and tested for grain size distribution using a series of standard sieves. “Disintegration ratio”, taken as the ratio of the area under the grain size distribution curve for a given clay-bearing rock to the total area encompassing grain size distribution curves of all 20 clay-bearing rocks, was used to quantify the grain size distribution of slaked material from each sample. A disintegration ratio close to 1 indicates a highly durable rock, whereas a value close to zero indicates very low durability. Results of the experiment show that the slaking behavior of clay-bearing rocks under natural conditions is highly variable. After 6 months of exposure to atmospheric conditions (fall and winter seasons), the disintegration ratio ranges from 0.034 to 0.965 (average = 0.408) for shales, from 0.020 to 0.155 (average = 0.068) for claystones, from 0.001 to 0.475 (average = 0.199) for mudstones, , and from 0.037 to 0.997 (average = 0.531) for siltstones. Thus, among the rocks tested, claystones are the least durable and siltstones the most durable. The advantage of using the disintegration ratio approach is that it indicates not only the durability of the rock tested but also the nature of slaked material in terms of particle sizes. The results are also being compared with the slake durability test results to see how well the lab test predicts the natural slaking behavior.

iv. Presentation 4

Using Close-Range Terrestrial Photogrammetry for Geohazard Evaluation on the US 460 Connector Project, Southwestern Virginia

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ABSTRACT: The US 460 Connector – Phase I Project being developed by Virginia Department of Transportation is a design-build project in rugged, mountainous terrain in Buchanan County, Virginia. MACTEC Engineering & Consulting, Inc. is providing geotechnical services to ENTRAN (Lexington, Kentucky) as part of the Bizzack Design Build Team.

MACTEC performed a design-level geotechnical analysis including rock and soil slope stability analyses/configuration design and rock fall analyses, in addition to foundation design recommendations, pavement section evaluation, and QA/QC support. MACTEC utilized close-range terrestrial photogrammetry in the slope stability and slope configuration evaluations. This technology developed by 3G Software & Measurement (3GSM) in Graz, Austria, allowed development of three-dimensional models of rock exposures suitable for measuring discontinuity orientation and spacing; x,y,z values extracted from the 3D models were imported into GIS software for estimating bedding-plane surface roughness. ROCKPACK III was used for stereographic projections and kinematic analysis. Rock mass properties were evaluated using field observations, rock core descriptions, laboratory test results, and calculated values of Hoek-Brown parameters using ROCLAB. Rock mass shear strength was represented as nonlinear equivalent Mohr-Coulomb cohesion intercept and friction angle.

The US 460 Connector – Phase I project elements consist of twin high-level structures approximately 1,600 feet long, a mainline four-lane divided highway approximately 4,800 feet long, and a two-lane connector road to Route 80. The connector road to Route 80 will provide improved access to the Breaks Interstate Park and includes a multi-span bridge crossing Route 768 and Hunt's Creek. The project also includes secondary connections to Route 609 and Route 693 from Route 80. The total project length is approximately 0.8 mile.

6. Structures

a. Chair: Wael Zatar

i. Presentation 1

Scour at Bridge Foundations on Rock: Status of NCHRP Project 24-29

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ABSTRACT: The essence of National Cooperative Highway Research Program Project 24-29 is geotechnical site characterization in scour-relevant terms for use by hydraulic engineers. The project goal is to develop guidelines for evaluating scour at bridge foundations on rock that can be integrated with the procedures of Federal Highway Administration HEC-18. Rock scour in natural open channels appears to be related to five processes: 1) physical and chemical weathering of rock surfaces exposed to scour, 2) dissolution of soluble rocks, 3) cavitation, 4) abrasion of degradable rocks, and 5) quarrying and plucking of jointed durable rocks. Defining 'rock' for scour purposes is just as problematic as it is for other engineering applications because physical properties can range from strong soil to much better than concrete. Bridge sites in Florida, Oregon, New York, Utah, and California visited in 2008 provided a range of conditions, data, and samples for the guidelines. Stream power is useful for characterizing hydraulic loading conditions because it is the product of hydraulic shear stress and velocity and it can be accumulated over a desired time period. Probability weighted flood frequency can be expressed in stream power as well as peak or mean discharge; mean discharge and flow duration must be used to calculate stream power. Repeated cross sections that document scour can be correlated directly with cumulative stream power for the time interval between the cross sections to provide a basis for estimating average annual scour per unit of stream power. Design scour depth is the product of average annual scour and the life of the bridge. Geotechnical evaluations are needed to verify uniformity of conditions. Laboratory test results provide a basis for comparing locations with and without repeated cross sections. Check-list guidance is provided for determining which scour processes can be dismissed and which deserve specific evaluation.

ii. Presentation 2

A GIS application to collect in-house geologic information for evaluating mine subsidence

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ABSTRACT: As Ohio's abandoned-underground mines age and deteriorate and further development occurs across the state landscape, the costs of mine subsidence continue to rise, and the need for accurate geologic data in transportation planning also increases. Such consideration of geologic information in highway planning processes enables engineers to minimize the costs of operations required for highway construction, reduce or eliminate reconstruction and mitigation costs, and prevent possible injuries and loss of life. During the past fourteen years, the Ohio Department of Natural Resources (ODNR), Division of Geological Survey has created statewide GIS datasets for a number of different data themes

that have direct applications in transportation planning and in mitigation of geologic hazards associated with transportation. A number of these statewide GIS datasets are used by the Ohio Department of Transportation to evaluate the hazards of abandoned-underground mines to overlying state and federal highways.

Recently, the ODNR Division of Geological Survey started a cooperative agreement with the Ohio Mine Subsidence Insurance Underwriters Association to assist with the evaluation of mine subsidence insurance claims. As part of the cooperative agreement, a GIS application has been created that gathers all known geologic information concerning a subsidence claim, presenting the geologic information to a geologist for evaluation. The GIS software application provides easy access to digital geologic information, which is delivered to geotechnical firms for use in evaluating subsidence insurance claims and potential property remediation. The new GIS application has significant potential for assisting with the evaluation of mine subsidence that may affect state and federal highways throughout the state.

iii. Presentation 3

Slope Stabilization using Drilled Shafts: Design and Long-Term Monitoring

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ABSTRACT: The use of drilled shafts for stabilization of slopes is one of the most common and popular techniques and the number of slopes stabilized with drilled shafts is increasing. With the rather complex interactions and parameters involved, many areas are still open for research. In this paper, the effectiveness of the system has been studied through many cases of research projects to for better understanding of the behavior and to improving the design methodology. In this context, current drilled shafts structural design methodology to accommodate the theoretical loads will be presented. Finally, comparisons with current design/analyses practice will be presented utilizing measurements from several instrumented projects.

iv. Presentation 4

Earthquake Disaster Prevention - Lessons From Recent Earthquakes

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ABSTRACT: Earthquake can cause catastrophic disaster. For example, the Wenchuan, China, earthquake (M8.0) of May 12, 2008, and the Haiti earthquake (M7.0) of January 12, 2010, both caused great disaster, killing hundreds of thousands of people and causing hundreds of billions dollar damages. Earthquake disaster can be prevented, however. The most effective way to prevent earthquake disaster is to implement a systematic mitigation measure or policy such as better building code. This can be seen from the Chile earthquake (M8.8) of Feb. 27, 2010. Although the Chile earthquake is the largest earthquake in recent years, the damage caused by the quake was not a catastrophic because Chile has well

developed and implemented engineering design and other measures. Only three modern buildings collapsed and 430 people (including 300 killed by the tsunami) were killed during the Chile earthquake. It is a great challenge for society to prevent earthquake disaster. Geo-scientists, seismologists in particular, play key role in earthquake disaster prevention by providing essential earthquake hazard information

7. Rockfall Mitigation Measures

a. Chair: Brian Bruckno

i. Presentation 1

Construction of Slope Repairs to the I-40 Landslide
Haywood County, North Carolina

Daniel Journeaux[1], Jody Kuhne, LG, PE[2], Noel Philippon[3]; Jeffrey Lloyd, EIT[4]; Peter Ingraham, PE[5]

ABSTRACT: Early Saturday morning, October 24, 2009 a massive rock slide of roughly 80,000 cubic yards of rock and debris occurred on Interstate 40 in North Carolina. The slide was roughly one mile from a similar slide that occurred in 1997 and closed the Interstate for months. A team of Phillips and Jordan and Janod Contractors Inc were called in under an emergency services contract to remove slide material from the roadway. Janod Contractors arrived on site Monday October 26th to assess the slope condition and develop a work plan with Phillips and Jordan. Initial high scaling on rappel below the metastable failure scarp commenced on October 28th. Initial scaling and material removal operations were closely monitored for movement as the slide was considered still active.

North Carolina Department of Transportation (NCDOT), completed geologic mapping of the slide mass and scarp and concluded the failure mechanism was a controlled by the slope geometry and a wedge feature along rock jointing and bedding. Because of the remaining rock in the wedge, further rockfalls could be expected from the feature. An initial plan was developed to remove the slide debris and remaining wedge structure extending up to 900 feet above the roadway where the joint planes daylighted. When wedge removal proved to be too expensive, NCDOT short listed contractors to bid on installing 50,000 linear feet of post-tensioned rock anchors up to 130 feet long in 60 days to stabilize the wedge structure. The team of Phillips and Jordan and Janod were the successful bidders on the project and the contract work started on December 28, 2009.

The precedent-setting stabilization was completed in record time, with over 50,000 linear feet of ground anchors installed to depths of up to 130 feet in high-angle conditions in 60 days in the harshest winter in 30 years. This paper discusses the ever-changing nature of slide repair work where design is modified to suit encountered/exposed conditions and alternative stabilization methods and construction techniques often have to be implemented as the design and conditions change.

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ii. Presentation 2

Rock Slope Stabilization Utilizing Polyurethane Resin Grout

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The Project

Using Polyurethane Resin Grout to stabilize a rock slope adjacent to the George WashingtonMemorial Parkway near Washington, DC.

Challenges

Preserving the natural appearance of the rock wall post stabilization, using a new,innovative stabilization technique

Innovative Solutions

To preserve the natural esthetics of the Rock Slope, the injection of a Polyurethane Resin (PUR) grout was chosen as the primary means for stabilization. As a secondary source, Rock Bolts could be used but only if deemed necessary, and if used, the exposed hardware was to be painted to match the surrounding rock.

A series of 33 primary and secondary grout holes were drilling 15' into the rock face at various locations along the wall. The polyurethane and resin were mixed at the injection point and pumped into the 2" holes under pressure. The PUR was pumped until a predetermined pressure was obtained or the gout became visible through cracks in the rock wall. Once completed the PUR setup and acted as the bonding agent that held, or glued, the loose rocks together, and provided a stable rock formation. The entries of the grout holes were then filled with dyed cement that matched the rock face, which concealed the method of stabilization.

The installation of Three Rock Bolts was deemed necessary due to the Rock Slope condition in one area. The 3 rock bolts were installed and the exposed hardware was painted to match the surrounding rock.

Also, 20 horizontal drain holes were excavated to a point of 10' behind the planar sliding service to help relieve potential pressure build up from water.

Conclusion

The challenge of reducing the rockfall hazard on the George Washington Memorial Parkway was met through the successful rock slope stabilization using slope scaling, installation of Rock Bolts, injection PUR grout and Horizontal Drain Pipe installation. Equipment design innovations were made to accommodate the topical features and innovative construction techniques were adopted to alleviate risk of rockfall from unstable rock blocks. The result was a safe, successful project completed on time, on budget, and with minimal disruption to traffic or the environment.

iii. Presentation 3

Evaluating Rock Fall Hazards for the US 460 Connector Project, Southwestern Virginia

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ABSTRACT: The US 460 Connector – Phase I Project being developed by Virginia Department of Transportation is a design-build project in rugged, mountainous terrain in Buchanan County, Virginia. MACTEC Engineering & Consulting, Inc. is providing geotechnical services to ENTRAN (Lexington, Kentucky) as part of the Bizzack Design Build Team.

MACTEC performed a design-level geotechnical analysis including rock fall analyses, in addition to rock and soil slope stability analyses/configuration design, foundation design recommendations, pavement section evaluation, and QA/QC support. MACTEC utilized planned rock cut slope configurations, photographs of rock exposures, rock core logs, and stereo models made with a close-range terrestrial photogrammetry system developed by 3G Software & Measurement (3GSM) in Graz, Austria, to define rock release zones and block sizes and shapes for analysis with the Colorado Rockfall Simulation Program (CRSP). Bench widths and positions were considered, in conjunction with Ritchie ditch configuration, to attain the design objective of fewer than 10 out of 1000 modeled rocks reaching the pavement without relying on rock reinforcement or wire mesh rock fall control components.

The US 460 Connector – Phase I project elements consist of twin high-level structures approximately 1,600 feet long, a mainline four-lane divided highway approximately 4,800 feet long, and a two-lane connector road to Route 80. The connector road to Route 80 will provide improved access to the Breaks Interstate Park and includes a multi-span bridge crossing Route 768 and Hunt's Creek. The project also includes secondary connections to Route 609 and Route 693 from Route 80. The total project length is approximately 0.8 mile.

iv. Presentation 4

The Use of Wire Mesh/Cable Net Drapes to Control Rockfall: Case Study and Guidelines

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ABSTRACT: Rockfalls constitute a hazard along roadways. Traditionally in Ohio the primary method used to remediate a slope to control rockfall has included the provision of larger catchment areas. To provide larger catchment this commonly entails the expensive option of removal of large amounts of rock. Where this option is not feasible due to costs or other constraints such as right-of-way restriction, placement of barriers (both rigid and flexible) have most commonly been used to control rockfall. In many cases, barriers still haven't provided adequate protection due to rockfall trajectories or energies.

The use of heavy gage wire mesh or cable net drapes s have been used along North American highways to control rockfall since the 1950's. However, this slope protection has only been used along roadways in Ohio in recent years. These drapes contain rockfall by allowing them after failure to move downward between the drape and slope in a controlled manner allowing them to come to rest in the catchment area for easy clean up and maintenance. The use of wire mesh/cable net drapes can be a cost effective alternative to address rockfall concerns. This paper presents case studies on the use of wire mesh/cable net drapes along with some guidelines on their applicability and design.

8. The Kettle

a. Chair: Vanessa Bateman

i. Presentation 1

How DIGGS Can Help You

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ABSTRACT: DIGGS (Data Interchange for Geotechnical and Geoenvironmental Data) is an international standard for the exchange of geotechnical data. It builds upon the experience of geotechnical data exchange in the United States, United Kingdom, and other countries and incorporates flexibility for the user. Best of all, it is free. DIGGS can open new opportunities for your geotechnical information exchange.

ii. Presentation 2

Ohio DOT's Geotechnical Data Management System: Drilling Request to GIS

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ABSTRACT: The Ohio DOT Geotechnical Data Management System (GDMS) is a large-scale implementation providing an enterprise-level data management framework for state and regional engineers, consultants, academia, and even the public in and around Ohio. In addition to accommodating field and laboratory technical data, the GDMS allows documents like permits, plans, maps, logs, or images to be associated with locations and retrieved with an easy-to-use web interface.

While the core system is based on EarthSoft's EQuIS, other softwares perform integral functions including Falcon from tsaAdvet for document management and Bentley's gINT for geotechnical logs and reports. The ODOT Geotechnical Lab LIMS will be integrated and, eventually, related applications such as geohazards, inventories, structures, pavements, and others may be accessible within the GDMS umbrella.

The primary technical focus is:

- the validation, import, archiving, display, and reporting using the EQuIS Data Processor (EDP) and
- interfaces to Falcon document management
- integration with ESRI GIS
- interfaces to RockWorks and gINT for data loading and reporting,
- Enterprise Planning Module planning drilling requests and
- a tool to facilitating field data collection

Ohio DOT is a founding member of the DIGGS consortium and GDMS will support the upcoming DIGGS format for exchange of geotechnical and geoenvironmental data.

iii. Presentation 3

MINE SUBSIDENCE DAMAGE DURING CONSTRUCTION OF MEDICAL CENTER AND REMEDIAL MEASURES TAKEN

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ABSTRACT: A problem related to surface subsidence occurred after the construction of shallow foundation system and utilities on the premises of a medical center in Arkansas. The first indication of the presence of underground mining occurred on July 10, 2008 when the elevator pit tilted and settled up to 20 in. and the neighboring spread footings titled towards the sag center about 1 in. from the surface subsidence. An adjacent hole was drilled in the north side of sag center, and a 4 ft void was encountered. The sag subsidence, which formed on the ground surface, was about 25 ft in diameter with tension cracks around the circumference. From a subsequent subsurface exploration conducted at various locations of the project site, flooded mine voids were encountered with void heights ranging from 1.5 ft to 4.0 ft. In order to determine how the subsidence problem could be remediated, an engineering evaluation was conducted which was focused on the mine roof stability. The investigation determined that the mine collapse could result in up to 1-2 ft of differential subsidence and the potential foundation settlement of up to 0.28 ft or more in the previously subsided area. Grouting of mine voids and the installation of micropiles were considered the best possible remedial measures to avoid future subsidence and settlement problem. This paper describes the subsurface investigation and engineering evaluation of the subsidence condition and the subsequent mine grouting as well as the installation of micropiles.

iv. Presentation 4

Emergency Slope Repairs as a Result of the May 2010 Nashville Area Floods

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ABSTRACT: Historic rains in the Nashville area on May 1-2, 2010, resulted in flooding throughout Middle and West Tennessee with flood levels reaching at or above the 500 year flood maps. Aside from the direct devastation of the flood waters, numerous landslides occurred due to these historic rains. Precipitation of 13-18 inches over a 24 hour period reactivated old colluvial slides, caused numerous slope issues due to scour, numerous mudslides, several sinkholes and a large block slide failure. The largest slope failure was a landslide in the fill for State Route 7 which affected over 1000 feet of roadway and extended to 200 feet in depth. Emergency response by TDOT was required in order to deal with a multitude of geotechnical and geological problems all of which occurred simultaneously. Along with the other damage experienced by the roadway network, this presented a serious challenge to the Tennessee Department of Transportation to assess, plan and execute repairs to these sites as quickly as possible. Assessment teams were sent out across all the affected areas to provide initial assessments which were then followed by more detailed work by the TDOT Geotechnical Section where needed. Over 25 larger landslides, sinkholes and other slope problems were assessed and repaired, many of which were completed within 2 weeks of the flood event. Several of the largest slope failures, include the large rock block slide and large State Route 7 slide will be let by the middle of July 2010.

9. Landslides

a. Chair: Matt Crawford

i. Presentation 1

Case Studies in Shallow Landslide Repair and Severe Erosion Mitigation along Roadway Networks in Appalachia

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ABSTRACT: Landslides and severe erosion along our nation's roadways present a real challenge to engineers, planners, and designers. Not only do these problems strain ever-dwindling maintenance budgets, many of the common tools available can be difficult to employ on smaller road networks common in Appalachia without disrupting transportation infrastructure (including road closures and utility relocation).

In the context of case studies from five recent design/build landslide repair projects in the Eastern United States, this presentation outlines some of the new and innovative erosion control and landslide mitigation methods available to designers that are both robust enough to

mitigate severe erosion and shallow landslides and specific enough to prevent unnecessary impact to roadway users. Relevant technologies include traditional soil nailing, high capacity tensioned wire mesh with vegetative inclusions and/or seeded turf reinforcement mats, reinforced architecturally sculpted shotcrete, micropiles, and fiberglass composite launched (or ballistic) soil nails/horizontal drains.

The five case studies for this presentation include a stream bank erosion repair below a small bridge using scour micropiles in Western Virginia; a roadway cut remediation using soil nails, seeded turf reinforcement mat and a tensioned high-capacity galvanized wire mesh facing in North Carolina, an embankment landslide repair using soil nails and reinforced shotcrete in Ohio, an innovative negative batter wall with an integral micropile foundation used to rebuild six feet of additional roadway width in Virginia, and an embankment repair in Kentucky using soil nails, horizontal drains, and reinforced shotcrete.

ii. Presentation 2

LANDSLIDES IN THE NORWOOD TUFF AND THEIR IMPACT ON HIGHWAYS IN WEBER AND MORGAN COUNTIES, NORTHERN UTAH

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ABSTRACT: Landslide movement caused by highway-related slope modifications (cuts and fills) and persistent movement of large pre-existing landslides pose a significant hazard to northern Utah highways underlain by the Tertiary (Late Eocene to Early Oligocene) Norwood Tuff. The unit consists of landslide-prone altered tuff, and tuffaceous siltstone, sandstone, and conglomerate. Dip slopes in the unit are particularly susceptible to failure. Numerous landslides, locally averaging about three per kilometer of highway, have formed in cut slopes along two highways constructed across the unit over the last two decades. The state of activity of the cut-slope landslides after the initial failure has varied, some remaining dormant for several years before reactivating, others moving persistently, and exhibiting either recurrent or continuous movement. Impacts from landslides in cut slopes are mostly limited to damage to landscaping and rock inlays that facilitate slope drainage, and blockage of drainage ditches at the base of cut slopes. Elsewhere, embankment and other fills have reactivated pre-existing landslides that have progressively and, to a lesser extent, retrogressively enlarged and moved persistently. Waste soil and rock placed on top of the upper part of pre-existing landslides caused two landslides below State Route 167 in 2004, one of which displaced a buried natural gas line. These landslides progressively enlarged by a process in which displaced material laterally loaded downslope landslide deposits, causing new thrusts (slide planes) to develop. Gradual retrogressive enlargement of one of the landslides resulted in encroachment of the main scarp zone onto the highway embankment slope.

State Route 226 (SR-226) was constructed across two large, complex persistently moving landslides—the Green Pond and Bear Wallow landslides. The highway crosses an unmitigated narrow portion of the Green Pond landslide that consists of active and inactive sections separated by a longitudinal shear zone. Damage resulting from persistent but very slow movement of the active section of the landslide includes two sets of en echelon road cracks across the highway and minor displacement and flexure of the pavement. Locally, a cut slope that parallels a short length of the landslide's active right-flank shear zone may be contributing to lateral enlargement of the slide. A shear key constructed on the upslope side of SR-226 across the eastern part of the Bear Wallow landslide, likely reduces movement on the uppermost of several stacked thrusts (slide planes) and has, to date, prevented damage to the highway. However, monitoring has detected continued movement of the landslide upslope of the highway. Movement of downslope parts of the landslide causes recurrent local damage to

a county road (former SR-226). Future highway construction across the unit may benefit from additional characterization of pre-existing landslides and landslide processes and reassessment of mitigative measures employed to date.

iii. Presentation 3

Geotechnical Aspects of the Rocky Road Embankment Failure and Repair

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ABSTRACT: A section of Rocky Road running parallel with the Levisa Fork of the Big Sandy River near the town Millard in Pike County, Kentucky failed as a result of slope instability during a flood erosion related event in May 2009. Factors contributing to the failure, which involved a narrow section of the two-lane county road extending about 170 feet in length, and the remedial measures taken to address the time-sensitive, design-build project are discussed. Our investigation considered the geologic setting, various geotechnical exploration methods including vertical and horizontal drilling, slope stability analyses and subsequent slope design to aid in identifying possible causes of failure and to plan for remedial action. The ultimate failure mechanisms involved erosion at the toe of the roadway embankment coupled with a naturally occurring increased depth to bedrock in the central portion of the failure zone and soft/loose fill and natural materials existing beneath the roadway.

Remedial measures were provided in five conceptual design-build options including: 1) a reinforced concrete cantilever retaining wall, 2) a mechanically stabilized earth retaining wall, 3) an anchored soldier pile retaining wall, 4) an anchored sheet pile retaining wall and 5) a soil nail retaining wall. Based on observations made at the site, it was determined that stabilization of the slope using rock anchors would be necessary to limit further erosion and to protect construction personnel, using top down construction techniques, during the construction of the permanent solution. Given the time sensitive nature of this repair and the fact that this road remained open to the public as the sole point of access to/from the town of Millard, it was critical to devise a solution to quickly stabilize the slope. Further, due to the physical constraints of the site (lack of overhead and lateral clearance, steepness of slope, etc.) it became apparent that the size of equipment used during construction would be highly limited. The final design alternative consisted of tensioned rock anchors with anchor blocks on a shotcrete slope facing and the road brought back to grade using a riprap rock buttress. Drainage installations included wick drains to collect water from the roadway fill to alleviate pore pressure behind the shotcrete wall and filter fabric in conjunction with a free draining rock buttress slope for armoring against future erosion.

iv. Presentation 4

Analysis of the geologic context of maintenance costs for rockfalls and landslides in Kentucky

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ABSTRACT: The Kentucky Geological Survey (KGS) is currently working on a project to assess the geologic context of landslide and rockfall maintenance costs along Kentucky roadways. The data are derived from the Kentucky Transportation Cabinet (KYTC) Operations Maintenance System, a database of maintenance activities derived from district work orders. Seven years of data are being analyzed. Phase I of the project converted the tabular data into GIS format in order to analyze costs geospatially. A program was developed that splits work orders into one-mile segments with a reference to route mile points, so that the database can be joined with shapefiles of the transportation system. Phase II is in progress and includes investigating the context of landslide and rockfall costs over time. Maps of high or repetitive costs will be created to identify target study areas. These areas will be field investigated to assess the geologic context in order to develop predictive models for maintenance issues.