COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Durable Wearing Surfaces for HMA
Study No: 010.37

Background The Colorado Department of Transportation spends a large sum of money each year on the design and placement of new asphalt pavements. Inevitably, these pavements will need rehabilitation. Wearing surfaces provide an alternative to CDOT's current rehabilitation strategies. A pavement design system incorporating wearing surfaces will both protect the existing pavement structure and provide a quality overlay system for all pavements. A durable wearing surface is essential for preserving CDOT's investment in its paving program. The wearing surfaces will be evaluated on an annual basis at eleven sites: Five SMA sites, three Nova chip sites and three SHRP SuperPave SX sites. The test sites will have their ruts measured, cracks mapped, general condition visually evaluated and the skid number and texture depth measured using the CDOT Pavement Friction Test System (skid truck and trailer).	Reporting Period: 4/01/15 through 6/30/15 Type: SP&R Start: 09/01/02 Ver: 12/31/02 Principal Investigator(s): Skip Outcalt, Research 303-757-9984 Dave Weld, Research 303.512.4052 Study Manager: Skip Outcalt (303)-757-9984 Study Panel Members: Bill Schiebel, Region 1 Materials Dave Eller, Region 3 Eng Jay Goldbaum, Materials and Geotechnical

MILESTONES

Planned	**% done**	**Achieved**	**Description, Discussion, and Related Issues**
		7/02	Request projects from regions to include in research study.
9/02		9/17/03	Monitoring of OGFC and SMA construction on I-70 near Geneese.
9/02		9/02	Monitoring of Nova Chip Construction in Region 3.
10/03		9/24/03	Construction field notes for OGFC placement on I70 near Geneese.
10/03		9/17/03	Annual evaluation of test sections
3/03		12/1/03	Notes documenting the construction and first year evaluation of the Region 3 NOVA chip project.
11/05		11/05	Annual evaluation of test sections.
11/08		11/08	Annual evaluation of test sections. This was delayed due to malfunction of the skid tester.
12/13			Final annual evaluation of test sections after skid system is calibrated to confirm validity of the data.
12/13			Draft Final Report. (May be adjusted pending decision of panel)
06/14			Publish final report.

SIGNIFICANT EVENTS

6/15 – The skid test system has been repaired and had new computer hardware and software installed. Testing will resume in July, 2015.

12/13 – Data collection has been prevented by problems with the skid test system. Repairs are scheduled for January, 2014.

9/13 –A PO has been generated and sent to International Cybernetics Corporation for the parts and labor for the skid system repairs. The ARIB is waiting for ICC to schedule its technician to perform the repairs. The system will then be returned to TTI at College Station, TX for calibration.

4/13 – During calibration of the skid test system malfunctions were discovered that make validity of data collected questionable. CDOT is currently evaluating the advisability and cost effectiveness of repairs to the system.

6/12: Data collection and analysis in progress

3/12: Data collection and analysis in progress

1/12: Data collection and analysis in progress

06/11: Site evaluations for 2011 in progress

09/10: Site evaluations for 2010 continue

06/10: Site evaluations for 2010 in progress

12/09: Site evaluations completed for 2009

10/09: Site evaluations are in progress.

12/08: Site evaluations have been completed.

08/07: Skid equipment is functional and site evaluations have begun.

11/06: Problems with the Skid testing equipment and weather made it impossible to evaluate the test sections during the fall of 2006. The testing will be done in July and August of 2007.

11/05: This study is now being handled by Skip and Dave. Eleven test sites were established and evaluated. The evaluations found no significant developments at any of the sites.

03/05: The study panel members for this study met and as a result expanded the scope of the study to cover more sites. There are now 10 sites for this study which covers: SMAs, Nova chips, SHRP SuperPave SX mixes.

12/1/04: Region 1 decided to cover up the OGFC test section due to problems with icing.

7/31/04: The principal investigator, Donna Harmelink, has retired.

9/17/2003: An open graded friction course (OGFC) section and a stone matrix asphalt (SMA) section were constructed in Region 1 on I-70 near Genesse and are being evaluated under this project.

10/2002: A Nova Chip project was constructed in Region 3 on SH82 north of Aspen and is being evaluated under this project.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

CDOT Pavement Crack Seal and Fill Best Management Practices
Study No: 11.40

Background Crack sealing and filling are cost-effective pavement preservation techniques that can provide significant return on investment, improve pavement performance and increase remaining service life, and provide potential contracting opportunities for disadvantage business enterprise (DBE) and other small companies bidding CDOT work. However, CDOT does not have an effective or current crack sealing and filling policy, contracting process, installation and inspection manual, and quality assurance protocols. The policy and manual used was developed in 1994, and is not readily available, understood, or applicable to the current state of practice. This research will: 1) recommend a policy for application and use of crack sealing and filling, 2) develop a *Best Practices Guidelines* for the design, construction, and maintenance of crack sealing and filling treatments. 3) develop *Design Guidelines* that identify the process and data requirements to develop a plan, specifications and estimates (PS&E) level project, and identify appropriate QA/QC procedures for crack sealing projects.	Reporting Period: 4/1/15 through 6/30/15 Type: SP&R PO: 211017617 Start: 11/1/12 End: 12/01/14 Principal Investigator: David Peshkin, Applied Pavement Technology, Inc. Study Manager: David Reeves, PE, Research Branch, 303-757-9518 Study Panel Members: Phillip Anderle, R-4 Maintenance Donna Harmelink, CO Div. FHWA Frank McCoy, R-6 Maintenance Mark Mueller, Staff M&O (retired) Tyler Weldon, Staff M&O Mike Stanford, Mat. and Geotech Branch

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
11/1/12		11/1/12	PO 211017617 issued to Applied Pavement Technology, Inc.
1/30/13	70		Task 1 literature review: Literature search completed
2/14/13	100	2/14/13	Kick-off meeting
		10/31/14	**Final Report # CDOT-2014-13 was published in October of 2014.**

SIGNIFICANT EVENTS

10/31/14 Final Report Published: This will be the final quarterly report on this study.

12/31/13 David Reeves will replace Roberto DeDios (retired) and Rich Griffin (retired) as the project study manager. In addition, Tyler Weldon has replaced Mark Mueller who also retired.

8/7/13 Peshkin and Truschke from APTech were able to meet with the study panel

	members and present the current status of the draft guidelines and procedures. A good deal of feedback was received.
4/1/13	Survey of crack sealing practices finalized and prepared for distribution to selected respondents.
1/31/13	The Study Manager, Roberto DeDios, retired from CDOT
11/13/12	Informal meeting between Griffin, de Dios, and Peshkin at CDOT.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Reflection Crack Attenuation in Asphalt Pavements

Study No: 011.50

Background

Asphalt overlays are one of the most common tools for rehabilitating existing asphalt and concrete pavements. Rehabilitation of existing pavements is often necessary after several years due to distress such as cracking, moisture damage and permanent deformation. However, the performance of new overlays is often jeopardized by the cracking distress in the existing pavement. This existing cracking will propagate, or reflect, through the new overlay to the surface of the new overlay. The rate at which this reflection cracking propagates to the surface is a function of overlay thickness, crack severity, traffic loading and subgrade or subbase support. Once reflection cracks appear on the surface of the new pavement, water and debris can enter the subbase and subgrade which can affect pavement strength and reduce the life of the overlay. Therefore, reducing the rate at which these reflection cracks propagate to the surface of the pavement is desirable in order to lengthen the time between rehabilitation projects.

Various methods have been used in past decades in an attempt to reduce the rate of reflection crack propagation. These include geosynthetic interlayers and asphalt stress absorbing interlayers between existing pavements and relatively thin overlays.

Two reflection crack reduction techniques have been installed by CDOT: Tensar, a grid reinforcing system, and a polymer modified asphalt-rich interlayer system called RCI. Tensar has been installe on I-70 at M.P. 255/256 and on US-160 west of Monte Vista. While RCI has been used on US-85 south of Evans. For each location a control section was set aside where no reflective crack reduction treatment was used.

All these test sections were built in 2009 or 2010, while the PI was not hired to perform the evaluation until 2013. However, CDOT Region staff have mapped the crack in the pavement before the overlay and monitored the crack re-apperance in the overlays. The PI will take over the crack performance monitoring in 2013 and provide a report documenting the performance of each material.

Reporting Period: 4/1/2015 through 6/30/2015
Type: SP&R Start: 10/5/12 End: 12/31/15

Principal Investigator:
Scott Shuler, CSU, PO: 211017352

Study Manager:
Skip Outcalt, Research Branch, 303-757-9984

Study Panel Members:
Michael Stanford, CDOT Materials and Geotechnical Laboratory, 303-398-6576
Shamshad Hussain, CDOT Region 1 Materials, 303-398-6802
Donna Harmelink, CO. Div. of FHWA, 720-963-3021
Robert Shanks, R-5 Materials, 970-385-1416
Gary DeWitt, CDOT Region 4 Materials, 970-350-2379

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
6/30/13	100	12/31/2013	Task 1 – Initial Crack Locations
9/30/13	100	12/31/2013	Task 2 – 2013 Reflection Crack Performance
9/30/14	100	12/31/2014	Task 2 – 2014 Reflection Crack Performance
9/30/15	50	6/30/2015	Task 2 – 2015 Reflection Crack Performance
10/31/15	0		Task4 – Draft Final Rport
11/30/15	0		Task 5 – Presentation to Materials Advisory Committee
12/31/15	0		Task 4 – Final Report

SIGNIFICANT EVENTS

6/30/2015: Field condition surveys were conducted for the RCI test sections on US34 and US85 on June 3, 2015 and for the Tensar test sections on I-70 on June 4. Analysis of the cracking performance is underway and will be included in the next progress report.

One final condition survey will be conducted on these three test sites in the final quarter of 2015 so the data can be included in the draft final report due in November, 2015.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Preventing Transverse Bumps and Cracks in New Asphalt Overlays Over Crack Sealants (Bumps Over Crack Sealants)

Study No: 11.60

Background A bump, and often transverse cracks, occurs in an overlay of hot mix asphalt when placed over crack sealant in the underlying substrate pavement. The cause of this phenomenon is largely unknown. However, recent research by the author for CDOT and Jefferson County, CO suggests some factors which may relate to the formation of bumps and some which do not appear to relate. The factors which seem to exacerbate the formation of bumps include: 1) the temperature of the overlay mixture, 2) the pavement grade, 3) 'overbanded' crack sealant, 4) vibratory breakdown compaction, and 5) number of passes of the breakdown roller. Factors which do not appear to contribute to bump formation or are less significant include: 1) crack sealant type, 2) crack sealant application geometry, 3) substrate pavement temperature, 4) pneumatic breakdown compaction, and 5) age of crack sealant. One factor which seemed to be significant, but was not evaluated in a controlled manner during the research for Jefferson County, CO, was the size of the 'bow wave' which occurs immediately ahead of the drum during breakdown rolling. The size of this 'bow wave' is affected by the temperature of the mixture, pavement grade and vibration.	Reporting Period: 4/1/2015 through 6/30/2015 Type: SP&R Start: 07/16/13 End: 07/16/16 Principal Investigator: Scott Shuler, CSU: PO 211019397 Study Manager: Aziz Khan, Research Branch, 303-757- Study Panel Members: (Tentative) Bill Schiebel Michael Stanford Donna Harmelink, CO. Div. of FHWA

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
9/30/13	100	12/31/2013	Task 1 – Literature Review
07/31/14	80	6/30/2015	Task 2 – Identify Test Site(s)
07/31/15	50	6/302015	Task 3 – Install Test Sections
07/31/16	80	3/31/2015	Task 4 – Progress Reports
05/31/16	0		Task 5 – Presentation
05/31/16	0		Task 6 – Draft Final Report
07/31/16	0		Task 7 – Final Report

SIGNIFICANT EVENTS

6/30/2015: A visit to Region 3 by the PI resulted in identification of the second experimental test site for this project. The site is located on SH13 north of Craig, CO in Region 3. Construction of the test sections is planned for the first or second week in July, 2015.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Asphalt Emulsion Full Depth Reclamation Best Practices
(Emulsion FDR)
Study No: 12.75

Background

Asphalt Emulsion Full Depth Reclamation (AEFDR)is process that recycles and rejuvenates the existing pavement surface and subgrade, providing an improved structure for the final surface pavement. AEFDR is a cost effective, green technology that could enhance available options for treating fatigued pavements and better implement practical design criteria. To increase the use of the AEFDR process, CDOT pavement designers, roadway design and construction staff need design guidance, standardized plans and specifications, construction inspection best practices and quality assurance and quality control protocols.

The research will develop AEFDR design criteria, standard specifications, plan sheets or other design aides, construction inspection requirements, materials testing procedures and frequencies, and a performance evaluation process guide.

Reporting Period: 4/1/15 through 6/30/15
Type: SP&R Start: 11/5/12 End:

Principal Investigators:
Scott Shuler, CSU, PO: 211017637

Study Manager:
Temporarily Skip Outcalt, Research Branch, 303-757-9984

Study Panel Members: (Tentative)
Gary DeWitt, R-4 Materials, 970-350-2379
Shamshad Hussain, R1Materials, 303-398-6802
Steven Henry, Mat. and Geotech Branch, 303-398-6579
Mike Stanford, Mat. and Geotech Branch, 303-398-6576
Donna Harmelink, CO. Div. of FHWA

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
8/31/12	100	9/5/12	Hold initial study panel meeting.
9/15/12	100	9/7/12	Develop scope of work
9/30/12	100	9/7/12	Issue RFP: issued to Colorado public universities, proposals are due 10/8/12
11/07/12	100	11/5/12	Select researcher: Scott Shuler with CSU was selected to perform the research
12/7/12	100	11/28/12	Notice to Proceed
2/1/13	100	12/31/13	Task 1-Literature Search: Literature and oral reviews continued with a discussion with Wyoming DOT personnel in Cheyenne concerning experience there and of planned projects in 2013 using emulsion FDR. The Wyoming DOT has a mixture design procedure that evaluates compacted samples of emulsion FDR materials that will be evaluated further.
4/1/13	100	12/31/13	Task 2-Design, Plans, Specs
12/7/13	100	12/31/13	Task 3-Progress Reports
12/7/13	100	12/31/13	Task 4-Panel Meetings
11/15/13	100	12/31/13	Task 5-Draft Final Report
12/31/13	100	6/30/15	Task 6-Final Report: Review by CDOT was overlooked, delaying final publication
09/09/15	0		Task 7-Presentation, scheduled to make presentation at September MAC meeting

SIGNIFICANT EVENTS

6/30/15 The final report has been published as 2015-04.
This will be the last quarterly progress report for this study.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Investigation of the Need for an HMA Layer Bond Strength Test
Study No: 12.94

Background Poor bonding between asphalt pavement overlays and the substrate pavement layer can greatly influence the long term performance of hot mix asphalt (HMA) in the form of premature cracking and fatigue. The primary method to achieve bonding between layers is by using an asphalt emulsion tack coat. Additionally, field staff is charged with determining whether an existing pavement, especially a milled surface, is clean enough prior to tack coat placement, to ensure an adequate bond. Because CDOT is prescriptive in its tack coat application specifications, responsibility for any pavement failures related to poor bonding is CDOT's. CDOT is considering adopting a bond strength test method and associated specification limits based on performance information. CDOT could then transfer responsibility to the Contractor for determining appropriate cleaning and tack coat application rates and practices.	Reporting Period: 4/1/2015 through 6/30/2015 Type: SP&R Start: 11/5/12 End: 12/31/15 Principal Investigators: Scott Shuler, CSU, PO: 211017637 Study Manager: Richard Griffin, Research Branch, 303-757-9975 Study Panel Members: (Tentative) Gary DeWitt, R-4 Materials, 970-350-2379 Shamshad Hussain, R1Materials, 303-398-6802 Steven Henry, Mat. and Geotech Branch, 303-398-6579 Mike Stanford, Mat. and Geotech Branch, 303-398-6576 Donna Harmelink, CO. Div. of FHWA

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
8/31/12	100	9/5/12	Hold initial study panel meeting.
9/15/12	100	9/7/12	Develop scope of work
9/30/12	100	9/7/12	Issue RFP: issued to Colorado public universities, proposals are due 10/8/12
11/07/12	100	11/5/12	Select researcher: Scott Shuler with CSU was selected to perform the research
12/7/12	100	11/28/12	Notice to Proceed
4/1/13	90	6/30/2015	Task 1-Reviews
9/1/13	70	6/30/2015	Task 2-Field Survey
12/7/14	85	6/30/2015	Task 3-Progress Reports
12/7/13	0		Task 4-Draft and Final Report-Phase I
7/15/14	0		Task 5-Pilot Project
12/7/14	0		Task 6-Draft and Final Report-Phase II

SIGNIFICANT EVENTS

6/30/2015: Attempts to core the test sections installed last year moved forward and are anticipated in the next quarter.

This project is approximately one year behind schedule because of the change in scope facilitated last year. A one year, no cost time extension is recommended so that the work may be completed.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Helicopter Avalanche Control – Phase I
Study No: 30.70

Background Avalanche danger presents many hazards to the transportation infrastructure in Colorado. In hazardous areas, near roads too arterial to close, these hazards must be mitigated by forcing slides during temporary road closures. Often the avalanches are triggered via high explosive charges dropped from helicopters. Many factors such as weather, explosive duds, or charges rolling away from trigger zones can prolong or even scrap a mission. When traffic is stopped, loaders are staged for snow removal, ground control is in operation, and the helicopter crew is working, costs drastically increase with mission time. Also, increasing the amount of time in flight increases the probability of an in flight accident. This research project is designed in two phases. The first is focused on a global survey designed to identify current methods in avalanche control. The goal of phase one is to determine what differences, if any, exist in the methods of helicopter avalanche control performed by CDOT in comparison to other agencies. The second phase is designed to field test any differences found in phase one, as well as test any promising technology not identified in phase one. One potential avenue of investigation in phase two is the DaisyBell system. The DaisyBell generates a compressed gas explosion, while tethered to a helicopter, and can therefore be fired many times. This increase in firings can potentially increase the number of avalanches triggered per flight. The DaisyBell apparatus itself, however, may cause more mission scraps due to wind and the increased aircraft cross-section. Phase two intends to field test such cost to benefit ratios with real world technologies. Upon analyzing the results of phases one and two, suggestions can be made, and training implemented, to help reduce the cost and safety hazards associated with CDOT's helicopter avalanche operations.	Reporting Period: 4/1/15 through 7/30/15 Type: SP&R Start: 5/1/11 PO: 271001410 PO Expiry: 05/22/13 Principal Investigator(s): Dr. Vilem Petr, Colorado School of Mines 303.273.3222 Dr. Ethan Greene, Colorado Avalanche Information Center 303.499.9650 Study Manager: David Reeves, DTD Research, 303-757-9518 Study Panel Members: Mark Mueller, Staff Maintenance Engineer (HQ) (retired) Tyler Weldon, Staff Maintenance Engineer (HQ) James Walker, Maintenance & Operations (HQ) Dr. Aziz Khan, CDOT Research Engineer (HQ-DTD)

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
			Phase 1
5/11	100	5/11	Task 1.1: Review of current practices in helicopter avalanche control at CDOT and by other agencies performing the same kind of work.
5/11	100	5/11	Task 1.2.0 thru 1.2.2: Perform national and international survey of current helicopter safety and use in avalanche control. Survey will include types of explosives used, their delivery methods, and respective initiation systems. Special focus on delivery methods of "turkey bombs" will be reviewed.
5/11	100	5/11	Task 1.2.3: Industry survey of available initiation systems for explosives used in helicopter avalanche control.
5/11	100	5/11	Task 1.3: Perform national and international survey for alternative methods to explosives within avalanche control such as DaisyBell and Gas-Ex avalanche control systems.
5/11	25	6/11	Task 1.4: Contingent on availability of equipment and coordination with CDOT maintenance operation, the research team will conduct a preliminary field experiment to

			help guide phase 2. The experiment will collect data and compare effectiveness of two types of ANFO charges, emulsions/heavy ANFO and the DaisyBell. The field data would include, but not be limited to, measuring crater dimensions, atmospheric overpressure, high-speed images, and initial and final snow structure. The data would be used to evaluate the different explosive methods and help to validate and benchmark the new numerical simulation of other blasting scenarios.
9/11	100	1/12	Task 1.5: Submit written report summarizing findings from tasks 1 through 3 as per CDOT research report format within six months from start of project. This report will compare effectiveness of current CDOT helicopter avalanche control efforts to other agencies in terms of number of successful efforts per mission, how often the efforts fail, and by what mechanism (snow failed to slide despite apparently good charge placement and initiation, dud, charge rolled/bounced down slope, weather caused scrub after takeoff, etc.) failure occurred.
Phase 2			
12/11	100		Task 2.1: Dependent upon evaluation of data obtained in phase 1, the research team will propose improved strategies in terms of new explosive types, delivery methods, and/or initiation methods which are intended to improve crew safety, mission effectiveness and cost effectiveness. The strategy should consider not only explosive characteristics but also avalanche/snow mechanics and how the process could be optimized for different conditions.
4/12	100		Task 2.2: Design and build a test matrix for comparison of actual explosives, and their alternative systems, studied in phase 1. The research team will perform and analyze these comparisons with different initiation systems, delivery methods, and explosive types in relation to snow mechanics, environmental effects using high speed imaging and other technologies. Numerical modeling will also be performed using results from these comparison tests. Test locations will be pre-selected be CDOT personnel, such as Independence Pass in early spring, to afford realistic snow conditions.
4/12	100		Task 2.3: The research team will design and implement training courses and materials in the proposed strategy based on the test results of Task 2.2 in order to minimize cost and help improve the effectiveness of CDOT's helicopter avalanche control program.
4/12	100		Task 2.4: Continue annual CDOT training while documenting the effectiveness of the newly implemented strategies described in tasks 2.2 and 2.3.
5/12	100		Task 2.5: The research team will submit a final written report on the new helicopter avalanche control strategies, implemented training, and effectiveness of new strategies in the field. This report will also highlight the comparison between current explosive methods to alternative methods such as the Daisy Bell avalanche control systems and will comply with CDOT Research Branch requirements.

SIGNIFICANT EVENTS

- **5/11** The project was funded and phase one began.
- **5/5/11** The survey was launched around the world to ski areas and transportation departments. As of this writing, 32 legitimate responders have been recorded. The analysis of this survey is to come in the next quarter but it has been noted that none of the survey participants thus far use the DaisyBell system.
- **7/20/11** The project kickoff meeting was held at the Colorado School of Mines. Overall project goals, as described in the project background, were discussed. It was determined that the primary goal of this study is to improve (and/or verify) CDOT efficiency in helicopter avalanche control. It was stressed that CDOT would like to see phase one completed as thoroughly as possible before moving on to phase two. Potential locations for phase two testing was also discussed, and determined to be Loveland ski area. Emphasis on the DaisyBell system was suggested. Also, interest in developing an easy means of ANFO quality control measurement was expressed.
- **7/20/11** The survey was launched again to all emails that have not yet responded. At the time of this writing ten more participants have been recorded due to this launch.
- **12/11** 32 responses to the survey have been received. Survey responses have been analyzed with the following results
- **1/5/12** Final survey report was sent to CDOT and other necessary personnel for revision.
- **2/12** Working on setting up testing with Loveland Ski area and finalizing test matrix with CDOT for 1 or 2 days of testing, according to availability of Loveland Ski Area, CDOT personnel, and CAIC personnel.

- **2nd Quarter 2012** – No significant events reported.
- **3rd Quarter 2012** – No significant events reported.
- **November 2012** – We have meeting with CDOT research team at CSM research team at CSM and we suggested and proposed a new schedule for the experiments which should be done by February 2013 in Loveland. This is dependent on snow conditions.
  We also agreed on 4 tests using different charges as well initiation systems.
- **4th Quarter 2012 –** No significant events reported
- **February 2012 –** Phase 2 experimental testing has been suspended indefinitely due to lack of snow. Recommendations will be compiled based on preliminary experimental test results, survey results, and numerical modeling results. This work will be completed and a report submitted by May 1, 2013
- **1st Quarter 2013 –** Plan for testing at ERL test pit moving forward. Relative effectiveness of ANFO versus ANNM charges will be evaluated based on air overpressure measurements and measurements of the detonation pressure of each explosive using the double pipe test. Final testing plan will be submitted to CDOT for approval by April 1, with testing to be completed by the second week of April
- **2nd Quarter 2013 –** Draft report submitted and presented to study panel. Project complete.
- **2nd Quarter 2015 –** Need to place final report (Report 2013-8.pdf) on CDOT research website but due to classified nature of this project the study panel needs to figure out what we will post. Report 2013-8 was assigned.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Potential Impacts of Solar Arrays on Highway Safety and Operations

(Solar Array Highway Impacts)

Study No: 032-08

Background The highway right-of-way provides the opportunity for the development of solar power systems across the state. However, this is only feasible if it can be done in a manner that does not interfere with the operation and maintenance of the highway system and does not create an unacceptable risk to transportation system users. Two reports will be produced, addressing general (not necessarily site specific), potential impacts from solar array installation and operation. The first report should identify visual and other potential impacts to highway user safety, evaluate the probability for these impacts to occur and recommended criteria for minimization or control of any impacts that have a high probability of occurring, or carry very high risk even if probability appears low. The second report will focus on the potential for solar arrays to affect on-going maintenance and operation activities.	Reporting Period: **04/01/15 through 06/30/15** Start: 10/29/12 Contract Amount: $74,970 End: 12/31/14 Principal Investigator: Dr. Ananda Paudel, Assistant Professor Engineering Department, Colorado State University-Pueblo Study Manager: Bryan Roeder, CDOT, 303-512-4420 Study Panel Leader: Yates Oppermann, CDOT Environmental Programs Branch Study Panel Members: Sasan Delshad, CDOT Region 2 Traffic and Safety Mike Delong, CDOT Region 1 Maintenance and Operations Jim Eussen, CDOT Region 1 Environmental Sarah Mitchell, CDOT Environmental Programs Branch Dave Ruble, CDOT Region 1 Utility Engineer Rick Santos, Colorado Div. of FHWA

MILESTONES/TASKS

Planned	% done	Achieved	Description, Discussion, and Related Issues
11/1/12	done	11/1/12	Notice to Proceed
11/6/12	done	11/16/12	Kick Off Meeting
3/1/2013	100%	12/31/2013	**Task 1. Literature study done:** ODOT, Volpe Institute, snow drifting Glare , Glint , Safety and Maintenance, • Solar Glare Hazard Analysis Tool (SGHAT) software (Sandia Laboratory) to analyze the glare effects • Dr.Tabler's studies on snow drifting and snow fences • Presentation in Transportation Research Board Hazardous Waste and Resource Conservation Efficiency Committee • Snow drifting model under study • New findings in Glare- Glare can cause severe impact • Germany has a glare test requirement • Solar highway in MI, NY and others • CDOT and federal highway guidelines reviewed
2/30/2013	100%	12/31/2013	**Task 2. Frame work development done via** Tele conference and in person meeting: Action items generation on literature review, field visit and interviews and work assignment • Main elements identified for each study scope(Environmental, maintenance, safety, design and location) • Generated an impact matrix • Talked to Dan Gullickson from the Minnesota Department of Transportation for snow control • studied snowfence.com • Identified design criteria and citing elements for further study • Impact matrix reviewed • Glare analysis of the study site performed
12/30/2012	100%	12/31/2012	**Task 3. Potential CDOT Reference Site Search/ study /Interview**
2/15/2013	100%		Reference Site Identification
9/01/2013	100%	12/12/2012	Reference Site Observations Performed: (CSUP, NW Parkway State Highway 93 (City of Arvada), Federal Center (Golden, Colorado) and US 36 near University Research

		1/28/2013 9/25/2013 12/24/2013	Park DIA Field Visit Meeting with safety personnel at CDOT head Quarter, E-470 Potential site searched for observation Site selected for study(358 mile road I-70) and field visited along CO50, CO 71, CO287, I-70 and I-76 potential PV plant Site location was observed and evaluated the potential impacts using Impact Matrix Interviewed maintenance staff in Limon Site layout and model created
9/01/2013	100%		**Task 4-Report Development: Draft Report** **Report on snow drifting**
10/30/2013	100%	12/31/2013	Report outline and referencing style are set Study Panel Meetings and comments Outline for the draft report is set Report writing is in progress
11/30/2013	100%		CDOT Draft Reports Review (Presentation)
12/30/2013	100%		Final User Impact Report Development/CDOT Transmittal
12/30/2013	100%	12/31/2012	**Task 5- PI Project Management (Communication)**
12/30/2014	99%		Project Close Out
	100%	12/31/2013	Meeting conducted with CDOT Staff (Traffic -Pueblo, Maintenance-zone 6, safety-HQ Documents in DropBox Meeting conducted with CDOT Staff (09/04/2013) research direction was reviewed • Revised project schedule • Meeting with CDOT maintenance in Limon • Internal communication
			{add additional rows as needed}

Latest Progress

SIGNIFICANT EVENTS

{This area is for issues that are outside the normal research work. Use the third column in the above table to expound on progress related to individual milestones/tasks.}

4/1/2015 Final Report receiving final edits.
12/30/14 – Final Report delivered to CDOT
03/10/14 – Draft report delivered to CDOT
05/13/14- CDOT draft report comments finished, sent to PI
8/5/14- Final report (draft 2) submitted to CDOT

mm/dd/yy – most recent issues above older issues

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Mule Deer and Elk Right-of-Way Escape Ramp Design Monitoring

(Escape Ramp Monitoring)

Study No: 32-47

Background Escape ramps are increasingly being used across the western United States as an escape mechanism in areas where wildlife fencing has been constructed. However, the design and effectiveness of such ramps have been poorly studied and most of the ramps are built with little research informing their design and placement. Much of the current knowledge base is derived from anecdotal experience and we know of no studies that have compared the effectiveness of different ramp designs for deer and elk. The research will provide systematic and focused documentation of ramp usage, and an analysis of attribute features (design or setting) which may influence usage of the ramps by the target species (mule deer and elk). Statistically analyzing pre- and post- construction accident data will serve as a baseline for determining effectiveness, but other aspects of ramp design that influence the benefit of the mitigation will also be documented. Documented effective ramp designs can be incorporated into engineering design standards for deer and elk escape ramps across the state and will contribute to the nationwide knowledgebase regarding the effective siting and design of escape ramps to reduce AVCs. The study aims to develop pilot construction specifications and/or guidance documentation on best practices to effectively locate, design, construct, and maintain mule deer and elk escape ramps.	Reporting Period: 04/01/15 through 06/30/15 Start: 0/09/12 Contract Amount: $ 71,994 Principal Investigator: Kenneth Wilson, Ph.D. (dept. head) & Jeremy Siemers, M.S. (research associate) Department of Fish, Wildlife, and Conservation Biology at Colorado State University (CSU) Study Manager: Bryan Roeder, CDOT, 303-512-4420 Study Panel Leader: Tony Cady, Region 5 Environmental Study Panel Members: Mark Lawler, CDOT Region 5 Environmental Jeff Peterson, CDOT Environmental Programs Branch Alison Michael, US Fish & Wildlife Service Jim Eussen, CDOT Region 1 Environmental Rob Frei, CDOT Region 2 Environmental David Valentinelli, CDOT Region 5 Engineering . . FHWA Washington Contact:

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
05/09/12	100%	05/09/12	Notice to Proceed
05/31/12	100%	5/31/12	Kickoff Meeting
06/20/12	100%	06/20/12	Field Meeting with CSU, CDOT, and CPW personnel
07/31/12	100%	07/31/12	Camera testing and deployment evaluation – test data evaluated and final deployment scheme decided upon
07/31/12	100%	07/31/12	Cameras deployed at all escape ramps as well as two jump-outs within the study area
11/09/12	100%	09/12/14	Collect ramp, road, landscape, and other covariates Data on landscape covariates, including gaps in fencing and status of exclusion structures (e.g. gates and cattle guards) collected.
07/31/14	100%	07/31/14	Monitoring – 24 months of video monitoring data collected. Review and compilation of results for 9 months of video data completed. Camera deployment efficiency and success evaluated.
01/14/15	100%		Cost-benefit analysis
01/14/15	100%		Ramp use and design analysis. Mule deer have been observed at and successfully using all of the 11 ramps. Elk have been observed at 3 ramps and 7 of 12 visits resulted in successful escapes. Based on data collected over the first 9 months, we recorded 784 mule deer visits, 318 of which resulted in successful crossings. Other large mammals observed include: black bears, mountain lions, and bobcats.
01/14/15	100%		Draft report (75 days prior to report publication)
03/30/15	90%		Final Report publication
03/30/15	90%		End of contract.

SIGNIFICANT EVENTS

6/25/2015 Final Report complete, awaiting editorial review

5/11/2015 Final Presentation given to CDOT

4/30/15 CDOT review of Draft report complete

2/5/2015 Draft Report submitted to CDOT

9/11/2014 – 9/12/2014. Field meeting with CDOT Biologist Mark Lawler. Camera set-ups and data collection methods were observed and discussed. A field survey of holes and gaps in the wildlife fence in the study area was conducted.

6/23/2013 – 6/26/2013. Presented preliminary data for mule deer at the International Conference on Ecology and Transportation.

Proceedings document can be found at: http://www.icoet.net/ICOET_2013/proceedings.asp

Project Summary to Date

Data collection of 24 months of picture and video data at the 11 escape ramps and 2 jump-outs within the study area is complete. Video data have been downloaded and placed on secure servers. Preliminary analyses have been conducted to evaluate camera effectiveness and limitations. Review of the video data is scheduled to be completed by November 15, 2014. Final analysis and data summary will begin after video review is completed.

In analyses conducted to date, mule deer are by far the most frequent visitors to the escape ramps. Other species of medium to large mammals observed include bobcat (*Lynx rufus*), mountain lion *(Puma concolor*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), American black bear (*Ursus americanus*), and elk (*Cervus elaphus*).

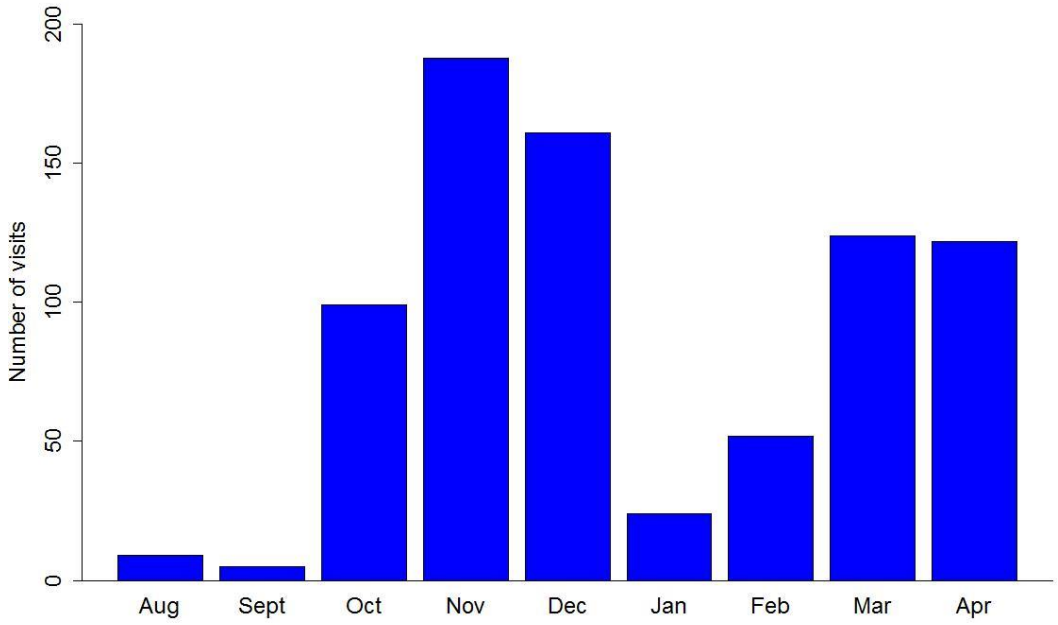
Elk, another focal species of this study, have not been observed as often as might have been expected. During video analysis conducted to date of the first 12 months of monitoring data, elk have been observed at 3 different ramps on 7 different dates in the months of January, March and April. Elk were not observed using escape ramps until January 2013 and a total of 12 visits have been observed thus far, 7 of which resulted in successful escapes.

In the video analysis of the first 9 months of data, we have documented 3 successful mule deer reversals, i.e., instances where animals used an escape ramp to cross the wildlife fence from the safe side to the right-of-way, 1 successful mountain lion reversal, and 1 successful bear reversal. The 3 successful deer reversals occurred at 2 different escape ramps, one of which had a horizontal bar present. One unsuccessful reversal attempt by a deer was observed when the animal was able to get its forelegs onto the ramp platform, but then fell back to the safe side of the fence; this escape ramp also had a horizontal bar present.

Mule Deer Preliminary Data Analysis - A preliminary data analysis was conducted for mule deer escape success based upon ramp characteristics. Our preliminary results indicated that ramp characteristics of height from which a deer needs to jump and slope of the escape ramp negatively affected whether or not a successful escape resulted when a deer visited a ramp. While the presence of horizontal bars appears not to have had a significant effect on successful escapes, the additional height of the bar was factored into the total jump height which was negatively correlated with the probability of a successful cross; therefore it is possible that a horizontal bar has an overall negative effect on ramp use, and it did not appear to completely prevent reversal entries from the safe side to the right-of-way.

We observed a seasonal peak of visits during the fall with decreased activity during the winter and another increase in March and April. The presence of snow or snow depth may be a component of seasonality that negatively influence successful escapes, and we will evaluate such factors related to seasonality in future analysis. Most of the deer activity we observed at ER was nocturnal with peaks during the crepuscular time periods

We recorded 784 visits of mule deer to the 11 escape ramps, 318 of which resulted in successful crossings to the safe side of the wildlife fence (41%). Most visits occurred daily during the early morning and late evening, and seasonally during the fall, peaking in November. Visits decreased during the winter and increased again in March and April.



Monthly distribution of visits of mule deer to 11 escape ramps along Highway 550, Ouray County, Colorado USA, from August 2012 – April 2013.

Following video data review, which is scheduled to be completed by November 15, 2014, we will complete an analysis of the ramp characteristics and escape success and will also conduct additional spatial analyses to better understand the landscape context of each ramp and investigate any patterns that may exist. Therefore, in addition to ramp characteristics and temporal variables, we plan to analyze escape ramp usage as a function of highway characteristics, proximity to other crossing structures, fencing gaps, topography, and other landscape features. As monitoring continues and further analyses are conducted, more insights into the factors influencing successful use of escape ramps by ungulates and other mammals will be gained.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Innovative Vegetation Practices for Construction Site Plant Establishment

(Innovative Revegetation Practices)

Study No: 042-00

Background

Proper final stabilization of disturbed soils in the form of plant establishment requires adequate soil preparation, grading techniques, amendments of proper soil fertilizers, plant selection, proper installation, and mulching during the ideal seeding conditions.

Once a CDOT construction project is completed, the CDPHE Stormwater Construction Permit holder must wait until the 70% ground cover (from baseline conditions) has been established in order to de-activate the permit. In the meantime, the project site must be monitored and BMPs must be maintained by CDOT or the contractor.

The study will provide a fresh and scientifically based review of the effectiveness or shortcomings of proposed and current CDOT specifications, guidelines, processes, and contractor compliance for construction site revegetation. The research project will review revegetation strategies used in other arid states and agencies. The research will survey CDOT contractors on techniques and equipment use; and survey CDOT engineers on successful and unsuccessful measures attempted or implemented. This study will provide species surveys conducted on existing highway areas and adjacent areas for use in ecologically relevant planting suggestions and seed mixes. The emphasis will be to identify ways in which site stabilization can be accelerated, improved and/or optimized using innovative techniques that take into account site specific habitat conditions and the difficulties present in transportation construction and planning.

Reporting Period: 10/1/2014-12/31/2014
Start: 5/21/13 Contract Amount: $135,992.50

Principal Investigator:
Arthur Hirsch
Terralogic, LLC, 303-786-9111

Study Manager:
Bryan Roeder, CDOT, 303-512-4420

Study Panel Leader:
Mike Banovich, CDOT Environmental Programs Branch
(303) 757-9542

Study Panel Members:
Jennifer Klaetsch, CDOT EPB Landscape
Tom Boyce, CDOT EPB Natural Resources
Mark Straub, CDOT R1 Project Development
Belinda Arbogast, CDOT R1
Fran Mallonnee, CDOT R5 Water Quality

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
7/15/12	100	7/11/12	Establish Study Panel and hold meeting: Invitations to be panel members have been sent out to the above staff.
08/15/12	100	9/14/12	SOW prepared based on problem statement and Study Panel input. Study panel decided to use the Procurement RFP process to select a research.
11/15/12	100	11/15/12	Issue request for proposals: Received preliminary Personal Services Agreement approval from Personnel. Purchase requisition submitted 9/14/12. Purchasing agent indicated that the SOW was too specific to for an RFP and work load in Procurement will delay processing RFP. May need to rewrite SOW to be less specific.
4/15/13	100	4/15/13	Select researcher
5/21/13	100	5/21/13	Notice to Proceed, begin study
5/22/13	100	5/22/13	Task 1 and 2 Informational Searches
7/10/13	100	7/10/13	Project Kick Off Meetings with Study Panel
7/29/13	100	7/29/13	Study Panel Working Meeting- Summary of Testing Variables and Recommendations (First/Second Screening)
8/19/13	100	8/19/13	Technical Memorandum on Task 1 and Task 2 Results
09/10/2013	100	10/10/2013	Draft Study Plan Submitted to CDOT for Review
10/17/2013	100	10/26/2013	Draft and Final Study Plan
10/18/2013	100	5/1/2014	Initiate field work (fall); Field QC Visited three of 5 sites- I-25 Colorado Springs and I-225 Aurora; scheduled first visit in Sterling and trying to coordinate site visit at I-225; scheduled Eagle Construction visit
4/14/2014	100	4/14/2014	Study Panel status review meeting
05/1/2014	100	8/29/2014	Schedule and conduct Construction QC field work
6/1/2014	100	8/29/2014	Schedule and conduct Forensic field work (summer)
09/14/14	100	10/31/2014	Draft Report (75 days prior to report publication)
1/31/2015	100		Final Report publication

SIGNIFICANT EVENTS

- Received the Google Survey results from CDOT
- Completed QC visit to US 36
- Completed Draft report to CDOT on 10/31/2014

- Initiated changes to document towards finalization in late January
- January 2015 Final Report submitted
- Feb 2015 Project Complete

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Assessment and Placement of Living Snow Fences to Reduce Highway Maintenance Costs and Improve Safety (Living Snow Fences)

Study No: 047-10

Background Living snow fences are designed plantings of trees and/or shrubs and native grasses along highways, roads and ditches that create a vegetative buffer that traps and controls blowing and drifting snow. These strategically placed fences have been shown to be cost effective in reducing highway maintenance associated with blowing and drifting snow conditions. The objective of the study is to equip CDOT with the tools and knowledge to expand the use of living snow fences. These tools should provide a roadmap for local CDOT maintenance staff which includes: 1) Identifying the best locations 2) Identifying land owners and securing their cooperation 3) Engaging resource agency support of the design and establishment 4) Insuring initial maintenance 5) Tracking these assets over time and documenting the benefits	Reporting Period: 04/01/15 through 06/30/15 Start: 11/29/12 Contract Amount: $ 70,000 Principal Investigator: Greg Sundstrom, Colorado State Forest Service, CSU Study Manager: Bryan Roeder, CDOT, 303-512-4420 Study Panel Leader: Mike Banovich, CDOT Environmental Programs Branch (303) 757-9542 Study Panel Members: Jen Klaetsch, CDOT Environmental Programs Branch Mark Harrington, CDOT Environmental Programs Branch David Vialpando, CDOT, R-5, Maintenance Jeff Peterson, CDOT Environmental Programs Branch FHWA Washington Contact:

TASKS, MILESTONES, AND DELIVERABLES **Planned**	**% done**	**Achieved**	**Description, Discussion, and Related Issues**
11/30/12		11/29/12	PO 211017905 issued to CSU to start project.
12/14/12	100	12/14/12	Kick Off meeting
12/31/12	100	1/22/13	Kick Off meeting minutes submitted
12/31/12	100	1/22/13	Quarterly project report
3/31/13	100	4/5/13	Inventory of existing LSFs on state highways 2/1913 – Received CDOT maintenance section LSF data from David Vialpando. 2/21/13 - Met with USDA Natural Resources Conservation Service and State Conservation Agency staff to discuss project and information needs for the inventory. Found that old Interagency LSF Program files had been pretty much disposed of. 2/22/13 – Sent CDOT maintenance section LSF data to CSFS District Foresters for review and additions to inventory. 2/22/13 through 4/5/13 – Received LSF inventory information from districts
3/31/13	100	4/5/13	Summary report of inventory information found along with copies of documents located 4/5/13 – Consolidated inventory information into summary report to be submitted with quarterly report.
3/31/13	100	4/8/13	Quarterly project report Inventory summary report and copies of documents/emails attached to email submitting report..
6/30/13	100	7/11/13	Quarterly project report Submitted as attachment to email
9/15/13	100% 100	6/28/13 research report Reviewing reference material and conducting interviews for most current and relevant LSF information. Have most current estimate of cost per mile of trees. Met with Wyoming State Forestry staff to learn more about the successful LSF program and relationship with WDOT. Developing outline for Guidelines and training session's agenda. 6/13/13 Received Living Snow Fence Procedure for WY and WDOT LSF program contact information. 9/15/13	Drafts of guidelines and Drafts of guidelines and research report prepared for Research Team review at upcoming 10/17/13 meeting
9/19/13	100% 100	Postponed 10/17/13	Status meeting – Postponed due to potential schedule issues caused by flooding and extreme damages to Hwys.– Rescheduled for October 17th. Status meeting was held on 10/17/13, 9:30 AM, CDOT Headquarters –

9/30/13	0% 100	Postponed 11/1/13 11/19/13 12/16/13	Status meeting minutes submitted – To be submitted after meeting which was postponed is held Status meeting minutes were submitted on 11/1/13 Dates and locations for 5 short courses have been set – workshops scheduled to start in February Notebooks reviews were received and comments incorporated into course.
9/30/13	100	10/14/13	Quarterly project report Submitted as attachment to email
12/31/13	100	1/6/14	Quarterly project report Submitted as attachment to email
3/31/14	100	3/27/14	Submitted as attachment to email
4/7-8/2014	100	2/4-2/5, 2014	First workshop Held in Poncha Springs – 13 attendees
4/9-10/2014	100	2/18-2/19, 2014	Second workshop Held in Pueblo – 17 attendees
4/15-16/2014	100	3/25-3/26, 2014	Third workshop Held in Greeley – 12 attendees
4/16-17/2014	100	4/2-4/3, 2014	Fourth workshop Held in Denver – 11 attendees
Unplanned - added to original SOW	125	4/16-4-17, 2014	Fifth workshop was added to SOW Held in Craig – 13 attendees
6/30/14	100		Completion of Workshops and end of study – 5 workshops were completed but due to family health issues PI requested an extension to the study on 5/15/2014. An extension until December 31, 2013 was granted.
New – December 31, 2014	100		Final report due – first draft was submitted for review on 6/6/2014
6/30/14	100	7/15/14	Quarterly project report Submitted as attachment to email
9/30/14	100		Final report submitted10/22/14
9/30/14	100	11/10/14	Quarterly project report Submitted as attachment to email
01/2015	100		Final Report accepted by CDOT

12/31, 3/31, 6/30, and 9/30

SIGNIFICANT EVENTS

07/02/12 – $70,000 now available from the 2013 SP&R Work Program
4/5/13 – Inventory report completed – 177 Living Snow Fences along state highways reported.
Workshops held as follows:

2/4 - 2/5, 2014	Poncha Springs, CO	Poncha Springs Conference Room
2/18 - 2/19, 2014	Pueblo, CO	902 Eerie Basement Conference Room
3/25 - 3/26, 2014	Greeley, CO	Platte Room
4/2 - 4/3, 2014	Denver, CO	Mt. Evans Conf Rooms A & B at HQ
4/16 - 4/17, 2014	Craig, CO	Black Mountain Conference Room (Maint Conf Room)

5/15/14 - PI requested an extension to the study on 5/15/2014. An extension until December 31, 2014 was granted.
10/22/14 – Final report submitted

January 2015 Final Report published, Project complete

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

"Optimization of Stabilization of Highway Embankment Slopes Using Driven Piles (Phase II – Development and Verification)"
Study No: 074.91

<table>
<tr>
<td>Background

Slope stability problems are of special importance to CDOT because of the number of mountain highway embankments which are vulnerable to progressive lateral slope failure, causing pavement distress and settlement which can be hazardous to highway users. This is often triggered by increased soil saturation during spring snow melt periods. While maintenance crews can often repave an affected area to mitigate the highway settlement, the original failure often creates a slip surface which sets up subsequent failure of the remolded soil in future years. Driven piles have been used with some success to solve the local slope stability problem, however, geotechnical research and input can improve these efforts both in regards to performance and economy.

This phase of the study follows a preliminary investigation in Phase I, where it was found that the stabilization of laterally failing slopes using driven piles could be effective and economical. To develop these findings, a literature review, surveys of state DOTs, cost comparisons analyses and targeted field inspections were performed.

Using extensions of traditional two-dimensional methods of analysis together with modern finite element computational techniques, this study aims to better understand the effectiveness of driven piles in reinforcing at-risk highway embankment slopes. Additionally, the research will lead to practical guidelines by which lateral piles can be prescribed and implemented at optimal locations. Specifically, the guidelines will address the most economical pile size, spacing and driven depth based on observed site characteristics and geotechnical investigation.</td>
<td>Reporting Period: 03/01/15 - 06/30/15
Type: SP&R Start: Ver:
Contract: (P.O. #)

Principal Investigator(s):
Panos Kiousis, Colorado School of Mines
303-384-2205
D.V. Griffiths, Colorado School of Mines
303-273-3669

Study Manager:
Aziz Khan, Research Branch
303-757-9522

Study Panel Members:
Steve Laudeman, CDOT Materials and Geotechnical Branch
Craig Wieden, CDOT Region-2 Materials
Del French, CDOT Region-3 Maintenance
Russel Cox,
Rex Goodrich, R-3 Material Engineer
John Hart, Coggins and Sons, Denver
Alan Lisowy, H-P Geotech, Denver
Matt Greer, FHWA-Colorado

FHWA Washington Contact:</td>
</tr>
</table>

MODIFIED RESEARCH TASKS

Planned	% done	Achieved	Description, Discussion, and Related Issues
7/1/11	100%	Y	Task 1: Analysis of test site
6/1/11	100%	Y	Task 2a: Spreadsheet-based model
12/31/11	100%	Y	Task 2b: Finite Elements-based model
1/1/13	40%	Y	Task 2c: Develop a plan for parametric study (see Note 5 below)
6/15/13	40%		Task 3: Numerical examination of pile load transfer and effects on stability
6/1/13	0%		Task 4: CANCELED
5/1/13	0%		Task 5: CANCELED
8/1/13	90%		Task 6a: Compare and calibrate results to develop design methodology
8/31/15	80%		Task 6b: Draft and Final Report

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
1/17/11	100%	Y	Unofficial project start
3/22/11	100%	Y	Kick-Off Meeting with CSM
5/1/11	100%	Y	Official project start
5/17/11	100%	Y	Update Meeting w/ Laudeman, Kiousis, Ebersole
7/7/11	100%	Y	Site Visit
2/8/12	100%	Y	Update Meeting w/ Laudeman, Kiousis, Ebersole
6/8/12	100%	N	Redirection of the resources and aim of the project to a parametric computational study.
10/30/15			Final Report

SIGNIFICANT EVENTS

Note 1: The site visit has been completed (July 2011), where visual data was collected to improve modeling accuracy.

Note 2: The spreadsheet-based model uses an extension of Bishop's Method of Slices to account for three-dimensional slope failure with end effects. Some common assumptions are made in this model, including a spherical failure surface and assumptions regarding interslice forces – it will be seen how reasonable these assumptions are in light of the results garnered from the finite elements model and test site implementation. These assumptions aside, the flexibility and options of this model are fairly robust, and results have been verified against two-dimensional problems with satisfactory accuracy. This model is substantially complete, with a possible extension based on Lu & Likos' work to improve vadose zone modeling.

The finite-elements model is essentially complete, using the LS-Dyna software package. While it can be expected that small improvements will be made during the remainder of the project, we are currently able to model any number of slope reinforcement scenarios given enough computational time. Each model run currently approaches 24 hours of computational time.

Note 3: Pile implementation plans will be considered as a part of the update meeting scheduled for February 2012. At this point, it is believed that enough evidence is presented by which an optimized

pile implementation plan can be reasonably developed. This comes from the realization that the best pile instrumentation data will come from a situation where the piles develop plastic hinges, but with small enough total deflection to still remain effectively in place (rather than being entirely swept away). This will reveal the precise point where the ability of the pile to contribute to slope stability is exceeded by the capacity of the soil to be supported by lateral piles. In this manner, both geotechnical modeling of the soil and structural modeling of pile fixation can be verified.

Note 4: Unfortunately, in light of the delay in model development, it was not possible to drive instrumented piles before weather made operations difficult for the winter. An instrumentation and pile location plan will be developed for implementation over the summer of 2012.

Note 5: Based on recent meetings between the CDOT and CSM research teams (6/8/12), it was concluded that the research emphasis needs to be shifted toward a parametric study on optimizing slope stabilization with driven piles. This decision is based on the fact that the originally selected site at Muddy Pass is no longer available to demonstrate the project, and the funding for demonstration on another site has not been secured yet.

Note 6: A new graduate research assistant, Tim Gilchrist, has been selected to replace Ian Ebersole who graduated and chose not to pursue a PhD.

Note 7: Tim Gilchrist has had to make significant modifications to improve on the results achieved by Ian Ebersole. We have requested, and Dr Aziz Khan agreed that a no-cost extension to the project until March of 2014 be granted.

Note 8: To achieve the goals of the new approach to this research, Tim Gilchrist has built multiple models, where the depth of the failed zone varies. The slope is examined for failure unreinforced. It is then reinforced with driven piles. The size and spacing of the piles is examined to determine WHAT configuration can stop the movement. This the main thrust of the new parametric study.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

"Real-time In-situ Monitoring of Infiltration-induced Instability of I-70 Embankment West of the Eisenhower Tunnel"

Study No. 74.92

Background

The objective of this study is to develop a thorough understanding of the factors influencing the stability of the I-70 embankment west of the Eisenhower Tunnel (Mileposts 212.0 to 212.1). In addition, we would like to develop a new methodology for in-situ, near real-time forecasting of the stability of highway embankments. This study is a continuation of a two year joint effort between CSM, USGS, and CDOT. The first phase of this study started in 2010.

As water infiltrates into the soil and rock hillslopes, soil suction and the water table vary dynamically, causing changes in effective stress and , in turn, changes in the stability of the slope. Recent advances in unsaturated hydrology and soil mechanics provide new opportunities to quantitatively measure soil suction and effective stress changes in highway embankments. In-situ measurements of the variations in soil-suction and moisture content in the upper 20 m of the embankment permit directly monitor stress changes, and thus, the occurrence of landslides can be forecast.

These objectives will be accomplished by: a) Continuing monitoring the sensors installed in the field, b) Setting up a numerical model that will analyze the hydrology and stability of the site. The model will be calibrated with data obtained in the previous phase, c) Perform a sensitivity analysis with the calibrated model, and d) setting up the system in the field so it requires minimum maintenance. The technology and knowledge obtained from this study can then be deployed at any similar geomorphologic environment around the country and the world.

Reporting Period: 03/01/15-06/30/15
Type: SP&R Start: 10/14/13 Ver:
PO: 211020012

Completion/End Date: 07/30/2016

CDOT SAP # 27100300

Principal Investigator(s):
Alexandra Wayllace, Colorado School of Mines
303-273-3961

Co-Principal Investigator(s):
Ning Lu, Colorado School of Mines
303-273-3654

Study Manager:
Aziz Khan, Research & Innovation Branch
303-757-9522

Study Panel Members:
Grant Anderson, Resident Engineer
Mark Vessely, Shannon and Wilson, Inc.
Trever Wang, Bridge Design and Management Branch
Russel Cox, R-1 Resident Engineer
David Thomas, Materials and Geotechnical Branch
Tonya Hart, CTL Thomson, Inc
Amanullah Mommandi, DTD-Research

Mathew Greer, FHWA-Colorado

RESEARCH TASKS

Planned	% done	Achieved	Description, Discussion, and Related Issues
07/30/2016	60	In progress	Task 1: Continuation of obtaining data from 3 piezometers
08/30/2014	90		Task 2: Setting up numerical model and calibration
05/30/2015	10		Task 3: Sensitivity analysis
08/30/2015	0	*waiting for permits*	Task 4: Improvement of experimental system in the field
05/30/2016	30		Task 5: Analysis of data and recommendations
07/30/2016	0		Task 6: Draft and final report

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
10/2011	100	Y	Proposal presented
05/2013	100	Y	Kick-Off Meeting with CSM and USGS Landslide Hazard Team
09/2013	100	Y	Notice to Proceed (NTP) to CSM
07/2016	10	Y	Data from sensors obtained and analyzed
08/2014	50	Y	Set up numerical model using previous data
09/2014	100	Y	Research update meeting with CSM
08/2015	90	Y	Set up new numerical model with expanded analysis area
04/2015	100	Y	Research update meeting with CSM to discuss drilling 2 new boreholes on site
06/2015	100	Y	Presented preliminary model results at EMI Conference – Stanford University

Project completion

The project is expected to complete on July 2016.

SIGNIFICANT EVENTS

09/2014 Meeting with CSM: The meeting group agreed on the importance of further understanding the hydrological conditions of the slope failure in two key locations: (1) the area north of I-70 and (2) the area in the middle of the slope. Based on the extreme water table fluctuations observed in the westbound piezometer when compared to the fluctuations in the eastbound and toe piezometers, the members present agreed that we should try to drill at least two more boreholes north of the highway to characterize the hydrogeological conditions that are contributing to such large changes in the water table. Mitigation options were also discussed, including the construction of a drainage trench along the westbound shoulder of I-70 but uncontrolled drainage was a concern because it could cause large settlements in the future. The power point presentation was submitted to CDOT.

04/2015 Meeting with CSM: The CSM research team presented a new soil profile and conceptual model along with a new 2D numerical model with preliminary results. Locations for two new boreholes north of I-70 were proposed to help characterize the entire hydrological system of the site. CDOT and CSM representatives agreed on the importance of obtaining this additional information and the recommended locations. It was agreed to start working towards obtaining necessary permits for access and drilling of the northern slopes. The power point presentation was submitted to CDOT.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Hybrid A-Frame Micro-pile/MSE Wall with Impact Barrier, Comprehensive Design (Phase-II)
Study No: 80.25

Background

Constructing or expanding highways in the mountains of Colorado is a challenging and expensive undertaking. For alignment needs, cuts into soil and rock materials or constructing a wall on marginal slopes are often needed. To repair the edge of the road and improve the safety of the highways, the need to add a passing lane, increase the width of the shoulder or install an impact-resistant barrier to enhance drivers' safety is a common task that CDOT has the responsibility for. With the potential usefulness and versatility of the hybrid A-frame micropile MSE design to support high-impact barriers for constructing roadways on steep terrains demonstrated in the pilot CDOT project No.12HAA 38229, further development of the design by a more complete evaluation of practical scenarios commonly encountered in Colorado and its mountainous regions is thus of serious interest. The use of a hybrid design which combines the benefit of an A-frame micro-pile system and a MSE wall offers an innovative and versatile option to solve the engineering problem. With suitable design guidelines, the required external and internal stabilities of the system under impact can be satisfied even when the slope is of marginal condition. With its potential usefulness substantiated in the Phase I project, it is deemed essential that a more complete study is conducted to ensure that key mechanics aspects and practical site-soil scenarios are better understood for sound engineering and construction. The outcome of this second phase research is expected to provide an enhanced engineering foundation for design guidelines, procedures, standard drawings and construction recommendations for the hybrid wall system.

Objectives of Study

The objective of this research is to achieve a next-level engineering assessment of the design of hybrid A-Frame micro-pile/MSE walls with impact barrier leading to the necessary design and construction procedures for use by CDOT and the key tasks are listed below:

1. Improve and extend computational modeling methodology in the CDOT Phase I project 12HAA 38229 "to validate strength and service limit state assessment of local and global stability of the hybrid system.
2. Evaluate the influence of different backslope's conditions, directional impacts and other loading conditions, wall heights, interfacial material properties on the hybrid wall system.
3. Provide specific results for the soil structure interaction issues in hybrid truncated base walls such as bearing pressure and its distribution along the truncated base for horizontal to vertical back slope of 3:4 and 1:2, reinforcement tension and it distribution with the presence of micro piles, and (iii) rail anchor beam load transfer mechanism to both micro piles and reinforced soil from top to bottom of the wall during rail impact.
4. Examine hybrid A-Frame MSE wall systems to other design loads and develop comprehensive design guide and worksheets for field implementation.

Reporting Period:
4/1/15 -06/30/15
Type: SP&R

Principal Investigator:
Ronald Pak
303-492-8613

Study Manager:
Aziz Khan, Research Branch
303-757-9522

Panel Leader:
Trever Wang, Bridge Design Branch
303-398-6541

Study Panel Members:
Ilyess Ksouri
Russ Cox
Rex Goodrich
Gregory, John
Richard Wenzel
Wieden, Craig

FHWA:
Daniel Alzamora

PROGRESS AND MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
4/1/15	75%		Development of methods for analysis of finite element computer models for limit state and service state assessment of A-frame micro-pile-MSE systems using code LS DYNA. Quasi static and dynamic loads on the A-frame micropile system are considered including bearing pressure and its distribution on the truncated base. Evaluation of the new 'threshold strain' concept for stability problems.
4/1/15	60%		Evaluation of influence of different backslope's conditions
4/1/15	25%		Evaluation of influence of oblique impact on barrier
6/1/15 Added topic	10%		Preliminary consideration of seismic resistance of A-frame micro-pile-MSE systems

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Evaluation of different types of waterproofing membranes (asphaltic and non-asphaltic) as cost effective bridge deck barriers in reducing corrosive chloride effects (AC and non-AC Water Membrane)
Study No. 084.50

Background The use of waterproofing membranes (WPM) has been the most popular method for providing some positive protection against chloride intrusion into our bridge decks. However, major concerns arise regarding the longevity of this system and its effectiveness against chloride intrusions and effectiveness as a corrosion barrier. Some of these major issues include but are not limited to maintaining the membrane thickness required per our current specification, the optimal time when this membrane should be applied after deck placement since our specs are silent regarding this constraint, the effect of construction joints or seems, the damage due to milling the existing overlay, the minimum or optimal thickness of asphalt required to protect the membrane and the freeze thaw damage incurred due to the presence of blisters after some time in service. The product of this research will be to document findings related to the field performance of different types of available membranes. This research will establish clear guideline regarding the reliability, constructability and cost effectiveness of such membranes as means for protecting bridge decks to attain the 75-year life of structure in service.	Reporting Period: 04/1/13 through 06/30/14 Type: SP&R Start: 10/10/13 End: 8/31/16 Principal Investigator(s): TBD Study Manager: Aziz Khan Study Panel Members: Ali Harajli, Bridge Design and Management Branch (Panel Leader) Mike Stanford, Materials and Geotechnical Branch Masoud Ghaeli, R-6 Materials Mike Mohseni, Design and Management Branch Eric Prieve, Materials and Geotechnical Branch Steve Pinero, R-6 Maintenance Skip Outcalt, DTD-Research Mathew Greer, FHWA-Colorado

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
8/15/13	100		Issue PO and notice to proceed: PI provide revised proposal based on using a new bridge being constructed on Arapahoe Road over Cherry Creek.
11/15/13	100	11/15/13	Literature review
11/15/13	100	04/15/15	Selection of testing site and materials
11/15/15	10		Field evaluation of WPMs
2/15/16			Analysis of test results
2/15/16			Performance of WPMs
2/15/16			Draft final report
4/15/16			Publish final report

SIGNIFICANT EVENTS

3/31/15 The construction project (Arapahoe Road over Cherry Creek) is just now beginning to work on the bridge where the test sections will be installed. The planned dates above have been revised to reflect this revised construction schedule.

4/15/15 A meeting was held on the construction site. The contracting issue was resolved. The materials to be used for testing, testing sections, installation procedures, coring method, coring locations, construction sequences were determined.

6/13/15 The installation of the first waterproof membrane testing section. There was a delay in the installation process because of the rainy weather in the summer 2015. Most of the membranes need a dry concrete surface to ensure a solid bond. All installations were completed in June 2015.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Investigation of Optimal Seismic Design of Typical Bridges in Colorado
Study No: 087-00

Background

Significant effort has been expended to develop comprehensive guidelines for the seismic design of bridges after the 1971 San Fernando earthquake near Los Angeles, CA, which led to the development and adoption of ATC-6 as the seismic provision of the AASHTO LRFD Bridge Design Specification. In the current LRFD design specification (called "Current Specification" hereafter), R-factor (also known as "ductility factor") is used to conduct seismic design of bridges, which is a force-based approach whereby elastic forces are reduced by a certain factor to allow for controlled large inelastic deformation and energy dissipation under seismic events. In 2009, the new "AASHTO Guide Specifications for LRFD Seismic Bridge Design" (called "Guide Specification" hereafter) was introduced by incorporating all the previous changes and guidelines for seismic design of bridges, which is based on displacement rather than force. In this approach, a target displacement is designed for to achieve certain performance level. The new "Guide Specification" was approved as an alternative to the seismic provisions in the "Current Specification". As a result, either the new "Guide Specification" or the "Current Specification" can be used in the seismic design of bridges in Colorado with a possible transition to the Guide Specification in the future. In addition to the western and southwest Colorado area with much higher acceleration requirements, some metro areas may also deserve extensive study because of its high population, busy traffic and potential hazardous consequence to the whole transportation in the area if any bridge is damaged or even fails. Therefore, all bridges are equally important in Colorado and the possible cost-effective design improvements in Colorado by considering the new return period as well as possible consequences for switching from designing with the "Current Specifications" to the "Guide Specifications" in the future is needed. Historically, Colorado has put little consideration on the seismic design of bridges due to the less significant seismic issue compared to those seismic-prone states. The goal of this study is to increase the awareness of seismic risk of bridges in Colorado and give CDOT a preview of the possible outcome to identify the best seismic design methodology to follow in future bridge designs.

Reporting Period: 04/01/15 - 06/30/15
Type: SP&R Start: 02/12 Ver:

Completion/End Date: 12/31/2016 (extended)

Principal Investigator:
Suren Chen & Hussam Mahmoud, CSU

Study Manager:
Aziz Khan, Research Branch, 303-757-9522

Panel Leader:
Richard Osmun, Bridge Design and Management (Panel Leader)

Study Panel Members:
Richard Osmun, Bridge Design and Management Branch
Mac Hasan, Bridge Design and Management Branch
H-C. Liu, Materials and Geotechnical Branch
Trever Wang, Bridge Design and Management Branch
Steve Yip, Bridge Design and Management Branch

Derrell Manceaux, FHWA-Colorado

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
2/21/2012	100	2-21-12	Kick-off Meeting
7/01/2012	100	7-30-2012	Finalized the survey questions and send out the survey invitations on 3-20-12. Await the response and analyze. Preparing literature review report
7/01/2012	100	7-01-2012	Two representative bridges selected. Bridges were modified to be skew and curved. The feedback of the bridge modification has been gathered.
2/01/2013	100	2-15-2013	9 SAP bridge models have been developed in SAP. The simulation has been finished. Some post-processing work is remaining.
09/01/2013	100	11-1-2013	The load capacity analysis was completed. Detailing analyses were finished. It was slightly delayed from the originally planned date.
04/01/2014	100	02-10-2014	The draft of illustrative examples has been finished. Currently checking the results and editing the writing.
01/20/2014	-	-	The non-cost extension[1] of the project has been approved.
05/15/2014	100	03-26-2014	The draft final report was submitted on 3/26/2014. The final report will be submitted by 06/31/2014. The report draft is currently under review.
10/15/2015	80%		Draft Final Report

1. By adding SDC B to the illustrative example, the study team discussed with CDOT study panel and agreed that a 6-month extension is needed to have enough time to finish all the tasks.

SIGNIFICANT EVENTS

1/24/12	Project officially begins. Project completion/end date is 01/31/2012. CSU would request an extension beyond the completion date (if needed) with brief justification at least six months ahead of the end date.
2/21/12	Kickoff meeting at CDOT.
3/20/12	Send out the national survey questions.
5/18/12	The summary of the survey was submitted to CDOT.
7/31/12	Literature review report submitted to CDOT.
01/30/13	The SAP-based bridge models have been developed and the simulations conducted. The post-processing is close to finish. The SAP models are ready to be submitted to CDOT upon request, if needed.
11/1/13	The investigation of design detailing was finished.
03/26/14	The final report draft was submitted to CDOT to review.
06/1/15	Final Report is updated by CSU

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Tension Cable Guard Rail
Study No: 091.06

Background

Tensioned cable guardrail (TCGR) systems have been used all over the world for several years. In windy areas, guardrails can act like a snow fence causing drifts across the highway. Cable guardrail systems could be very useful in Colorado in areas with snow-drifting problems. Cable guardrail is bi-directional making it a useful option in narrow medians in addition to shoulder applications. It provides a relatively "soft" barrier that, in most situations, is somewhat more gentle on vehicle occupants than steel rail or concrete barriers. In addition, after an accident, maintenance is simple, fast and inexpensive, and the system retains its functionality even before repairs are made. Cable guardrail is also visually less obtrusive than other designs.

This study will monitor the performance of tensioned cable guardrail systems installed in Colorado. Important factors include: Severity of injuries and damage to vehicles; cost for repairs including time and materials; availability of materials and product support; ease of repair and maintenance.

Accident, maintenance and repair data will be evaluated to establish criteria to help in selection of the best system and best configuration for a particular situation.

Implementation

Accident data together with maintenance and repair data will provide insight into the suitability of tensioned cable guardrail used under varying conditions. The data will also provide information regarding situations where cable guardrail is not the best alternative and the reasons why. Recommendations will be made for use of various criteria in selecting the appropriate system.

Reporting Period: 4/01/15 through 6/30/15
Type: Experimental Feature

Principal Investigator:
Skip Outcalt, CDOT Research, 303.757.9984

Study Manager:
Skip Outcalt CDOT Research 303.757.9984

Study Panel Members:
Tony DeVito R1 303.716.9925
Larry Haas, R4 Traf. 970.350.2143
Darrell Dinges, Stds & Design 303.757.9083
Al Roys, Sec 1 Maint 303.910.8574

FHWA Contact:

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
06/02		09/02	Monitor and document the installation of Brifen guardrail on US 285 at MP 141 – Windy Point.
04/03		04/03	A study panel meeting will be held to discuss the work plan for the study, what information will be kept in the databases, and to establish the length of the study and the number of sites that will be accepted for evaluation under this study.
08/03		08/03	Monitor construction of the site on I-25 near MP 250
12/03	90		Evaluate the systems based on repair costs and time needed to repair hits and the effectiveness of the system in reducing the severity of accidents.
05/04		06/04	Write and distribute interim report with recommendations for suitable situations and specific items that should be addressed on each project
12/04		05/05	Construction of median WRSF systems has begun on I-25 mp 229 – 269. CASS is being installed along the frontage road at mp 252. Very little accident data has been received in Research for inclusion in the accident database.
04/05		04/05	Study panel meeting to evaluate the progress of the study and discuss accident reports.
10/05		12/05	Installation of Trinity CASS systems in the median on I-25 ≈mp 174 – 181 and SH-86 near Castle Rock.
07/07		07/07	Install approximately 1 mile of each of the 5 certified manufacturers' systems in the median of C-470 from mp 14 to 19
12/13	90		Evaluate accident and MMS system data. Write and distribute the final report.

SIGNIFICANT EVENTS

6/15 – Tensioned cable barrier has been accepted for use, particularly in median locations on divided highways. A report has been written and will be published on the Research web site. New site information will be added to the data base as it becomes available.

6/14 – No activity.

12/13 – No activity.

9/13 – Tensioned cable barrier has been accepted for use, particularly in median locations on divided highways. The databases will continue to be updated as data becomes available.

9/12: A short report is being written. The Cable Barrier database will continue to be updated as information is received. Crash data will be added annually.

6/12: Median crash data from January 1, 2000 through December 31, 2010 has been entered into the database for 31 project locations. 22 of the locations have some post construction crash data. In the database, a separate sheet for each location calculates the number of crashes per million vehicle miles traveled at that location. It shows severity of crash, type of crash, and the percent change for a given type of crash from before installation of the cable rail to after.

3/12: New TCB sites are being added to the database and will be monitored for performance.

1/12: Data collection and analysis in progress

6/1/11: Crash data through 12/31/2009 has been added to the Tensioned Cable Barriers (TCB) Crashes spreadsheet database. Crash data for 27 projects is in the database and is in the process of being verified. The database analyzes Traffic Accident Reports (TARs) of crashes that were or could have been affected by the presence of TCB. It includes all median and off-left types of crashes in locations where median TCB is installed. On roadway and off-right types of crashes are not included since the presence of median TCB would have no effect on the cost or the outcome of that type of crash. Crash data for sites with right shoulder TCB are also listed, but it is much more difficult to determine the effects of the barrier for these locations because of the way the data is listed in the TARs.

1/1/11: Crash data through 2008 is available for most TCB locations. Post-construction crashes can now be compared to pre-construction crashes so the TCB can be evaluated for cost and crash prevention effectiveness.

12/09: Crash Data and maintenance costs are being summarized and analyzed for the final report.

6/09: A spec has been drafted for TL-3 and TL-4 Tensioned Cable Barriers.

12/08: A database with site locations, construction specifications and costs, and traffic data is completed for projects completed through summer of 2008.

09/08: Data from the C-470 project which includes all five of the NCHRP 350 approved TCGR systems is being included in the study.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Phase II Study on Safety Performance at the Colorado DOT

Study No: 093-01

Background

In numerous studies sponsored by contractor associations, the Construction Industry Institute (CII), and the Construction Users Roundtable, the consistent outcome has been the need to address safety at all levels of the organization. In the Phase I study of safety practices at the Colorado Department of Transportation (CDOT), the study identified the gap between expected safety practices and the actual implementation of safety policies in the field offices. This finding, along with the industry-wide documentation of the necessity for a strong and mature safety culture, provided the motivation for CDOT to undertake initial efforts toward enhancing organization safety perspectives. The purpose of the current research is to continue the CDOT effort to build upon recent safety successes and by investigating opportunities improve worker safety. The primary intervention strategy to be considered is the strengthening of CDOT's safety culture.

The current research effort will examine how to put in place specific project, policy, and organization actions that will lead to the improvement of the CDOT safety record based on a combination of: 1) understanding existing CDOT safety elements and improvement efforts from an organization perspective, 2) understanding comparable organizations, 3) determining insertion points for safety improvement, and 4) providing specific recommendations for building on existing CDOT efforts to enhance the CDOT safety culture.

The research effort encompasses the following phases:

- Assess and articulate a comprehensive understanding of the existing safety culture within CDOT
- Use case studies to: (1) identify shared characteristics of safety culture within high performing organizations in comparable, high risk industries; (2) document best practices for rapid advancement, measurement, and continuous improvement of safety culture; and (3) identify target areas for CDOT improvement.
- Conduct a focus group session with a minimum of 10 members of leading firms in the construction, manufacturing, and industrial industries to review CDOT's safety program
- Develop recommendatioons to build on current CDOT safety efforts

Reporting Period: 4/1/15 through 7/31/15
Type: SP&R Start: 03/06/12
PO: 411004738 Expires: 3/2/2017

Principal Investigator(s):
Paul Chinowsky and Matthew Hallowelll;
University of Colorado Denver, 303-735-1063

Study Manager:
David Reeves, Applied Research Branch (HQ)
303-757-9518

Study Panel Members:
Darrel Lingk / OTS Director (HQ)
Steven Gasowski / OTS Safety Officer (HQ)

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
3/1/12	100	3/6/12	CU Contract Complete
5/18/12	100	12/1/12	Project kickoff meetings
4/30/12	100	9/1/12	Literature Review
5/31/12	100	10/1/2012	Survey and Interview Development
1/31/13	100	1/31/13	Test of Survey
6/30/15	100	6/30/15	Development of Updated Survey
8/31/15	0		Test of Field Survey
9/15/15	0		Place any modifications to survey in place
9/30/15	0		Full Survey deployment
10/31/15	0		Survey data completion
12/31/15	0		Recommendation Development
3/31/16	0		Draft Report
6/30/16	0		CDOT Review
9/30/16	0		Final Report Submission

SIGNIFICANT EVENTS

- 6/30/15 – Completion of survey for deployment
- 7/15/15 – CDOT identifies test group

ANTICIPATED EVENTS FOR NEXT QUARTER

- Deployment of survey to test group
- Analysis of test data
- Deployment of full survey

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Development of New Corrosion/Abrasion Guidelines for Selection of Culvert Pipe Materials
Study No: 106.01

Background

The existing CDOT corrosion guidelines for pipe material type selection do not specify the service life for any pipes used for drainage. A 50-year service life is assumed for any pipe that satisfies the corrosion level criteria in the existing guidelines. New design and retrofit procedures are needed to incorporate corrosion and abrasion factors to select the proper type of pipes for specific drainage applications with realistic estimates of the service life. Soil and water resistivity and/or abrasion factors will be investigated in addition to pH, chloride, and sulfate level concentrations in areas where drainage pipes failed due to corrosion and/or abrasion. Some of these locations where pipe failures occurred had been or are still being identified in a comprehensive culvert pipe inspection effort conducted by the Bridge Branch across the State of Colorado.

The current guidelines (Corrosion Resistance, CR Table) developed in 1983 use pH, chloride, and sulfate concentrations to determine the corrosion resistance levels that any pipe material should be capable of handling. Since the development of the CR table, various pipe sizes with different types of materials (CMP, RCP, HDPE, etc.) were installed under CDOT roadways using the CR table criteria. However, no concerted effort was made to evaluate these culvert pipes to assess their performance. It was assumed that any pipe material that satisfied the requirements of the CR table would have a service life of 50 years or more. This may be true for pipe materials that are inherently resistant to corrosion/abrasion by virtue of their physical, chemical and biochemical properties. However, this may not be true for other pipes that may fail due to corrosion/abrasion if not properly treated, protected, or coated. New guidelines with information on reliable estimate of service life for each type of pipe material should be developed.

Neighboring states have general guidelines incorporating pH, chloride, sulfate, total dissolved solids, resistivity, water velocity, and slope to assess the impact of corrosion and abrasion on various types of pipes. Some of these factors are associated with estimated service life of the pipe structures. However, this information is site specific and may not be totally applicable to Colorado's unique site conditions. This information from other states will help in the development of Colorado's procedure to determine reasonable service life using various parameters including resistivity and/or abrasion.

The new procedure for selecting pipe material depending on the results of the investigation may include resistivity level and/or abrasion factors in addition to pH, chloride and sulfate concentrations in soil and water. The flexible pipe industry is requesting CDOT to include resistivity and abrasion in developing new pipe materials selection guidelines.

The collected data including the findings and recommendations resulting from the inspection effort conducted by the Staff Bridge Branch across the State of Colorado will be used accordingly in the development of the new guidelines for culvert pipe materials selection procedure.

Reporting Period: 3/01/15 through 6/30/15
Complete: TBD

Principal Investigator(s):
CSU/Dr. ChristopherThornton, 970-491-8394
Dr. Albert Molinas, Mobile: 970-222-2393

Study Manager:
Aziz Khan, CDOT Research 303-757-9975

Panel Leader:
Amanullah Mommandi, CDOT Staff Hydraulics 303-757-9044

Study Panel Members:
Lynn Croswell, CDOT Staff Bridge 303-757-9188
Mike Banovich, CDOT Environmental 303-757-9542
Al Gross, CDOT Staff Hydraulics 303-757-9342
Mohan Sagar, CDOT Specifications 303-757-9649

FHWA Washington Contact:
Matt Greer, FHWA 720-963-3008

MILESTONES

Planned	% Done	Achieved	Description, Discussion, and Related Issues
	100		Develop scope of work and RFP
	100		Complete the RFP process. The RFP will be issued on 10/22/04.
	100		Select the Principal Investigator: Chris Thornton, CSU
	100		Award the contract.
2/27/09	100	2/27/09	Send Notice to Proceed
3/18/09	100	3/18/09	Attend CDOT's First Culvert Committee Meeting of 2009 to meet panel members
12/31/09	100	12/31/09	Task 1- Literature review
12/31/09	100	12/31/09	Task 2- Applicability of CDOT's CR table
12/31/09	97	12/31/09	Task 3 – Field Testing (97 sites out of 100 tested)
12/31/09	97	12/31/09	Task 4 – Data Analysis (97 sites out of 100 analyzed)
12/31/09	97	12/31/09	Task 5 – Develop service life procedure
04/01/10		04/01/10	Start Phase 2 B – Data collection from Western Colorado
12/31/10	50	06/19/10	Collected data along HW 160 and connecting highways at 34 sites. Data included approximately 10 sites from the critical culvert list.
12/31/10	70	07/16/10	Collected data along I-70 and connecting highways at 30 sites. Data included sites from the critical culvert list.
12/31/10	75	09/17/10	Collected data along HW 40 and 14 and connecting highways at 11 sites. Data included sites from the critical culvert list.
12/31/10	100	10/1/10	Collected data along HW 50 and connecting highways at 29 sites. Data included sites from the critical culvert list.
2/27/12	100	2/27/12	Laboratory analysis of soil samples collected along HW 50 and connecting highways.
9/30/12	100	2/27/12	Results of soil testing have been tabulated for final analysis.
2/27/12	100	3/5/13	Completing additional testing on missing laboratory data.
9/30/12	100	6/30/13	Re-tabulation of soi testing results for final analysis
9/30/13	100	9/30/13	Additional literature review completed.
10/31/15			Draft Final Report
12/31/15			Final Report

SIGNIFICANT EVENTS

3/18/09	PI attended CDOT's First Culvert Committee Meeting of 2009 to meet majority of panel members and outline preliminary project goals.
5/5/09	PI met with Research Panel Leader to select initial culvert test sites. The PI scheduled to do field testing starting 6/01/09.
6/03/09	Culvert testing along HW 34 between Loveland and EstesPark
6/05/09	PI met with Research Panel Leader to select additional culvert test sites.
6/09/09	Culvert Testing along I 70 between MP280 and MP370 with CDOT participation
6/15/09	Culvert testing along I-70 between MP370 and MP 425 and along HW40
6/19/09	Culvert testing along I-76 with CDOT participation
6/24/09	Meeting with CSU Soils Testing laboratory to analyze the water and soil samples from the first batch of 40 sites.
7/28/09	Met with Research Panel to update them on the status of the project and to get their approval on the sites that will be included in the study. Phase 2A will include the Eastern half of Colorado.
12/31/09	Completed Phase 2A
04/01/10	Started Phase 2B of the study to compile data from the Western Colorado
06/19/10	Conducted a 4-day trip along State Highway 160 covering the area between I-25 and Cortez, Colorado. Collected water and soils data and soil resistivity data from 34 sites along HW 160 and connecting highways.
07/16/10	Conducted a 3-day trip along Interstate State Highway 70 from Denver to Utah border. Included sites along HW 13, HW 131 and HW 139. Collected water and soils data and soil resistivity data from 30 sites along I-70 and connecting highways.
09/17/10	Conducted a 3-day trip along HW 40 from Walden to Craig. Included sites along HW 13, HW14, and HW 131. Collected water and soils data and soil resistivity data from 15 sites along HW 40 and connecting highways.

10/1/10	Conducted a 3-day trip along I-70 and HW 50 and collected data from Grand Junction to Gunnison. Inspectedculvert sites along HW 6, HW 340, and HW 141. Collected water and soils data and soil resistivity data from 29 sites along HW 50 and connecting highways.
9/30/12	Results of soil testing have been tabulated for final analysis.
3/5/12	Completing additional testing on missing laboratory data.
6/30/12	Re-tabulation of soil testing results for final analysis.
9/30/13	Additional literature review for new research on the topic completed.
5/31/14	Hydrologic analysis for the 560 rain gage stations across Colorado was conducted to identify a new parameter for relating the service life to Flow-Days at different regions in Colorado.
12/31/14	Data Tabulation and analysis
06/30/15	Final report drafting initiated

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Evaluation and Performance of HDPE Pipes under CDOT Highways, T-Rex and Other Locations
Study No: 106.02

Background

It is assumed that HDPE pipes used in CDOT drainage systems will have a 50-year design life. Some HDPE pipes used on CDOT projects failed due to shallow cover, moving and static loads (construction equipment) and disturbances in or near the pipe trenches. In addition to existing corrosion and abrasion guidelines, CDOT must develop guidelines to determine how and where HDPE pipes may be safely installed.

For corrugated HDPE pipes, the failure mechanisms are ductile failure due to high stresses, brittle cracking due to intermediate stress levels, and corrosion cracking caused by low stress levels. The performance of buried HDPE pipes is influenced by earth loads, vehicle (live) loads, backfill materials, trench dimensions, backfilling compaction, and in situ soils. A research panel will investigate sites where HDPE pipes were used in Colorado and evaluate the performance of the pipes with regard to site conditions. Since CDOT has a limited number of such sites, the panel may also conduct a literature search to determine if other Cities and Counties within Colorado and other State DOTs have evaluated the performance of HDPE pipes in climate zones, terrain and construction zone conditions similar to those found in Colorado.

In accordance with SAFETEA-LU, the CDOT Pipe Selection Policy requires consideration of HDPE pipes for cross-drains, side-drains and subsurface drains. Currently, any pipe that meets the corrosion and abrasion criteria in this policy and is installed per the plans and specifications is assumed to have a 50-year service life. There is uncertainty regarding the cost effectiveness of using HDPE pipes because of CDOT's experience with failed HDPE pipes. During the T-Rex project in 2003, a number of HDPE pipes were installed with shallow cover. The pipes were later removed and replaced after they were damaged by construction equipment running over installed pipes and excavations occurring near installed pipes. HDPE pipes have been used successfully in some States, but in Colorado designers must consider extremes in climate and terrain in addition to construction practices. There is insufficient information regarding performance of HDPE pipes locally. In particular, there is a lack of information that correlates construction practices, depth of cover, trench configuration and cracking of HDPE pipes.

The objective of the study is to evaluate the performance of the HDPE pipes for use under the roadways and other facilities. The research aims to improve design methods, materials specifications and construction techniques. These improvements could lead to cost savings by preventing HDPE pipe failures and encouraging innovation and competition in construction. The research will be helpful in updating the CDOT Drainage Design Manual to include recommended methods for choosing, installing and maintaining thermoplastic pipe materials.

Reporting Period:3/1/2015-6/30/2015
Start: 10/5/12
Complete: TBD

Principal Investigator(s):
CSU/Dr. ChristopherThornton, 970-491-8394
Dr. Albert Molinas, Mobile: 970-222-2393

Study Manager:
Aziz Khan, CDOT Research 303-757-9975

Panel Leader:
Amanullah Mommandi, CDOT Staff Hydraulics 303-757-9044

Study Panel Members:
Lynn Croswell, CDOT Staff Bridge 303-757-9188
Mike Banovich, CDOT Environmental 303-757-9542
Al Gross, CDOT Staff Hydraulics 303-757-9342
Scott Leiker, CDOT R-6 Hydraulics 719-2485493

Ken MacKenzie, UDFCD Manager, Mater Planning Program 303-455-6277

Saeed Farahmandi, City and County of Denver

FHWA Washington Contact:
Matt Greer, FHWA 720-963-3008

MILESTONES

Planned	% Done	Achieved	Description, Discussion, and Related Issues
	100		Develop scope of work and RFP
	100		Complete the RFP process. The RFP will be issued on 10/22/04.
	100		Select the Principal Investigator: Chris Thornton, CSU
	100		Award the contract.
7/5/12	100	7/5/12	Send Notice to Proceed
1/18/13			Attend CDOT's Research Panel Meeting of 2013 to meet panel members and discuss goals
5/16/13	5	5/16/13	Meet with CDOT Research Study Manager and Panel Leader to finalize research panel and to refine objectives.
6/4/13	100	6/4/13	Kickoff meeting with Research Panel to discuss research goals, identify resources within CDOT and other agencies, define tasks.
6/30/13	20	6/30/13	Obtain pricing information for laser profiling and measurement, meet with equipment supplier for refining the project equipment needs, initiate a literature review.
9/30/13	100	7/30/13	Completed inventory of CDOT pipe inspection equipment and obtained a complete list of additional equipment needed for a laser-ring setup. Visited R3 installation and inspected the components.
9/30/13	100	9/30/13	Completed the literature review for HDPE pipes
5/31/14	30	5/31/14	Identified methodology to analyze data
4/30/16			Draft Final Report
6/30/16			Final Report

SIGNIFICANT EVENTS

7/12/12 Work on literature review pertaining HDPE pipes commenced.

1/18/13 PI will attend CDOT's Research Panel Meeting of 2013 to meet majority of panel members and outline preliminary project goals.

6/4/13 Kickoff meeting with Research Panel to discuss research goals, identify resources within CDOT and other agencies, define tasks.

9/30/13 Completed literature review related to HDPE pipes and their performance evaluation

9/30/13 Completed inventory of CDOT pipe inspection equipment and obtained a complete list of additional equipment needed for a laser ring setup. Visited an HDPE installation project in Region 3 in Grand Junction and inspected the components of CCTV setup available at Region 3.

5/31/14 Revised project goals to include HDPE pipe inspection methodology available to CDOT in Colorado.

3/31/15 Project Extended to 6/30/2016.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Developing Design Procedure for Debris Culverts
Study No: 106.3

Background

The Colorado Department of Transportation builds and maintains many roadway projects along debris-flow producing watersheds and canyons. Most of these projects need to maintain continuity of traffic in the case of debris flows during flood events. Following forest fires, watersheds that lose their vegetative cover are very susceptible to producing debris flows. Such debris-flow events are commonly encountered after every major forest fire (e.g. Buffalo Creek, Hayman fires). After debris flow events, CDOT has to spend large sums of money and effort to clean the drainage structures or rebuild them. In light of the continued drought and the beetle killed pines in Colorado forests, the potential for debris flows is a serious concern to CDOT. Many existing design guidelines are not applicable to determining the design capacity of debris culverts since the amount of discharge and type of flow are not adequately accounted for. The majority of culverts are designed for clear water flows and do not provide additional capacity needed for debris flows.

CDOT's Drainage Design Manual lacks a methodology to design culverts to pass debris flows. At the present time, by deductive reasoning, experienced engineers use a "bulking factor" to increase the design discharge to account for the presence of 30% to 60% sediment in suspension for the debris flows. The value of the bulking factor is chosen from experience.

In addition to increasing the discharge passing through the system, the high sediment concentrations greatly increase the viscosity of the fluid. The resulting debris flow moves at a slower velocity but at a greater depth than a "bulked-flow." As a result, the commonly used method of "bulking the flows" is not adequate to size debris culverts.

The current knowledge on this topic has matured enough to be implemented into CDOT's DDM and the proposed study is needed urgently for CDOT. The objectives of the study are:

1. New design procedure for debris culverts will be developed.
2. The procedure will be based on rigorous treatment of debris flows.
3. Design nomographs will summarize results of debris flow computations through culverts so that the design engineer will not be facing complex numerical modeling tasks.
4. New design procedures will guide the user to select proper sizes of culvert pipes.

In order to accomplish these objectives, enhancements to the current design guidelines are needed. These enhancements can be grouped under 2 major categories:

- Introduction of new parameters to pipe size selection guidelines to accommodate debris flows.
- Development of criteria by debris-basin material types and ranges of basin slopes.

Reporting Period:3/1/2015-6/30/2015
Start: 10/5/12 Complete: TBD

Principal Investigator(s):
CSU/Dr. ChristopherThornton, 970-491-8394
Dr. Albert Molinas, Mobile: 970-222-2393

Study Manager:
Aziz Khan, CDOT Research 303-757-9975

Panel Leader:
Amanullah Mommandi, CDOT Staff Hydraulics 303-757-9044

Study Panel Members:
Lynn Croswell, CDOT Staff Bridge 303-757-9188
Mike Banovich, CDOT Environmental 303-757-9542
Al Gross, CDOT Staff Hydraulics 303-757-9342
Dennis Cress, CDOT R-2 Hydraulics 719-2485493

FHWA Washington Contact:
Matt Greer, FHWA 720-963-3008

MILESTONES

Planned	% Done	Achieved	Description, Discussion, and Related Issues
	100		Develop scope of work and RFP
	100		Complete the RFP process. The RFP will be issued on 10/22/04.
	100		Select the Principal Investigator: Chris Thornton, CSU
	100		Award the contract.
10/5/12	100	10/5/12	Send Notice to Proceed
1/18/13			Attend CDOT's Research Panel Meeting of 2013 to meet panel members and discuss goals
5/16/13	5	5/16/13	Meet with CDOT Research Study Manager and Panel Leader to finalize research panel and to refine objectives.
6/4/13	100	6/4/13	Kickoff meeting with Research Panel to discuss research goals, identify resources within CDOT and FHWA, define tasks.
9/30/13	20	6/30/13	Conduct literature review for recent studies on debris flows including laboratory, field, and numerical modeling.
9/30/2013	100	9/30/2013	Completed the Literature review
12/31/2013	60	9/30/2013	Development of case studies for debris accumulation at culverts
3/31/2013	20	9/30/2013	Development of numerical tools for debris flow modeling
5/31/14	30	5/31/2014	Compiled the literature review and revised the goals of the project to include debris countermeasures
10/30/15			Draft Final Report
12/31/15			Final Report

SIGNIFICANT EVENTS

12/1/12 Work on numerical modeling of debris flows commenced by transporting PI's existing programs into Windows 7 environment. These programs will be used to develop nomographs.

1/18/13 PI will attend CDOT's Research Panel Meeting of 2013 to meet majority of panel members and outline preliminary project goals.

6/4/13 Kickoff meeting at CDOT with Research Panel to discuss research goals, identify resources within CDOT and FHWA, define tasks.

8/30/13 Collected water and debris flow samples from floods along Highway 14 (Poudre Canyon), Highway 36 (Boulder).

9/30/13 Collected documentation for the numerous debris-producing runoff events that occurred during the September 2013 floods in Boulder-Greeley-Johnstown-Milliken-Fort Collins areas

5/31/14 Compiled the literature review, collected case studies from September 2013 flood events around the Denver-Boulder-Lyons-Estes Park area, and revised the goals of the project to include effective debris flow countermeasures.

8/1/15 A new PO planned to be issued to complete the work

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Developing Bridge Scour Equations for Colorado Mountain Streams

Study No: 106.04

Background

The Colorado Department of Transportation builds and maintains many roadway projects that cross rivers and small streams by bridges. The safe and economic design of these bridges requires hydraulic computation of potential pier and abutment scour. For existing structures, potential pier and abutment scour computations are needed for the safety assessment of these structures. The Colorado Department of Transportation (CDOT) presently uses FHWA's HEC-18 methods to estimate bridge pier and abutment scour values in bridge scour computations. In applying the FHWA methods, first a hydraulic computation method (FHWA's WSPRO or US Army Corps of Engineers' HEC-RAS) is used to compute velocities, depths, and energy slopes for the bridge site. Next, applying these computed hydraulic parameters to pier and abutment scour equations given in the FHWA's HEC-18 design manual, scour values are computed for the bridge under consideration. Depending on the strength of flows and the regime of sediment movement, clear-water and moveable-bed scour equations are used for different bed material properties.

HEC-18 equations were developed using hydraulic conditions for channels with flat channels. The laboratory and field data used in developing the FHWA equations were based largely on stream with subcritical conditions with flatter gradients. These conditions may be applicable to a large portion of streams in the Eastern and Southern parts of the United States. However, in Midwestern states where many bridges cross steep mountain channels, bridge scour equations are applied beyond the range of conditions for which they were derived. For hydraulic conditions that are encountered in steep mountain streams, traditional equations overestimate bridge scour. For these cases, hydraulic engineers need customized equations suited for Colorado's geographic conditions. In the proposed approach, bridge scour for steep mountains will be related to excess velocity rather than the presently used Froude number or shear stress in HEC-18 equations.

CDOT identifies the primary objective of the study to provide a technical tool to compute bridge scour in steep mountain channels. The pier and abutment scour equations developed from the study is required to be applicable to the range of slopes, velocities, and depths encountered in bridges crossing steeper Colorado streams.

In order to accomplish these objectives, enhancements to the current bridge scour equations are needed. These enhancements can be grouped under 3 major categories:

1. Introduction of new parameters into scour equations to represent steep mountain hydraulics (shallower depths, high velocities, coarser bed material in the form of gravels, cobbles, and boulders).
2. Calibration of the new relationships with Colorado specific data. This data is currently being collected during the Plan of Action for Scour Critical Bridges project.
3. Development of pier and abutment equations for mountain streams.

Reporting Period: 3/1/2015-6/30/2015
Start: 10/5/12 Complete: TBD

Principal Investigator(s):
CSU/Dr. ChristopherThornton, 970-491-8394
Dr. Albert Molinas, Mobile: 970-222-2393

Study Manager:
Aziz Khan, CDOT Research 303-757-9975

Panel Leader:
Amanullah Mommandi, CDOT Staff Hydraulics 303-757-9044

Study Panel Members:

Lynn Croswell, CDOT Staff Bridge 303-757-9188
Mike Banovich, CDOT Environmental 303-757-9542
Al Gross, CDOT R-1 Hydraulics 303-757-9342
Stuart Gardner, CDOT R-3 Hydraulics 970-683-6354
Phan Long, CDOT R-4 Hydraulics 970-350-2205
Walter Buckholtz, CDOT R-5 Hydraulics 970-385-1445
Dave Wieder, CDOT-Maintenance 303-357-8973

FHWA Washington Contact:
Matt Greer, FHWA 720-963-3008

MILESTONES

Planned	% Done	Achieved	Description, Discussion, and Related Issues
	100		Develop scope of work and RFP
	100		Complete the RFP process. The RFP will be issued on 10/22/04.
	100		Select the Principal Investigator: Chris Thornton, CSU
	100		Award the contract.
10/5/12	100	10/5/12	Send Notice to Proceed
1/18/13			Attend CDOT's Research Panel Meeting of 2013 to meet panel members and discuss goals
5/16/13	5	5/16/13	Meet with CDOT Research Study Manager and Panel Leader to finalize research panel and to refine objectives.
6/4/13	100	6/4/13	Kickoff meeting with Research Panel to discuss research goals, identify resources within CDOT and FHWA, define tasks.
9/30/13	20	6/30/13	Start literature review for recent studies on bridge scour including laboratory, field, and numerical modeling.
9/30/13	100	9/30/13	Completed literature review
12/30/13	100	9/30/13	Completed data collection from 20 sites.
3/31/13	40	9/30/13	Development of bridge scour equations using excess velocity approach
5/31/14	60	5/31/14	Completed sediment size analysis using photographic gradation analysis, coarse particle size analysis, and sieve analysis. Started tabulating hydraulic and hydrologic parameters of stream segments for developing bridge scour equations.
4/30/16			Draft Final Report
6/30/16			Final Report

SIGNIFICANT EVENTS

12/1/12 Work on numerical modeling of debris flows commenced by transporting PI's existing programs into Windows 7 environment. These programs will be used to develop nomographs.

1/18/13 PI will attend CDOT's Research Panel Meeting of 2013 to meet majority of panel members and outline preliminary project goals.

6/4/13 Kickoff meeting at CDOT with Research Panel to discuss research goals, identify resources within CDOT and FHWA, define tasks.

8/30/13 Completed literature review

9/30/13 Completed data collection from steep Colorado streams from 25 different sites in CDOT Regions 1, 3, 4, and 5.

5/31/14 Completed sediment size analysis using photographic gradation analysis, coarse particle size analysis, and sieve analysis. Started tabulating hydraulic and hydrologic parameters pertaining to stream segments for developing bridge scour equations.

3/31/15 Project Extended to 6/30/2016.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Alternative Outlet Structure for Water Quality Detention Basins to Reduce Clogging (Alternative Water Quality Outlet Structure)

Study No: 106.20

Background Extended detention and full-spectrum detention basins improve the quality of stormwater runoff through settling of sediment. This is achieved by detaining and slowly releasing the stormwater over a prescribed time duration of generally 40-72 hours. An alternative outlet that is less susceptible to clogging and therefore requires less frequent maintenance would be of great benefit to CDOT and others. The primary objective is to study a new type of outlet metering device which is referred to as an elliptical slot weir, its name derived from the elliptical curvature of the weir. Ken MacKenzie with the Denver Metropolitan Area Urban Drainage and Flood Control District will be undertaking a research study in partnership with Colorado State University to investigate an elliptical slot weir for metering water from settling ponds.	Reporting Period: 04/01/2015 through 06/30/2015 Start: 09/21/12 Contract Amount: $70,000 Principal Investigator: Ken A. MacKenzie, P.E., CFM Master Planning Program Manager Urban Drainage and Flood Control District Study Manager: Bryan Roeder, CDOT ARIB, 303-512-4420 Study Panel Leader: Mommandi, Amanullah, CDOT PDB Hydraulics Program Manager Study Panel Members: Kenneth Quintana, CDOT R2 Maintenance Al Roys, CDOT R4 Maintenance Aziz Khan, CDOT ARIB FHWA Washington Contact:

MILESTONES

(Highlighted Milestones represent work undertaken during this reporting term)

Planned	% done	Achieved	Description, Discussion, and Related Issues
7/13/2012	100	7/18/2012	Establish Study Panel: Panel meeting scheduled for 7/30/12.
7/20/2012	100	8/8/2012	Finalize scope of work that will be attached to the IGA. Purchase requisition submitted.
8/19/2012	100	9/19/2012	Execute an intergovernmental agreement (IGA) with the Urban Drainage and Flood Control District.
10/1/2012	100	9/21/2012	Begin Study. Notice to proceed issued 9/21/12
12/15/2012	100	3/31/2013	Physical modeling at the CSU hydraulics laboratory (reference UDFCD agreement 11-12.01). A 1/3 scale model will be constructed to determine the hydraulic characteristics of the elliptical slot weir.
1/15/2013	100	3/31/2013	Debris modeling at the CSU hydraulics laboratory. The weir will be tested

			for debris handling efficiency and maintainability.
2/15/2013	100	8/15/2011	Computational Fluid Dynamics (CFD) modeling by ARCADIS using the FLO-3D mathematical model (reference UDFCD agreement 11-04.04). ARCADIS will perform CFD modeling on the same configurations physically modeled at CSU. This will serve to calibrate and verify the validity of the CFD model.
3/30/2013	0	N/A	CFD modeling of two additional weir heights for the three curvatures and three slot widths described above.
4/30/2013	50		Derivation of a practical sizing method (e.g., equation or functional relationship for this weir given input parameters that include storage volume, drain time, storage depth, and storage bottom slope.
5/31/2013	50		Creation of design charts and/or an Excel spreadsheet computer model for water quality detention elliptical slot weir outlet designs.
4/30/2013	100	11/28/2013	Installation of a prototype elliptical slot weir at a UDFCD-monitored water quality detention basin (monitoring hydraulics and debris handling characteristics will continue for two years at this test site)
9/30/2013	0		Determination of clogging potential and consideration of clogging mitigation strategies (e.g., well screen or trash rack) for this new outlet compared to the current standard.
9/30/2013	0		Coordination with CDOT, who will install and monitor the prototype device at a rural water quality detention pond, to insure the device is installed and monitored correctly.
9/30/2014	0		Comparison of maintenance requirements for this new outlet vs. the current standard.
8/18/2015	0		Submission of draft final report no later than 75 days before end of contract
8/18/2015	0		Presentation of findings to study panel and other invitees with electronic copy of associated PowerPoint presentation.
8/18/2015	0		Submission of guidance document on best practices in producing, installing and maintaining an alternative outlet water quality structure.
10/2/2015	0		Address the comments of the study panel.
10/2/2015	0		Submission of a final report per CDOT manuals and specifications (re: CDOT Research website, http://www.dot.state.co.us/Research/)
10/2/2015	0		Creation and delivery of CD(s) containing reports, all electronic files, photographs, and data generated for the project at the close of the study.

SIGNIFICANT EVENTS

7/2/2012 – $70,000 now available from the FY13 SP&R Work Program

9/30/2012 – A $36,346 agreement has been signed between UDFCD and CSU for physical modeling of the elliptical slot weir at the CSU hydraulics lab. Modeling for six of nine agreed-upon configurations has been completed, and modeling of the final three configurations is under way. UDFCD is negotiating an amendment to the UDFCD - CSU agreement to add modeling debris handling capabilities to the scope. A $6,250 agreement has also been signed between UDFCD and ARCADIS for mathematical modeling of the elliptical slot weir. Calibration of the math model to the physical model is under way, but additional funding will be necessary to move ARCADIS forward on this important task. UDFCD is also negotiating with the USBR hydraulics lab in Lakewood for additional testing of overflow weir configurations, necessary to refine sizing assumptions for the entire system.

12/31/2012 – All nine slot weir configurations have been modeled at the CSU hydraulics lab, preliminary results on six of those nine have been forwarded to UDFCD by CSU for review and comments – we are waiting for the lab results for the final three configurations.

On October 5, 2012, an $8,942 amendment to add debris modeling to the scope of work was signed between UDFCD and CSU. CSU experimented with different types of debris to test the clogging characteristics of the weir. It was found that vegetal debris, simulated by straw and wood chips, tended to not clog the weir sufficiently to cause a significant reduction in flow rate. On the other hand, plastic bags easily clogged the weir and significantly impaired the flow capacity. This tells us that the elliptical slot weir will not function well without some protection to prevent clogging from plastic and paper litter.

On October 4, 2012, a $51,000 agreement was signed between UDFCD and the U.S. Bureau of Reclamation (USBR) to conduct 1/3-scale physical modeling of an overflow weir at their hydraulics lab in the Lakewood Colorado Federal Center. Because their policy is to not begin construction on the model until full payment has been made, that work has not yet begun (a $51,000 check from UDFCD was delivered on 12/18/2012). The purpose of this work will be to refine and calibrate the hydraulic calculations necessary to estimate overtopping flow for storm events greater than the 80^{th} percentile, or "water quality event." To this point, we have always used classic weir and orifice equations with some reduction factor applied to represent the interference of the grate plus a clogging factor, plus adjustments to reflect the trapezoidal shape of the outlet overtopping weir (having a low front edge, two sloping sides, and a high back edge). We hope through the work at USBR to better calculate these flows.

3/31/2013 – The debris modeling has been completed. CSU has submitted a final report on the testing setup and process titled "CSU Elliptical Weir Hydraulic Testing Final Report 2013-03-29." Work is progressing on derivation of an equation-based sizing methodology for field installations. A 3-dimensional CFD model of three different elliptical slot weirs was completed by ARCADIS and a report titled "ARCADIS Calculation of Rating Curves for Three Elliptical Slot Weirs 2011-08-15" has been submitted. Testing of overflow structure hydraulics at the

USBR hydraulics lab also continues. To date, an overflow structure with a 3:1 sloping top weir and a 4:1 sloping top weir have been modeled and the results have been compared to the classical and modified equaitons used by UDFCD and others to size detention basin overflow outlet structures.

3/31/2013 – All work at CSU has been completed. Two reports have resulted from that work, namely:

1. *Hydraulic Testing of a Sharp-Crested Elliptical Weir Outlet Structure* (March 2013); and

2. *Stage-discharge Rating Equation Development for an Elliptical Sharp-crested Weir using Physical Hydraulic Modeling* (June 2013).

The first report contains all of the laboratory setup information and data gathered during the actual physical modeling, including debris modeling with plastic bags, newspapers, and turf-reinforcement mat material (selected for its inherent neutrally-buoyant property). The second report documents the derivation and development of the final equation to approximate the discharge for a given head condition. An explicit solution was found to be unobtainable due to the complexity of the definite integral equation; but a trapezoidal numerical integration resulted in a close approximation that could be calibrated to modeled results via a correction factor. This equation takes the form of:

$$Q_{app} = \frac{1}{8}h\left[t\sqrt{2gh} + 2\sum_{i=1}^{3}\left(\sqrt{2gM}\left(\frac{2H\left(1-\sqrt{N}\right)}{R}+t\right)\right)\right] \qquad \textbf{Eq. (4.5)}$$

where

$$M = h - \frac{1}{4}ih \qquad \textbf{Eq. (4.6)}$$

and

$$N = 1 - \frac{1}{16}\frac{h^2 i^2}{H^2} \qquad \textbf{Eq. (4.7)}$$

Equation 4.5 gives us the basis for developing a sizing algorithm for implementation of the elliptiacal slot weir in the field and work is currently underway by UDFCD personnel to size an elliptical slot weir for the Orchard Pond extended detention basin in the Grant Ranch subdivision in southwestern Denver, and for a yet-to-be constructed regional treatment wetland at 52nd Avenue and Emerson Street in north-central Denver.

Work completed to date at the USBR hydraulics lab includes overflow rectangular weir modeling for overflow weris that were 1) horizontal, 2) at a 3H:1V slope, and3) at a 4H:1V slope. That physical model is currently being reconfigured at model the elliptical slot weir in conjunction with the overflow weir and a culvert at the bottom of the outlet vault which may draown out the effects of both the elliptical slot weir and the overflow weir at high head conditions (simulating the 100-year flooding condition). Actual testing will resume at USBR in September.

9/30/2013 – UDFCD investigated retrofitting the Grant Ranch Orchard Pond extended detention basin with an elliptical slot weir and found that, due to a relatively small storage volume and large storage depth. This information will help bracket the limits of applicability for this type of outlet control plate. Two other sites have been identified for retrofitting withing the Park Creek Metropolitan District, managed by the Stapleton Master Community Association. Retrofitting of those two ponds is currently being negotiatied with the owners.

CDOT had expressed an interest in retrofitting a detention basin on the north side of 120th Avenue on the east bank of the South Platte River, but has not followed through with design information for that detention basin. Reconaissance by UDFCD at the site indicates that it is probably a bad site for this, but UDFCD may be able to recommend a different retrofit option.

12/31/2013 – UDFCD fabricated and installed two elliptical slot weirs in stormwater quality extended detention basins at the Northfield retail development near Quebec Street and I-270.

Site of two UDFCD elliptical slot weir monitoring site; Northfield to the south and Postal Service to the north.

These extended detention basins are very large, as shown in the figures below:

REGIONAL DETENTION FACILITY WATER QUALITY FACILITY TYPE : EXTENDED DRY WATERSHED AREA (ULTIMATE) : 460 ACRES PERCENT IMPERVIOUSNESS : 90% 100-YR WATER SURFACE : 5227.00 WQCV WATER SURFACE : 5223.50 NORMAL POOL WATER SURFACE : 5220.50 MICRO-POOL BOTTOM ELEVATION : 5218.00 WATER QUALITY CAPTURE VOLUME : 18.5 AC. FT. 100-YR DETENTION VOLUME : 75 AC. FT. 100-YR DISCHARGE INFLOW : 1,600 CFS 100-YR DISCHARGE OUTFLOW : 75 CFS	US POSTAL SERVICE DETENTION FACILITY WATER QUALITY FACILITY TYPE : EXTENDED DRY WATERSHED AREA : 81.6 ACRES PERCENT IMPERVIOUSNESS : 82% 100-YR WATER SURFACE : 5219.70 WQCV WATER SURFACE : 5215.50 NORMAL POOL WATER SURFACE : 5213.00 MICRO-POOL BOTTOM ELEVATION : 5210.00 WATER QUALITY CAPTURE VOLUME : 2.2 AC. FT. 100-YR DETENTION VOLUME : 16.3 AC. FT. 100-YR DISCHARGE INFLOW : 313 CFS 100-YR DISCHARGE OUTFLOW : 4 CFS
	
Northfield Pond F14	Postal Service Pond

We are still waiting for the design report for the CDOT detention basin on the north side of 120th Avenue on the east bank of the South Platte River, so we can recommend a retrofit for that basin.

June 2015 - No progress updated this quarter

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Design of Forebay and Micropool for Highway Stormwater Detention Basins

(Forebay & Micro Pool Design)

Study No: 114.02

Background Low Impact Development or green infrastucture, often begins with a learning process through the best management practices (BMP), and needs to be tested with field data. Currently, there are two popular methods developed for stormwater detention designs. The first method is termed water quality capture volume (WQCV) approach that was developed to intercept frequent runoff events. The second method was proposed to incorporate excess urban runoff volume (EURV) into a detention pond design to control flow releases from frequent to 100-yr events. A WQCV pond is built to intercept up to 6-month rainfall event for water quality control, while a EURV pond is designed for all flow release controls from small to extreme events. It is proposed: (1) to investigate the performances of these two existing ponds to determine if their performances agree with the original goals and assumptions defaulted in the design methodology, and (2) how to refine the designs of forebay and micro pool to avoid or to minimize standing pools.	Reporting Period: 04/01/15 through 06/30/15 Start: 11/20/13 Contract Amount: $ 70,000 Principal Investigator: Ken MacKenzie, Urban Drainage and Flood Control District and Dr. James Guo UC-Denver (Contracted with Ken MacKenzie, UDFCD) Study Manager: Bryan Roeder, CDOT, 303-512-4420 Study Panel Leader: Mike Banovich, CDOT Environmental Programs Branch (303) 757-9542 Study Panel Members: Amanullah Mommandi CDOT Research Bob McDade, CDOT Environmental Randy Richards, CDOT R1 BMP Maintenance crew Al Gross, CDOT Staff Hydraulics FHWA Washington Contact:

Quarterly Report Periods End: 12/31, 3/31, 6/30, and 9/30

MILESTONES (Planned and Progress)

Planned	% done	Achieved	Description, Discussion, and Related Issues
11/20/13	100	11/20/13	PO # 211020742 issued to James Guo and MacKenzie to start project
11/20/13	100	12/13/13	A kick-off meeting was held. Watershed information was retrieved. Three M.S. students were assigned to investigate the flood flows at the two ponds at S. Knox and HW285 and S. Federal and HW285
12/14/13		3/31/2013	Watershed models with and without a detention pond have been completed. Survey of these ponds will be contracted out. Expected the CDOT maintenance force will clean up the sites.
3/1/2014	90%	3/1/2014	The field survey is delayed to the early December. The tributary area to the SW ramp pond on HW 285 and S federal was identified. I could not find any report for the detention pond at the SW corner ramp at S Federal and HW 285. It will rely on field survey to confirm the existing condition. Watershed models have been expanded from single event simulation to continuous simulation. Both watersheds have been modeled to investigate the effect of residual water depths.
8/10/2014	90%	81/2014	Two water depth loggers have been installed in these two detention basins, one for each basin. Field data has been collected through the summer.
3/16/2015	100%	3/16/2015	We conducted field surveys on the outlets for two ponds. We have verified our computer models to reflect the as-built outlets. We have collected sediment samples along HW 285 before, during, and after winter sanding practice. These sediment samples have been analyzed in the laboratory for their gradation curves. We also collected the float deposits on the screens in front of the perforated plates installed on the outlet vaults. The float particles were also analyzed for their gradation curves. We have verified the effectiveness of the as-built forebay in terms of sediment trap ratio. We have also developed a new design procedure for dimensions of micro pool.

SIGNIFICANT EVENTS

07/30/13 Pre-project scoping meeting
08/02/13 Budget increased from $65,000 to $70,000, now available from the 2014 SP&R Work Program

11/20/13 Notice to Proceed issued.
3/1/15 Field work proceeding

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Post Fire Ground Treatments

Study No: 115.02

Background The main objective of this study is to assess the efficacy of post-fire ground treatments in mitigating soil erosion, runoff, and debris flows towards developing guidelines for conducting needs and feasibility assessments to enhance post-fire emergency response actions. A coupled laboratory and numerical research program will be used to determine a priori means for assessing post-fire ground treatments for soils near critical transportation infrastructure. The PIs envision three categories of practical tools to assist personnel at the Colorado Department of Transportation: (1) laboratory experimental techniques to yield physical data on runoff and erosion; (2) numerical modeling techniques to assess different soil and ground treatment combinations; and (3) empirical relationships to guide emergency response decision making. The third tool will be the most applicable to the broad transportation community, and this tool will be developed as an endstate deliverable of the proposed project.	**Reporting Period:** 04/01/15 to 06/30/15 **Start:** 01/05/15 **End (Estimate):** 1/31/17 **Contract Amount:** $ 60,000 **Principal Investigator:** Christopher Bareither Colorado State University christopher.bareither@colostate.edu 970-491-4669 **Study Manager:** Bryan Roeder, CDOT, 303-512-4420 Bryan.roeder@state.co.us **Study Panel Leader:** TBD **Study Panel Members:** Basil Ryer, CDOT Rozellynn Hall, CDOT .

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
01/31/15	100%	01/31/15	Project initiation – review proposal and refine objectives as needed
06/30/15	85%		Literature review focusing on the following: (i) wildfire in Mountain West States; (ii) wildfire effects on soil composition, properties, and behavior; (iii) debris flow initiation and impacts; (iv) wildfire effects on watershed and water quality; and (v) post-fire ground treatment implementation.
06/01/15	100%	06/01/15	Literature review on Discrete element modeling and assessment
09/01/15	75%		Synthetic soil design and preparation
09/01/15			Block sample collection, and geotechnical property testing
09/01/15	35%		Develop discrete element models (DEMs) that couple particle-hydraulic-reinforcement effects encountered in post-fire ground conditions
09/01/15	100%	07/01/15	Design and contract fabrication for laboratory-scale slope model experiment
09/01/15	20%		Set-up and calibrate laboratory-scale slope model experiment
05/01/16			Conduct laboratory-scale slope model experiments and coupled DEM simulations to evaluate the efficacy of post-fire ground treatments on mitigating erosion and runoff
09/01/16			Verify DEM Code with experimental model
12/20/16			Develop preliminary guidelines for post-fire feasibility assessments of ground treatment methods used to prevent loss of or damage to critical transportation components
01/01/17			Final Report publication

SIGNIFICANT EVENTS

02/25/15 – Developed particle contact algorithm for DEM code. The contact algorithm detects which particles need to be "checked" for contact, as opposed to the model automatically checking every particle with ever other particle. This allows the code to have higher computation efficiency for a large number of particles.

03/26/15 – Presented short research and modeling project that focused on modeling infiltration of precipitation in post-fire soils. Modeling was completed in HYDRUS 1-D.

04/02/15 – Coded particle-particle contact forces in the DEM model. Using a simplified Hertzian model, which is referenced from O'Sullivan (2011) *Particulate Discrete Element Modeling*.

04/22/15 – Coded rigid wall boundary conditions in the DEM model.

05/06/15 – Linked DEM output to ParaView for visualization of simulation results. This approach is currently working for everything except boundary conditions (still in progress). This visualization process will allow for sophisticated imaging of the DEM results and the potential to develop videos to show ground treatment effects of particle behavior.

05/20/15 – Established location for laboratory-scale slope model experiment Engineering Research Center of Colorado State University.

06/02/15 – Coding hydraulic forces from rain in the DEM model. In addition to this, the model updates saturation as time-steps progress and has capabilities to model rain events of different intensities and raindrop sizes. As the water begins to flow through the soil, drag forces are introduced in the system. This is still in progress.

06/22/15 – Finalized design drawings for slope-model experiment, which includes three key components: (i) experiment stand, (ii) test box to contain the soil specimen, and (iii) rainfall generator. The experiment stand was constructed by our research team and the test box and rainfall generator are in the process of being constructed by machinists at the Engineering Research Center. Also, a final design was prepared for a soil "cut box" that will be used to collect block samples. This cut box is also being fabricated by the Engineering Research Center.

06/26/15 – High Park Fire site visit (Hill and Skin Gulch). Soil samples collected for geotechnical property testing.

COLORADO DEPARTMENT OF TRANSPORTATION

ROADSIDE RESTORATION PROGRESS REPORT

Improving Roadside Restoration Through Site Specific Training and Intra Agency Cooperation

Study No: 115.03

Background

One responsibility of the Colorado Departments of Transportation (DOTs) includes efficiently managing and maintaining rights-of-way. Sustainable management of roadside vegetation can lead to overall cost savings, increased water quality, decreased erosion, and increased species diversity (Lucey and Barton 2010). An Integrated Roadside Vegetation Management (IRVM) plan using competitive planting and selective herbicides to manage invasive weeds has proven effective in states such as Arkansas, California, Florida, Illinois, Iowa, Maryland, Minnesota, New York, Ohio, Pennsylvania, Washington, Wisconsin, and Texas (Berger 2005). Establishing native perennial species can help stabilize the soil surface, increase infiltration, and can potentially filter chemical pollutants. Increased biodiversity can be a direct result of the integrated approach of seeding desirable species combined with herbicide applications, in order to provide a window for these desirable species to re-establish. Roadsides are challenging environments; however, there are management approaches that can assist in the recovery and sustainability of these areas. To reduce the costs of follow up treatments, it is important to determine what actions to take to increase restoration success of rights-of-way. It is the goal of this research project to help CDOT begin to develop IRVM protocols for Colorado.

Berger, R. L. 2005. Integrated roadside vegetation management. Transportation Research Board.

Lucey, A., and S. Barton. 2010. Public perceptionand sustainable roadside vegetation management strategies. *MANAGEMENT* 6:8.

Reporting period: 04/10/2015-08/01/2015
Start Date: 04/10/15
Contract Amount: 60,000.00

Principal Investigator:
Dr. Scott Nissen, Professor, Weed Science

Students:
Kallie Kessler (Ph.D. student)
Derek Sebastian (Ph.D. student)
John Coyle (M.S. student)

Study Manager:
Bryan Roeder, CDOT, 303-512-4420
Bryan.roeder@state.co.us

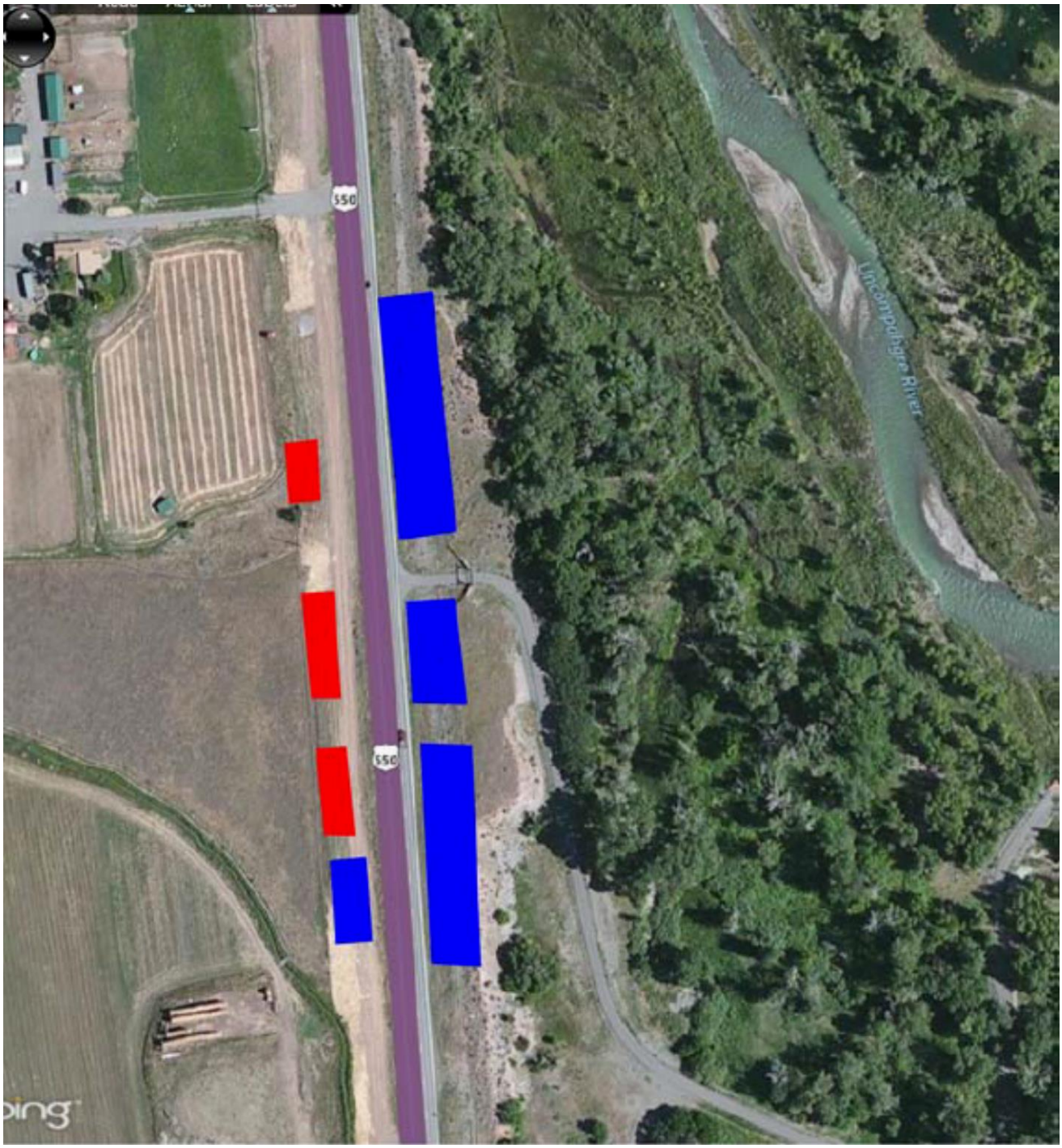
Study Panel Leader:
Becky Pierce, CDOT Wetlands Program Manager

Study Panel Members:
Jim Walker CDOT Noxious Weed Coordinator
Steve Saur, Boulder County Noxious Weed Coordinator
Ron Mabry, Ouray County Noxious Weed Coordinator
Myron Cunningham, CDOT R1 MTCE
Pat Hickey, CDOT Region 4 Environmental

MILESTONES

Planned	% Complete	Date Achieved	Description, Discussion and related issues
04/10/2015	100%	04/10/2015	Notice to Proceed
04/13/2015	100%	04/13/2015	Kickoff Meeting – final plan of action decided
04/21/2015	100%	04/21/2015	Boulder County treatment plots were identified and boundaries flagged
05/12/2015	100%	05/12/2015	Boulder county sites were treated with the initial spring herbicide treatments, identified initial plant species present, suitability for seeding method evaluated
05/14/2015	100%	05/19/2015	Ouray county treatment plots identified and boundaries flagged. This action was weather delayed. A landowner adjacent to previously identified ideal treatment area had sprayed an unknown herbicide prior to our planned applications so site was discarded for one ¾ mile to the north.
05/21/2015	100%	05/21/2015	Ouray county treatment plots were treated with the initial spring herbicide treatments, identified initial plant species present, suitability for seeding method evaluated
06/19/2015	100%	06/19/2015	Site check of treatment progress. It should be noted that moderate ATV traffic on the west side of the highway was observed through the study area. Minimal but noticeable damage to study plots was noted.
08/2015			GreenSeeker Cover Evaluation
08/2015			Cover and Control Evaluation
09/2015			Fall timing herbicide treatments applied
12/2015			Seeding
12/2015			Data Analysis
12/2015			Report Prep/Submission

Ouray County Site



Ouray County Site Map – Blue indicates study plot location, red indicates demonstration plot locations. All plots located approx. 5 miles south of Colona, CO on highway 550.

Ouray County Site

Study plot layout looking North (left) and demonstration plot layout looking South (right).

Boulder County Site


Diagonal Highway Study Site (left) and spring application timing- May 12, 2015 (right).


Diagonal site June 5, 2015 showing spring timing treatments and untreated fall treatments

Boulder County demonstration plots with 20 treatments at both fall and spring timings

Boulder County Highway 287 study site

Project Summary to Date

Spring herbicide treatments and other applicable baseline data for both Boulder County and Ouray County sites were completed on time at both sites. Initial evaluations suggest that herbicide treatments at both sites were effective, although in depth post-application data collection has not been completed. Data collection is scheduled to be completed by August 2015, followed by the fall treatment applications in September of 2015. Data analysis will be compiled in December 2015 to complete the 2015 schedule.

There were some challenges that arose at the Ouray County site, briefly mentioned in the milestone table above. A local landowner, who was not specifically identified, had sprayed some unknown herbicide along the highway in the site initially chosen leading to a necessary change of site ¾ of a mile north. The alternative site is just as suitable for the study but was initially passed over due to the other site accessibility issues. The local weed manager, Ron Mabry, contacted adjacent landowners and advised them of the study and the necessity to refrain from further spraying. The treatment site also has an unauthorized ATV trail running through the edge closest to the road. Landowners were advised to refrain from travel through the treatment areas, marked with flagging. The local sheriff was also advised of the unauthorized traffic to aid in enforcement.

No adverse conditions were observed at the Boulder County sites. These sites have received greater than average precipitation following the spring application timing. Visual evaluations one month after treatment showed excellent weed control. Weed species at the 287 site included kochia, field bindweed, marestail, downy brome, lambsquarter, Canada thistle, redstem filaree, tumble mustard, and curly dock. Weed species at the diagonal site included kochia, musk thistle, field bindweed, marestail, tumble mustard, prickly lettuce, downy brome, and curly dock. Greenseeker normalized difference vegetation index (NDVI) values will be taken in August to quantify treatment efficacy.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Paleoflood Investigations to Improve Flood-Frequency Estimates in Eastern Colorado
Study No: 107.10

Background

Reliable peak-streamflow information is critical for the proper design of stream-related infrastructure, such as bridges and dams, and floodplain inundation maps. At gaged sites, where sufficient long-term streamflow data have been collected, statistics can be obtained from available publications, by an analysis of available data in the U.S. Geological Survey (USGS) National Water Information System database, or other sources of flood information. However, estimates also are needed at ungaged sites where no site-specific streamflow data are available. Large areas with few streamflow gages having short periods of record may cause large uncertainties in the regional-regression equations used to estimate streamflow. Additional flood information may improve the reliability of the regional-regression equations in the Plains hydrologic region of eastern Colorado. With the recent completion of the USGS Colorado Flood Database, a unique opportunity exists to use additional flood data, along with collection of new paleoflood data, to improve at-site flood-frequency relations and develop new regional flood-frequency equations for the ungaged sites in eastern Colorado. Engineers and scientists then will be able to incorporate these updated estimates for proper floodplain regulation, dam-safety design, and other uses.

The objective of this study is to provide updated regional peak-streamflow equations for the Plains hydrologic region by collecting paleoflood data to supplement the existing flood data. Site specific and regional flood-frequency analysis will be performed using existing flood data in addition to the newly collected paleoflood data to develop the improved regional peak-streamflow equations for the Plains hydrologic region. With the expectation that prediction errors will be reduced, these new equations will replace the regional peak-streamflow equations in the Plains hydrologic region developed by Capesius and Stephens (2009). Also, these new equations in the Plains hydrologic region will update the USGS StreamStats program, a web-based interactive tool for determining streamflow statistics (U.S. Geological Survey, 2013a). The scope of this effort includes evaluation of existing flood data and the collect new paleoflood data in the field. In this proposal, additional paleoflood studies will be performed primarily at gaged sites in eastern Colorado from Capesius and Stephens (2009).

The primary benefit of this study is to update the regional-regression equations for the Plains hydrologic region in Colorado, which would greatly benefit from improved accuracy of flood-frequency estimates.

Reporting Period: 04/01/2015-06/30/2015

Start: 7/1/2013
Complete: 9/30/2015
Contract:

Principal Investigator(s):
Michael Kohn, P.E., USGS,
303-236-6924

Study Manager:
Aziz Khan, Research Branch
303-757-9255

Study Panel Leader:
Amanullah Mommandi,
Project Development Branch
303-757-9044

Study Panel Members:
Alfred Gross, Staff Hydraulics
Veronica Ghelardi, Hydraulics Engineer,
FHWA - Resource Center

FHWA Washington Contact:

MILESTONES

Planned	% Done	Achieved	Description, Discussion, and Related Issues
9/30/13	100	September 2013	Determine sites in Plains hydrologic region to be used in flood-frequency analysis
9/30/13	100	September 2013	Compile all previously collected paleoflood data in Plains hydrologic region
9/30/13	100	September 2013	Prioritize a list of sites that will require paleoflood data to be collected
6/30/14	100	September 2014	Collect, document, and archive paleoflood data at each site
6/30/14	100	November 2014	Determine the peak discharge, age, and uncertainty of each paleoflood
6/30/14	100	November 2014	Perform site specific flood-frequency analysis using PeakFQ/EMA
12/31/14	100	February 2015	Develop regional flood-frequency equations
3/31/15	100	February 2015	Determine the uncertainty of the new flood-frequency equations
9/30/15	80	Expected: September 2015	Publish USGS Scientific Investigations Report and update StreamStats and Colorado Flood Database

SIGNIFICANT EVENTS

The paleoflood data collection was delayed due to the September 2013 flooding which delayed the completion dates of some of the earlier milestones but should not affect the delay of the final product, the USGS Scientific Investigations Report. All USGS and Colorado Division of Water Resources streamgage data was compiled and the 126 sites to be used in the flood frequency study and paleoflood data collection have been determined. The preliminary (no paleoflood data) at-site flood-frequency analysis was completed using PeakFQ/EMA in June 2014. All known previously collected paleoflood data has been compiled for eastern Colorado. The remaining sites were prioritized to make sure the most critical sites were visited and where paleoflood data existed and was feasible to collect, it was collected. New paleoflood data collection began in July 2014 and was completed in September 2014. After the new paleoflood data collection was completed at 41 sites, the peak discharge, age, and uncertainty of the paleoflood data were determined. Then, the at-site flood frequency analysis was also finalized using the 41 new paleoflood sites and 3 previously determined paleoflood sites in November 2014. The updated regional flood-frequency equations for eastern Colorado were developed and the uncertainties of the equations were finalized in February 2015. The USGS Scientific Investigations Report has been written and is going through the USGS report review and publication process with a completion date of September 2015. The StreamStats program and the Colorado Flood Database are currently being updated and will be completed by September 2015.

PROJECT COMPLETION

The project completion/end date is September 30, 2015 per the CDOT/USGS Funding Contract signed in September 2013 and the project is expected to be completed on time.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Web-based Historic Flood Information Database for Colorado
Study No: 107.10

Background

The accuracy of flood-frequency estimates can be greatly improved when historical flood information is used in conjunction with systematic flood data. The recent completion of the Colorado Flood Database (http://cwscpublic2.cr.usgs.gov/projects/coflood/COFloodMap.html) provides a unique opportunity to improve at-site and regional flood-frequency equations with easier access to flood data. Having an easy-to-use Web-based database of flood and paleoflood information allows engineers and water-resource managers to fully use these data to help improve flood-frequency estimates of large floods in Colorado. Maintaining this database will ensure continued access to these data and regular updates will keep the database current, further enhancing its value and use.

The objective of this study is to maintain and enhance the Colorado Flood Database (http://cwscpublic2.cr.usgs.gov/projects/coflood/COFloodMap.html) annually by updating the database with new flood data, and performing routine Website maintenance as needed. The data sources of historical flood information include: high outliers at gages used in the latest Colorado flood frequency report published by the USGS; unpublished USGS indirect and paleoflood measurements; and the peak flood of record at all USGS gages.

The updated Web-based interface containing links to systematic data and historic flood information is the ultimate product of this project. A short USGS Open-File Report (http://pubs.usgs.gov/of/2012/1225/) has been published to describe the contents of the database, its features, and how to use them.

Reporting Period: 04/01/15 – 06/30/15

Start: 10/1/10
Complete: 9/30/16
Contract:

Principal Investigator(s):
Michael Kohn, P.E., USGS,
303-236-6924

Study Manager:
Aziz Khan, Research Branch,
303-757-9255

Study Panel Leader:
Amanullah Mommandi,
Project Development Branch
303-757-9044

Study Panel Members:
Alfred Gross, Staff Hydraulics
Veronica Ghelardi, Hydraulics Engineer,
FHWA - Resource Center

FHWA Washington Contact:

MILESTONES

Planned	% Done	Achieved	Description, Discussion, and Related Issues
10/1/10	100	January 2011	Agreement between CDOT and USGS finalized and signed.
4/1/11	100	April 1, 2011	Review sources of flood information
7/1/11	100	July 1, 2011	Compile USGS flood data
5/15/11	100	June 2011 and Dec. 7, 2011	Meeting with CDOT and other agencies
12/31/11	100	December 31, 2011	Develop database structure and select web interface
4/1/12	100	Expected: November 15, 2012	Build web interface, populate database, and test
5/1/12	100	Expected: June 1, 2012	Go LIVE to Web
8/30/12	100	Expected: December 31, 2012	Complete USGS publication
7/31/13	100	Expected: July 31, 2013	Update Database with data from FY2012 once it's published.
7/31/14	100	Expected: September 30, 2014	Update Database with data from FY2013 once it's published.
7/31/15	25	Expected: July 31, 2015	Update Database with data from FY2014 once it's published.
7/31/16	0	Expected: July 31, 2016	Update Database with data from FY2015 once it's published.

SIGNIFICANT EVENTS

All USGS data that compose the database has been compiled and is located in a Microsoft Excel database. This includes USGS indirect discharge measurements from USGS offices, historical flood events from indirect discharge measurements chronicled in USGS publications, published paleoflood studies, and the peak streamflow record from all USGS gaging stations in Colorado.

The USGS report has been approved for publication and is available at http://pubs.usgs.gov/of/2012/1225/. The Website is complete and includes the recently implemented CDOT Mile Post search. Meetings were held with CDOT/USGS on November 2, 2012, December 5, 2012, and January 11, 2013 to solicit comments and feedback from CDOT about the database. Feedback from these meetings was incorporated to the website. The feedback received from the meeting was extremely helpful and the Website and USGS report were not completed until the feedback could be incorporated. The final flood database URL is http://cwscpublic2.cr.usgs.gov/projects/coflood/COFloodMap.html. It is linked from the USGS project page which can be accessed at http://co.water.usgs.gov/preview/projects/COFloodDB/index.html. The project page has a link to the report and flood database, a general project description, contact information, a link to downloadable GIS shapefiles of all the sites and their drainage basins in the database with metadata, and links to related projects. The easiest way to find the Colorado Flood Database is by simply searching for it any search engine.

Database was updated to include flood data through water year 2012 (October 1, 2011 to September 30, 2012) and water year 2013 (October 1, 2012 to September 30, 2013). Currently, the database is being updated to include data through water year 2014 (October 1, 2013 to September 30, 2014) and this should be completed by July 31, 2015. During the summer of 2016 the database will be updated again to include data through water year 2015 (October 1, 2014 to September 30, 2015).

PROJECT COMPLETION

The initial project completion/end date was 09/30/2013 per a PI/USGS no-cost extension which was requested to update the database in FY 2013 to include data up through water year 2012. However, a USGS Joint Funding Agreement was signed with CDOT in August 2013 that will fund the annual update and maintenance of the flood database for water years 2014-2016 so the current completion date will be September 30, 2016 and the project is expected to be completed on schedule.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Survey, Evaluation and Long- term Monitoring of the EDC GRS Abutment Performance for Multiple Spans CDOT Bridges Replacement Project (GRS Abutment)
Study No. 214.05a

<table>
<tr>
<td>Background

O The CDOT Region 1 project to replace the twin bridges over the Union Pacific Railroad and Smith Road incorporates innovations that implement the CDOT/FHWA mandate − EDC GRS (Geosynthetic Reinforced Soil) abutment technology. These twin bridges carry I-70 east and westbound traffic on three-span, (107'+ 158' + 155') horizontally-curved steel welded-plate girder structures. The mid-span piers are founded on deep foundation; however, the GRS abutments are supported by spread footings and founded on embankments. This unique feature of a GRS transition zone, to a GRS abutment founded on an embankment (shallow foundation), to pier (deep foundation) is a new design methodology to eliminating bridge "bumps". Such "bumps" are typically caused by differential settlement between the bridge founded on deep foundations and the roadway founded on embankment (shallow foundation) and can result in roadway maintenance problems.

The objective of the study is to validate the performance of GRS abutment for multi-span bridges, and the use of geofabric without positive connections to the fascia blocks.
.</td>
<td>Reporting Period: 04/1/15 through 06/30/15
Type: SP&R Start: 12/26/13
End: blank (12/31/15 on Kent's Spreadsheet)
PO: 411000057
Principal Investigator(s):
Dr. N.Y. Chang, Professor (UCD)

Study Manager: Aziz Khan, ARIB

Study Panel Members:

Panel Chair: ShingChun (Trever) Wang, Bridge Design and Management
Skip Outcalt, ARIB
Ilyess Ksouri, Materials and Geotechnical Branch
Steve Yip, Bridge Design and Management Branch
Teddy Meshesha, Bridge Design and Management
Roman Jauregui, Region 1 Resident Engineer
Matt Greer, CO Division of FHWA
Daniel Alzamora, Resource Center, FHWA
Duane (Jay) Hendickson, Region 1 Resident Engineer
Larry Quirk, Region 1 Project Engineer</td>
</tr>
</table>

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TASKS AND MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
12/26/13		12/26/13	Notice to proceed
4/30/14	100	4/30/14	Task 1 Feedback to Geotechnical Consultant
4/30/14	100	4/30/14	Task2: Review and Analyze Construction Records
5/31/14	100	2/15/15	Task 3: Geo-fabric Strength Test
12/31/14	100	6/15/15	Task 4: Review and Analysis of Phase 1 Monitoring Data
12/31/14	100	6/18/15	Task 5 Adjust the Instrumentation Program
8/31/15	95		Task 6 Numerical Modeling of GRS Abutment Performance for Phase 1 Study
12/31/14 (revised for 10/31/15)	75		Task 7 Interim Report for Phase 1
9/30/14 (rescheduled for 8/15/15)	75		Task 8 Presentation at the CDOT Showcase/Open House
8/31/15	15		Task 9 Extension of Modeling and Data Analysis to Phase 2 Study
9/30/15	50		Task 10 Draft Report Covering Phase 1 and Phase 2 Studies
11/30/15	0		Task 11 Submit a Final Report for Comments
12/31/15	0		Task 12 Submit the Final Report
11/30/15	50		Task 13 Present the Findings to Geotechnical and Bridge Engineers
4/30/14	100	2/15/15	Task 14 Lab Backfill Property Tests
10/15/15	0		Task 15 Probabilistic Evaluation of the GRS Abutment Performance
10/31/14	25		Task 16 Large-Scale GRS Abutment Test

6/30/15 The construction project is behind the original schedule. Planned dates above have been revised to reflect this delay.

Comments on Tasks

Task 1: Due to construction delay and lack of communication between the consultants and the Center for Geotechnical Engineering Science Research Team (briefed as CGES Team or Team), whenever the opportunity presented itself, the Team continued to present the comments on pertinent subjects, the Team met with S and W engineers many times throughout the project period. The final opportunity came at the joint meeting among the CDOT Bridge and Research, Shannon and Wilson and the Team at which the pros and cons of the instrumentation program and recommendation for the Phase II project were discussed extensively and vigorously. It was, at this meeting on June 18, decided to drop the use of Optic Fiber Strain Gauges for geo-fabric strain due to its inability to provide the strain measurement, and limit the instrumentation program to the vertical and horizontal earth pressure measurement and four survey points along the face of sheet pile wall.

Task 3 Geo-fabric strength tests: Due to construction delay, the exhumed geo-fabric samples and new completed. Thus, in February, all geo-fabric testing was completed and results shared at the meeting in CDOT attended by CDOT Bridge, Research and Geotechnical Branch, Shannon-Wilson, the Team and Dr. Peter Hoffman from GRS wall group.

Task 4 Review and Analysis of Phase I Monitoring Data: The field monitoring data were ready for review till May, 2015. This caused the delay.

Task 5 Adjust the Instrumentation Program: The adjustment was made at the June 18 meeting held at S-W office. Before then the full extent of the data was not available for comprehensive comments and discussion.

Task 6 Numerical modeling of Phase I GRS abutment: Knowing the urgency of the analysis, it was done by March 31, 2014 anticipating the inflow of data for comparison with the field instrument monitoring. Then, another comprehensive analysis was completed on July 31, 2014, but the field data were still not available for comparison. Then the Team waited till the end of May, 2015 when some quality data were becoming available and another comprehensive numerical analysis was performed with the updated material data. The comparison was made for horizontal and vertical earth pressures and the earth pressure comparisons were excellent. The comparison for sheet pile wall displacement and anchor bar strains are progressing.

Task 7 Interim report for Phase I: The Interim Report for Phase I Study will be made available before 10/31/2015 to include the comments to be collected at the Show Case meeting scheduled for August 15, 2015.

Task 8 Presentation at CDOT Show Case (or Open House): The Show Case Meeting was rescheduled for August 15, 2015. It will be a CDOT-FHWA joint effort. The power point presentation is about 65% completed and it will be ready for review by July 31, 2015 before the data for Show Case meeting.

Task 9 Extension of modeling and data comparison to Phase II study: The extension plan was completed at the meeting on June 18, 2015, the numerical analyses will begin by August 31, 2015 and the field data collection should start momentarily by S-W. If the construction were carried as scheduled, the data flow should take place beginning July 15, 2015. If so, the numerical-field data comparison could be completed by September 30, 2015 under the condition of on-time delivery of field monitoring data.

Task 10 Draft report covering Phase I and Phase II studies: The draft report will be submitted for review and comments by October 31, 2015, anticipating on-time delivery of the field monitoring data.

Tasks 11 Submit a final report for further comments: The final report is expected for comments by November 30, 2015.

Task 12 Final Report: The final report will be submitted by December 31, 2015.

Task 13 Presentation of findings to bridge and geotechnical engineers: The findings will be presented as scheduled by November 30, 2015.

Task 14 Lab backfill property tests: All property tests were completed by the end of February, 2015 and results presented to CDOT at the progress meetings. These properties included: specific gravity test,

gradation analysis, Standard Proctor and modified Proctor compaction tests, triaxial tests of the Colorado Class I backfill of crushed rocks and wide-width tensile strength test of geo-fabric.

Task 15 Probabilistic analysis of GRS abutment performance analysis: The completion of the probabilistic analyses of abutment performance is expected by October 15, 2015.

Task 16 Large scale abutment model tests: The large scale abutment tests using the Tiger Cage is progressing and is expected to complete three tests by October 15, 2015. These tests will be performed with instrumentation program including horizontal and vertical earth pressure, settlement and geo-fabric strain measurements and the results compared to the numerical analysis results for mutual validation.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Survey, Evaluation and Long- term Monitoring of the EDC GRS Wall Performance for Multiple Spans CDOT Bridges Replacement Project (GRS Walls)
Study No. 214.05b

Background The CDOT Region 1 project to replace the twin bridges over the Union Pacific Railroad and Smith Road incorporates innovations that implement the CDOT/FHWA mandate − EDC GRS (Geosynthetic Reinforced Soil) abutment technology. These twin bridges carry I-70 east and westbound traffic on three-span, (107'+ 158' + 155') horizontally-curved steel welded-plate girder structures. The mid-span piers are founded on deep foundation; however, the GRS abutments are supported by spread footings and founded on embankments. The objective of the study is to validate the performance of GRS walls for multi-span bridges, and the use of geofabric without positive connections to the fascia blocks for GRS retaining walls.	Reporting Period: 04/1/13 through 06/30/13 Type: SP&R Start: 12/26/13 Ver: End: blank (12/31/15 on Kent's Spreadsheet) Principal Investigator(s): Dr. Jonathan Wu, Professor (UCD) Dr. Peter Hoffman, Professor (UCD) Study Manager: Aziz Khan, ARIB Study Panel Members: Panel Chair: ShingChun (Trever) Wang, Bridge Design and Management Skip Outcalt, ARIB Ilyess Ksouri, Materials and Geotechnical Branch Steve Yip, Bridge Design and Management Branch Teddy Meshesha, Bridge Design and Management Roman Jauregui, Region 1 Resident Engineer Matt Greer, CO Division of FHWA Daniel Alzamora, Resource Center, FHWA Duane (Jay) Hendickson, Region 1 Resident Engineer Larry Quirk, Region 1 Project Engineer

The PI has not submitted a report the this quarter.

TASKS AND MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
10/15/13		12/26/13	Issue PO and notice to proceed to researcher(s). *CDOT issued PO on 12/26/13 to CU Denver's Reinforced Soil Research Center (Wu & Hoffman).*
1/23/14		1/23/14	*Kickoff Meeting was held 1/23/14, and plans of the geotechnical instrumentation contractor (Shannon & Wilson) were discussed.*
3/31/14	20		Task 1: Review and analyze construction records, material properties, and monitoring data. *CU Denver achieved a state of test readiness. Delays may cause difficulties: no test samples were available as of May 15, 2014, and the person doing the tests will depart June 15. In accord with the contract, six reinforcement samples will be tested. CDOT's RFP did not request soil testing, but results of limited testing will be used by CU Denver in order to properly accomplish analysis tasks.* *In view of the presentation by FHWA's Adams and Nicks at the 2014 Geo-Congress, continued monitoring over the two year study period is emphasized. FHWA's tests indicate that initial deformation may be followed by a comparable amount of secondary deformation.*
9/30/14			Task 2: Conduct finite element analysis of Phase 1 and 2 GRS walls, prepare interim report, and present findings as needed.
3/31/15			Task 3: Compare results of finite element analysis with measured data of Phase-2 wall, and make recommendations for future GRS walls.
9/30/15			Task 4: Prepare draft final report.
12/31/15			Task 5: Submit a final report that addresses comment on the draft and make presentation.
9/12/14			Tasks associated with Phase II Wall
2/20/15			Complete geotechnical monitoring during construction
3/31/15			Geotechnical consultant delivers data report and data to CDOT
10/13/15			Research Draft final report
12/15/15			Publish final report

SIGNIFICANT EVENTS

6/30/15 Construction delays and the decision to move all GRS wall test sections to Phase 2 have resulted in significant delays to this study.

5/15/14 Construction project delays have resulted in no test samples being made available as of May 15, 2014.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Surface Chloride Levels in Colorado Structural Concrete
Study No. 214.06

Background CDOT Bridge Design and Management Branch is investigating updates to its reinforcing steel corrosion protection strategies. In order for this to result in an efficient and economical policy, the branch needs to know how surface chloride levels vary at different structures around the state, with respect to differences in local climate, traffic volume, location on the bridge (deck at wheel lines, deck at gutter, curb faces and tops, barrier faces, columns exposed to splash.) To be meaningful chloride samples need to be taken from exposed locations on bridges with similar concrete to current concretes (built after 1978), taken at a shallow depth sufficient to eliminate seasonal chloride variations (~0.5 in.). Data can be used to determine the appropriate corrosion protection strategies across the state. The study will be a cooperative effort between CDOT research staff and the selected university. CDOT will collect the samples while the university will analyze the samples and data and provide a report on the results.	Reporting Period: 4/1/15 through 06/30/15 Type: SP&R Start: 9/6/13 End: 3/31/16 Ver: Principal Investigator(s): Yunping Xi, CU Study Manager: Aziz Khan, ARIB Study Panel Members: Panel Chair: Ali Harajli, Bridge Design and Management Eric Prieve, Materials and Geotechnical Branch Matt Greer, CO division of FHWA Lynn Croswell, Bridge Design & Management Skip Outcalt, ARIB Dave Weld, ARIB Mike McMullen, Retired CDOT Bridge Engineer

TASKS AND MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
9/15/13		9/6/13	Issue PO and notice to proceed
10/8/13	100	10/08/13	Kick Off meeting: Dr. Xi and Ben Gallaher made a presentation on the scope of work.
12/12/13	100	12/12/13	CU-Boulder established the contract for the project
3/31/14	100	3/31/14	Task 1: Literature Review
12/31/14	100	12/31/14	Task 2: Sampling Matrix. Study CDOT bridge database and prepare a list of bridge for sample collection
3/31/16	20		Task 3: Field Sampling
6/30/16	20		Task 4: Laboratory testing
6/30/16	10		Task 5: Analysis of test results
5/31/16			Draft final report
6/30/16			Publish final report

SIGNIFICANT EVENTS

12/12/2013: CU-Boulder established the contract for the project. An account number was assigned to the research team.

10/07/2014: A meeting was held at CDOT. Sampling method was determined. Sampling criteria were established. CU-Boulder research team will develop a list of bridges for sampling.

5/5/15: A meeting was held at CDOT. Available sampling results and analyses were presented. A plan for

modifying the list of bridges was discussed.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Modified StreamStats Application to Accommodate Known Flows
Study No: 215.02

Background

The Colorado Department of Transportation (CDOT) has been an active participant in the development and use of the StreamStats interface (http://water.usgs.gov/osw/streamstats/colorado.html). StreamStats currently implements regression equations for estimating instantaneous peak flows for various return flows (2 -, 5-, 10-, 25-, 50-, and 100- year floods) or equivalent Annual Exceedance Probabilities (50-, 20-, 10-, 4-, 2-, and 1- AEP flood). StreamStats develops these peak-flow estimates for any location in Colorado, using the regression equations and basin characteristics for the entire contributing area to a particular hydrologic pour point; however, CDOT often needs to estimate flow for an area downstream of a known control such as a reservoir release or a weir. In order to facilitate use of the StreamStats interface to address these known flows, the StreamStats interface will be customized for use by CDOT and will include a new "partial basin" tool to provide estimates of flow for only those drainage basins downstream of the known control. The U.S. Geological Survey (USGS) Colorado Water Science Center (CWSC) will develop methodology to allow CDOT personnel to estimate flows for "partial basins" and will work with the StreamStats development team, through the USGS Wisconsin Internet Mapping (WiM) group, to implement the methodology for incorporating known flows.

The objective of the study is to develop the techniques and implement a new tool for use by the CDOT personnel to produce partial-basin delineations and estimates of flow for Colorado. The results will be disseminated via a web interface.

The primary benefit of this research to CDOT will be to allow them to estimate peak flows for areas downstream of known discharges. This enhancement to the StreamStats interface will extend the utility of StreamStats to additional areas within Colorado currently limited by flow structures. The StreamStats interface will be more robust and useful for the CDOT staff.

Reporting Period: 04/01/2015-06/30/2015

Start: 4/1/2015
Complete: 9/30/2016
Contract:

Principal Investigator(s):
Kristine Verdin, P.E., USGS,
303-236-6929

Study Manager:
Aziz Khan, Research Branch
303-757-9255

Study Panel Leader:
Amanullah Mommandi,
Project Development Branch
303-757-9044

Study Panel Members:
Alfred Gross, Staff Hydraulics
Veronica Ghelardi, Hydraulics Engineer,
FHWA - Resource Center

FHWA Washington Contact:

MILESTONES

Planned	% Done	Achieved	Description, Discussion, and Related Issues
5/15/15	100	May 2015	Identification of the appropriate control structures within the National Inventory of Dams to include in the StreamStats interface.
6/30/15	100	June 2015	Geolocate all dams on the StreamStats flow accumulation grids and delineate watersheds for each dam location.
6/30/15	100	June 2015	Develop database of the basin characteristics necessary for evaluation of the regional regression equations for each watershed
12/31/15	10	December 2015	Modify StreamStats interface to allow for generation of partial basin estimates.
6/30/16	0	March 2016	Test the interface by USGS and CDOT personnel

SIGNIFICANT EVENTS

The database enhancements needed for the Partial Basin tool were developed. This involved selecting the National Inventory of Dams locations with contributing drainage areas of 1 square mile or more. This resulted in 129 dams for which basin delineations and characteristics were to be developed. These dam locations were snapped onto the StreamStats flow accumulation raster using both automated techniques and manual inspection, where needed. The contributing areas for each of the dam locations were developed using the StreamStats flow direction grid and standard GIS processing techniques. The basin characteristics necessary for evaluation of the regional regression equations by StreamStats were developed. These characteristics were (1) watershed area (sq. mi.), (2). mean watershed elevation (feet), (3). mean watershed slope (%), (4). percent of the watershed with elevation above 7500 feet (%), (5). mean annual precipitation (inches), and (6). the mean 6-hour, 100-year precipitation (inches). This database was passed to the team modifying the StreamStats interface. The initial map services were developed and published and the new REST Service to calculate the regulated upstream areas was started, along with the client-side functionality.

PROJECT COMPLETION

The project completion/end date is September 30, 2016 per the CDOT/USGS Funding Contract and the project is expected to be completed on time.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Real-time monitoring and evaluation of streambed scour at selected bridges in Western Colorado, 2015-2016

Background

The Colorado Department of Transportation (CDOT) maintains roadway crossings over streams and rivers where sediment transport and channel alignment changes can affect the structural stability of bridges. Streambed scour at bridges (bridge scour) can affect bridge integrity by undermining bridge substructure components (typically pier-footings) during streambed-scour producing flow events. Determination of the structural stability of bridges during and immediately following peak streamflow (high-flow) events is often necessary to assess the safety of bridges. Performing safety assessments with manned equipment can be difficult, hazardous, and time consuming. Survey comparisons of pre- and post-high flow streambed elevations are often used in place of high-flow monitoring. However, continuous monitoring of streambed elevations can reveal erosion and deposition patterns that would not be observed utilizing pre- and post-high flow surveys.

The installation of streambed scour monitoring instrumentation can provide site specific assessment of scour conditions at bridges in real-time as well as supplement CDOT's current techniques (on-site inspections at flows exceeding thresholds specified in the bridge's Plan of Action). The USGS NWISweb and WaterAlert services can provide near real-time information and alerts regarding streambed scour conditions at monitored locations. These services can provide information to relevant CDOT staff and other interested parties rapidly through webpage access or through automated email or text messages. These services also allow for rapid dissemination of information to CDOT staff to help them ensure public safety during scour events as well as alert staff to possible maintenance needs and/or long-term bridge stability needs. The data collected by the USGS as part of this study will also demonstrate methodologies that are useful for monitoring scour at bridges where mitigation of current designs is not possible or is cost-prohibitive, while maintaining needed bridge safety.

Reporting Period: 04/01/15 – 06/30/15

Start: 04/01/15
Complete: 09/30/16
Contract:

Principal Investigator(s):
Mark F. Henneberg, USGS,
970-628-7149

Study Manager:
Aziz Khan, Research Branch,
303-757-9255

Study Panel Leader:
Amanullah Mommandi,
Project Development Branch
303-757-9044

Study Panel Members:
Alfred Gross, Staff Hydraulics

FHWA - Resource Center

FHWA Washington Contact:

MILESTONES

Planned	% Done	Achieved	Description, Discussion, and Related Issues
10/1/15	100	April 1, 2015	Agreement between CDOT and USGS finalized and signed.
3/1/15	100	May 2015	Selection of 2 bridge scour monitoring sites
5/1/15	20	July 31, 2015	Bridge scour monitoring instrument installation

SIGNIFICANT EVENTS

A few of the early milestones were delayed because of the tardiness of the agreement being signed but that should not affect any other milestones. The two bridge scour sites were selected and right-of-way permits were obtained in May. River flows are currently too high to safely install the echo sounders. Data collection will begin as soon as flows recede to safe levels to permit construction work at the selected bridges.

PROJECT COMPLETION

The initial project completion/end date is September 30, 2016 per a CDOT/USGS bilateral task order signed April 1, 2015; however ideally, this study would be extended and become a long term data collection effort.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

CDOT Joint Removal Implications Constructability and Thermal Analysis
Study No: 215.01

Background

With the deterioration of US infrastructure systems, bridge maintenance, performance and the necessity of deck joints and bearings has gained the attention of states, municipalities, engineers, researchers, and practitioners alike. Deck joints are designed to accommodate translational and rotational movements between two adjacent bridge spans while bearings are used in bridges to transfer vertical, translational and rotational loads from the superstructure to the abutments or piers. It is commonly recognized that deck joints and bearings are costly and complicated to install (Tsiatas and Boardman 2002; Wasserman 1987). In addition to greater complexity of construction, deck joints and bearings require maintenance throughout their life cycles to remain functional and to prevent damage to the superstructure (Hawk 2003). Water seepage through deck joints can cause significant corrosion to the superstructure and substructures below (Lam et al. 2008; Loveall 1985). The American Association of State Highway and Transportation Officials (AASHTO) also recognizes this problem in the commentary section of Chapter 2.5 of the current AASHTO LRFD Bridge Design Specifications, which states:

"*Other than the deterioration of the concrete deck itself, the single most prevalent bridge maintenance problem is the disintegration of beam ends, bearings, pedestals, piers, and abutments due to percolation of waterborne road salts through the deck joints. Experience appears to indicate that a structurally continuous deck provides the best protection for components below the deck."*

The current abundance of deck joints originated from the straightforwardness of simply supported bridge span design. During the time that simple span bridge construction was prevalent, the infrastructure system in the US rapidly grew into its current state and a large quantity of bridges and roadways were constructed. Without information available regarding the necessary maintenance and repair costs of deck joints, a multitude of bridges were constructed as multiple simple spans and separated at each pier with deck joints (Tsiatas and Boardman 2002). Recently, the use of structural analysis software programs by practicing engineers has become commonplace and, therefore, continuous span bridges can now be designed with less effort than in the past. However, a substantial amount of older bridges with numerous deck joints still exist and pose maintenance and performance challenges to state transportation agencies. Bridge retrofits to eliminate deck joints and bearings have been proposed and implemented in many cases to alleviate the substandard performance of the deck joints (Burke Jr. 1990; Tsiatas and Boardman 2002; Wasserman 1987). However, the removal of deck joints in order to improve bridge performance and increase longevity raises questions about the thermal movement bridges must be able to accommodate.

In the current AASHTO LFRD Bridge Design Specifications discussion of thermal effects and discussion of joints and bearings are found in Sections 3 and 14, respectively. Multiple requirements for the performance of deck joints and bearings are

Reporting Period: 4/01/15 - 6/30/15
Type: SP&R Start: 04/22/15 Ver:

Completion/End Date: 04/21/2017

Principal Investigator:
Hussam Mahmoud, CSU & Rebecca Atadero, CSU

Study Manager:
Aziz Khan, Research Branch, 303-757-9522

Panel Leader:
Jessica Martinez, Bridge Design and Management (Panel Leader)
Trever Wang, Bridge Design and Management (Co-Panel Leader)

Study Panel Members:
Bahrooz Far, Bridge Unit Leader - Region 3
Richard Griffin, Research Administration
Gabriela Vidal, Research Administration
Mathew Greer, FHWA-Colorado
Thomas Kozojed, Bridge Design and Management Branch
Joe Jimenez, R-3 Structural Trades
Kane Schneider, R-3 Maintenance

listed, but the number of each should be minimized for a given bridge. The definition of setting temperature is provided and processes for estimating thermal movements of bridges are explained (AASHTO LRFD Bridge Design Specifications 2014). Current AASHTO provisions only require consideration of the total longitudinal thermal movement based on the average bridge temperature. A vertical thermal gradient is defined in Section 3, but consideration of this gradient is not required if past experience indicates that it is not necessary to maintain the functionality of the bridge. No mention of gradient in temperature is mentioned along the transverse or longitudinal axes. This over-simplified approach may result in a minimized design and analysis time since a uniform cross-sectional temperature can be assumed, but could potentially lead to inaccurate estimation of the demand resulting from the thermal loads and subsequent poor bridge performance.	

MILESTONES

Planned	**% done**	**Achieved**	**Description, Discussion, and Related Issues**
April 2015	100	5-13-15	Kick-off Meeting and Minutes

TASKS

Planned	% done	Achieved	Description, Discussion, and Related Issues
	80		**Task 1: Conduct extensive literature review and multi-state survey** Notes: Extensive literature review complete, survey administered to state DOTs
	80		**Task 2: Identify the representative bridges** Notes: Initial bridge selection report submitted
	25		**Task 3: Collaborate with CDOT on developing an instrumentation plan and data collection** Notes: Scratch gages, strain gages, thermocouples, and string pots/LVDTs selected as instrumentation for finely tuned bridges. General instrumentation plan developed.
	10		**Task 4: Develop three-dimensional finite element models of the selected bridges and model calibration against collected field data** Notes: Simply supported span of one suggested bridge modeled in CSi Bridge
	0		**Task 5: Design detailing for joint elimination**
	0		**Task 6: Life-cycle cost assessment**
	0		**Task 7: Illustrative design examples**
	0		**Task 8: Quarterly reports & Final report**

SIGNIFICANT EVENTS

04/23/15 Project officially begins. Project completion/end date is 03/31/2017.
05/13/15 Kickoff meeting at CDOT
7/1/15 MPC project with matching funds is awarded

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Development of Cost-Effective Ultra-High Performance Concrete (UHPC) for Colorado's Sustainable Infrastructure

Study No: 215.04

Background

UHPC is generally defined as a very high strength cementitious composite material, containing optimally graded aggregate and fiber reinforcement. Typical composition of UHPC includes portland cement, fine aggregate, water, supplementary cementitious materials, a superplasticizer, and discrete reinforcing fibers. Unlike conventional concrete, coarse aggregate is not typically used. Compressive strength of UHPC ranges between 25,000 psi [170 MPa] and 33,000 psi [230 MPa] in most cases (Ahlborn et al. 2008). To achieve such a high strength, UHPC has a very high cementitious content and a low water-tocementitious materials ratio (e.g., less than 0.25). The porosity characteristics of UHPC reduce the flow of water, thereby improving durability in aggressive environments (FHWA 2011). Use of a superplasticizer addresses the workability concern of UHPC.

The overarching goal of the research is to seek a systematic methodology that will adequately formulate UHPC with regionally available materials in Colorado. The three specific objectives are:

- To develop a cost-effective UHPC using locally available materials
- To quantify and characterize the behavior of the developed Colorado-specific UHPC to meet the need of CDOT
- To propose step-by-step implementation guidelines for use of the UHPC in Colorado's bridge construction projects

Reporting Period: 6/25/2015 through 6/30/2015
Type: SP&R Start: 6/25/15 End: 5/19/2018
PO: 41105452

Principal Investigator:
Jimmy Kim, UCD

Study Manager: Aziz Khan, Rich Griffin of Applied Research and Innovations Branch

Study Panel Leader:
Mansour (Mike) Mohseni, Bridge Design and Management Branch

Study Panel Members:
Andrew Pott, Bridge Design and Management Branch
Eric Prieve, Materials and Geotechnical Branch
Matt Greer, CO división of FHWA

MILESTONES/TASKS

Planned	% done	Achieved	Description, Discussion, and Related Issues
6/25/15		6/25/15	Notice to Proceed
7/29/15			Kickoff Meeting
10/31/15			Task 1: Conducting a comprehensive literature search
10/31/15			Task 2: Identification of locally available materials for UHPC formulation in Colorado
n/a	-	-	Task 3:An experimental parametric study to optimize the performance of UHPC
6/30/16			Task 3.1: Constituent materials
10/31/16			Task 3.2: Design of UHPC mix.
2/28/17			Task 3.3: Mix and formulation procedures and evaluation
10/31/17			Task 3.4: Testing of cured UHPC specimens and date interpretation
10/31/17			Task 3.5: Quality assurance
2/28/18			Task 4: Development of a design mix and procedures manual
3/19/18			Draft Final Report
5/19/18			Final Report

SIGNIFICANT EVENTS

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Web-based Historic Flood Information Database for Colorado
Study No: 107.10

Background

Reliable peak-streamflow information is critical for the proper design of infrastructure (bridges and dams) and the development of floodplain inundation maps. At gaged sites, where sufficient long-term streamflow data have been collected, statistics are available using data in the U.S. Geological Survey (USGS) National Water Information System (NWIS) database or other sources of flood information. However, estimates also are needed at ungaged sites where site-specific streamflow data are not available. Additionally, in areas with short periods of record and few streamgages, large uncertainties may occur in the regional-regression equations used for estimating streamflow. Additional flood information will improve the reliability of the regional-regression equations in the Plains hydrologic region of eastern Colorado should these equation be updated in the future. This study will provide two years of flood data at 10 sites in eastern Colorado.

The objective of this study is to collect peak-streamflow data at 10 sites in the Plains hydrologic region of eastern Colorado using crest-stage gages. The scope of this effort for each site includes site identification, site construction, and site installation in the first year and survey levels, data collection, data entry, streamgage records, publication of peak streamflow, and site maintenance in the first and second years. In order for this data collection effort to be most effective, crest-stage gage operation will need to continue for a period of 10 years or more, well beyond the 2-year scope of this project.

Reporting Period: 04/01/15 – 06/30/15

Start: 10/01/15
Complete: 09/30/16
Contract:

Principal Investigator(s):
Michael Kohn, P.E., USGS,
303-236-6924

Study Manager:
Aziz Khan, Research Branch,
303-757-9255

Study Panel Leader:
Amanullah Mommandi,
Project Development Branch
303-757-9044

Study Panel Members:
Alfred Gross, Staff Hydraulics
Veronica Ghelardi, Hydraulics Engineer,
FHWA - Resource Center

FHWA Washington Contact:

MILESTONES

Planned	% Done	Achieved	Description, Discussion, and Related Issues
10/1/15	100	April 1, 2015	Agreement between CDOT and USGS finalized and signed.
3/1/15	100	May 2015	Selection of 10 crest-stage gage sites
4/1/15	100	June 11, 2015	Crest-stage gage installation
10/31/15	20	October 31, 2015	Data collection and maintenance for 2015
10/31/15	0	October 31, 2015	Finalize annual peak measurement for 2015
11/30/15	0	December 31, 2015	Publish annual peak measurement in NWIS for 2015
10/31/16	0	October 31, 2016	Data collection and maintenance for 2016
10/31/16	0	October 31, 2016	Finalize annual peak measurement for 2016
11/30/16	0	December 31, 2016	Publish annual peak measurement in NWIS for 2016

SIGNIFICANT EVENTS

A few of the early milestones were delayed because of the tardiness of the agreement being signed but that should not affect any other milestones. The 10 crest-stage gages were installed the first two weeks of June 2015 and all gages are collecting data. The data collection will continue until October 31, 2015 and the 2015 annual peak flood will be published in the USGS NWIS database by December 31, 2015 for all 10 sites.

PROJECT COMPLETION

The initial project completion/end date is September 30, 2016 per a CDOT/USGS bilateral task order signed April 1, 2015; however ideally, this study would be extended and become a long term data collection effort.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

CDOT Snow Route Optimization Research Project
Study No: 314.01

Description: The purpose of this project is to provide route optimization that will improve snow removal operations in Region 4 (Boulder Maintenance Area) by reducing cycle time and simultaneously utilizing fewer resources. This will balance resources and levels of service across our regional network to assign work crews to the roads that require them rather than traditionally assigning them to geographical boundaries. Current cycle times in some areas are above and not compliant with the LOS outlined. The Research project will provide a full review of current operations (including vehicle and material utilization) and suggestions as to how efficiency and job satisfaction can be improved. The project will also look at the current DSS employed by CDOT and identify any enhancements that could be utilized to improve/help with decision making. This will be done in conjunction with decision makers in the Boulder Maintenance area.	**Reporting Period:** 04/01/15 through 06/30/15 **Type:** SP&R **PO:** 411000103, **Amount**: $80,000 **Invoiced to Date:** $10,000 **Start:** 12/31/13 **End:** 12/01/16 **Principal Investigator(s):** Stephanie Haynes, Project Manager Tel 303-436-2916 stephanie.haynes@vaisala.com Bert Murillo, Sales Manager Tel 314-346-2094 bert.murillo@vaisala.com Matt Harley, Traffic Weather Consulting Specialist Tel +44 121 683 1218 matt.harley@vaisala.com **Study Manager:** David Reeves, CDOT Division of Transportation Development, 303-757-9518 **Study Panel Members:** Isaac Lopez (Champion) Ed Gentry (Co-Champion) Kyle Lester (Sponsor) Mark Eike Tim Miles David Reeves Thomas Aguilar Wesley Templeton

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
	100	01/06/14	Notice to Proceed
	100	03/12/14	Kick-Off Meeting
04/30/14	100	06/06/14	Current operations defined and investigation complete into other road authorities operations
06/30/14	100	09/02/14	First draft of report compiled. Discussions with Boulder Maintenance area continuing into improvements needed to decision making. Colin Walsh investigating software applications that may enhance the process.
07/31/14	100	04/02/15	Task 3 – Review by CDOT. Feedback received via email and in a conference call on 4/2/15.
12/31/14	50		Task 4 – Final research report and review. Final report submitted to CDOT 6/10/15. Follow-up meeting held 7/8/15. Report recommendations to be reviewed with the study panel in-person at the end of August 2015.

SIGNIFICANT EVENTS

- 02/25/15 – Draft report submitted.
- 04/02/15 – Conference call to review draft report and CDOT comments/questions.
    - Tom Aguilar, Mike Eike, Arnold Lopez, Eddie Gentry – CDOT
    - Steve Sciscione, Rose Mooney, Bert Murillo, Matt Harley, Colin Walsh – Vaisala
- 06/10/15 – Final report submitted.
- 07/08/15 – Follow-up meeting to discuss next steps.
    - David Reeves, Tom Aguilar, Dave Weld – CDOT
    - Stephanie Haynes, Bert Murillo, Tony Coventry – Vaisala
    - Decision to schedule final review meeting with Study Panel at the end of August.

ANTICPATED WORK NEXT PERIOD

- Meet with the Study Panel to review the research report and recommendations, anticipated end of August.
- Publish report.

ISSUES

- No issues to report.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

CDOT Winter Maintenance Performance Measure
Study No: 314.02

Description: CDOT has deployed a network of Road Weather Information Systems (RWIS) statewide tomonitor atmospheric and pavement conditions. However, the analysis and maintenance decisions and procedures driven by the RWIS data are not standardized across the state in any uniform method that would tie all this data in some simple and useful fashion. Currently the main performance measure for snow removal is the Bare Regain Time – which is the time after a winter event ends to when CDOT regains bare-lane driving conditions where 95 percent of the road is free of snow and ice. This performance measure does not take advantage of all the real time road and weather technology such as the RWIS sites, invasive and non-invasive road sensors (friction sensors and traffic monitoring devices, ATR, Radar, etc) to name a few. All these other technologies would help our maintenance crews and managers in conjunction with Maintenance Decision Support System (MDSS) better manage our roads during a storm. It would also assist management and public policy personnel with better metrics to report to the public and transportation stakeholders. We would like to learn from what Idaho Transportation Department (ITD) in this area and try to implement what they did in Region 4 along I-25 north. ITD has integrated MDSS with a Winter Performance Index and a Mobility Index. A detailed review of the ITD system will be performed and tested in CDOT Engineering Region 4.	**Reporting Period:** 4/1/15 through 06/30/15 **Type:** SP&R **PO:** 411000388, **Amount**: $24,780 **Start:** 01/27/14 **End:** 12/01/16 **Research Project Manager(s):** Stephanie Haynes, Project Manager Tel 303-436-2916 stephanie.haynes@vaisala.com Bert Murillo, Sales Manager Tel 314-346-2094 bert.murillo@vaisala.com Colin Walsh, Traffic Weather Consulting Product Manager Tel +44 121 683 1231 colin.walsh@vaisala.com **Study Manager:** David Reeves, CDOT Division of Transportation Development, 303-757-9518 **Study Panel Members:** Kyle Lester (Co-Champion and Sponsor) Thomas Aguilar (Champion) Mark Eike Isaac Lopez Ed Gentry Wesley Templeton Matthew Rickard

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
Q2	100	05/01/14	Kick off /detailed training of ITD Index and Winter Performance Index
JUN 14-SEPT 14	100	05/01/15	CDOT Review and Feasibility of Mobile Sensor. Mobile sensors used in Region 4 throughout 2014-2015 winter season with good success. Mobile sensor data will not be incorporated into the Winter Index at this time.
SEPT 14-FEB15	50		Assessment of Winter Performance Measures for Non-Invasive Installations. RWIS data from 2014-2015 downloaded and analyzed. Draft report will be sent to CDOT for review/comments.
MAR 15-JUL 15			Final Research Report.

SIGNIFICANT EVENTS

- 07/08/15 – Meeting to review progress and discuss next steps.
    - David Reeves, Tom Aguilar, Dave Weld – CDOT
    - Stephanie Haynes, Bert Murillo, Tony Coventry – Vaisala
    - Draft report will be submitted to CDOT for review. Vaisala will present study findings/recommendations at the Superintendents' meeting the first week of September.
    - Opportunities for additional training on Navigator II and the Winter Index were discussed.

ANTICPATED WORK NEXT PERIOD

- Incorporate general overview/recommendations on statewide RWIS program into research report.
- Submit draft report, incorporate CDOT comments, and finalize.
- Present recommendations at Superintendents' meeting the first week of September.
- Follow-up on CDOT training needs/opportunities.

ISSUES

- CDOT personnel did not use the Winter Index during the 2014-2015 season, so Vaisala will not be able to include any initial feedback in the research report.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Highway Deicing Products and Applications Best Practices
Study No: 314.03

Description:

Application of deicers is a key tool for winter maintenance staff to improve the friction of roads affected by snow and ice. Deicers melt snow and ice and prevent, weaken or break the bonds between snow/ice and the pavement, facilitating removal by plows. While laboratory tests can provide some indication of field performance, field testing is preferred because it is more realistic. However, it can be difficult to reproduce field tests because of ever changing conditions in the field environment. Documenting sufficient data over the course of an entire winter when different types and amounts of deicers are applied for different weather scenarios can provide insight to deicer effectiveness, recommended application rates, and associated pavement conditions.

The objectives of the proposed research are to develop a measurement and analysis tool to assess the performance of deicers in the field based on friction. The performance measure will be based on pavement friction before, during, and after deicer application. Field tests will be conducted to develop and refine the methods of data collection and analysis. A successful performance measurement tool will:

- provide the ability to evaluate the performance of deicers at any given location and time, during any weather scenario
- correlate pavement friction to deicer type and application rate, and
- ideally, be useful for correlations to laboratory tests.

Reporting Period: 4/1/2015 through 6/30/2015
Type: SP&R
PO: 400000042
Start: 06/12/14
End: 12/31/16

Principal Investigator:
Michelle Akin, P.E.
Western Transportation Institute,
Montana State University
michelle.akin@coe.montana.edu
406-994-6356

PI Team Members:
Anburaj Muthumani
Laura Fay
Na Cui

Study Manager:
David Reeves, CDOT Division of Transportation Development, 303-757-9518

Study Panel Members:
Wes Templeton / Deputy Maintenance Superintendent (Region 4, Section 1) – Project Champion
David Wieder (retired) / Maintenance & Operations Branch Manager (HQ)
Kyle Lester / Maintenance Superintendent (Region 5, Section 3)
Mark Eike / Deputy Maintenance Superintendent (Region 3, Section 6)
Matt Rickard / ITS Maintenance Manager (ITS/Operations)
Tom Aguilar / LTC Ops (Region 4)
Ed Gentry / LTC Ops (Region 4)

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
	100	6/12/14	Notice to Proceed
07/22/14	0		Kick-Off Meeting
09/30/14	100	09/30/14	Task 1 – State of the Practice Survey
10/31/14	100	11/9/14	Task 2 – Plan & Coordinate Field Testing
12/31/14	100	3/2/15	Task 3 – Field Test Trials
06/30/15	75		Task 4 – Winter I Field Testing & Data Analysis
06/30/16			Task 5 – Winter II Field Testing & Data Analysis
08/31/16			Task 6 – Draft Report
10/31/16			Task 5 – CDOT Review Draft Report
12/31/16			Task 5 – Final Report

SIGNIFICANT EVENTS

- 6/30/15
  - — Identified individual storms along I-70 from Taper logs and combined deicer application data with rwis and atmospheric data
  - — Began grouping storms with similar atmospheric conditions and deicer applications
- 3/31/15
  - — Received Taper logs periodically from Region 4 throughout the quarter
  - — Received taper logs for I-70 test sections for winters 2013–14 and 2014–15
  - — Received rwis, mdss, and atmosphereic data for I-25 and I-70 test sections monthly throughout the quarter
  - — Conducted a winter field test with Halliday RT3 on I-25 test sections 298S and 277N during a winter storm Feb. 28 – Mar 2
  - — Continue to identify individual winter storms and combine rwis, atmospheric and taper log data
- 12/31/14
  - — Collected baseline (dry pavement) friction data with Halliday RT3 on November 9, 2014
  - — I-25 test sections by milepost: 298S, 277N, and 251S
  - — I-70 test sections by milepost: 253W, 247E, 221W, 218W, 217E, 214E, 213E, 205W
  - — Received Taper logs from Region 4 on 12/19/14
- 9/30/2014
  - — Received seasonal deicer logs delineated by region, highway and patrol from FY08–FY13
  - — Developed modified TAPER log to track deicer application and plow data on routes with DSC111 grip data
  - — First field trip to collect information from RWIS sites with DSC111 grip data. Planned on five locations, learned DSC111 grip data is not available at all five locations, but there may be others in the state that can be used.
- 6/30/214
  - — Developed a revised schedule
  - — Drafted survey to identify current CDOT deicers, typical application rates, RWIS locations, and use of MDSS and AVL.

ANTICPATED WORK NEXT PERIOD

- Finish assembling Taper, rwis and atmospheric data for individual storms. Begin looking for trends in friction improvement in respose to deicer application.

ISSUES

- I-25 experienced relatively mild winter storms. A storm predicted in early April had forecast temperatures too similar to the field test conducted Feb 28 – Mar 2. Additional field tests (likely three) will need to be conducted during winter 2015–16. The goal is to observe a variety of storm conditions (temperature, snowfall intensity/depth).

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Automated Placement and Retrieval of Traffic Cones
Study No: 314.04

Background	Reporting Period: 04/01/2015 through 06/30/2015 Type: SP&R PO: 411002554 Start: 9/01/14 End: 8/1/17 Contract Amount: $40,000 Principal Investigator: LuAnn Theiss Texas A&M Transportation Institute (TTI) 979-845-9949 Study Manager: David Reeves, CDOT Applied Research & Innovation 303-757-9518 Study Panel Leader: Kyle Lester, Director of Highway Maint. Division 303-512-5218 Study Panel Members: Gary Goldsberry, Deputy Maint. Supt. (R1) Kyle Lester, Director of Highway Maint. Division Darrel Lingk, Statewide Regional Safety Officer Richard Marquez, Deputy Maint. Supt (R2) Alfonso Martinez, Maint. Asset Manager Adam Padilla, Maint. Supt. (R2) Bill Pentek, Deputy Maint. Supt (R5) Chris Volkert, Equipment Manager Tracie Smith, Risk Management Supervisor Tyler Weldon, Maint. Engineer
The placement and retrieval of lane closures is one of the most dangerous activities our maintenance forces perform on a daily basis. It generally requires two FTE, one driving the vehicle and one standing in a well on the back of the truck leaning out and placing the cones. This individual on the back of the truck is minimally protected from the other vehicles on the roadway. When picking up the lane closure, the truck backs up the highway while the individual on the back leans out and retrieves the cones. The act of backing up a closed lane is in itself dangerous. Leaning out from the vehicle placing a 15 – 30 pound cone contributes to sprains and strains increasing workmen's compensation claims and injury lost time. Colorado DOT would like to obtain (1) a report detailing the available automated cone placement and retrieval devices, as well as (2) recommendations for best practices for automated traffic cone placement and retrieval. CDOT anticipates that the benefits of the research would include increased safety of CDOT crews, reduced workman's compensation claims, and reduced lost time accidents. The increased safety of CDOT crews is the primary benefit of this research.	

MILESTONES

	Task	Start	Finish	Months After Contract Award 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Percent Complete
	Project Management	**9/1/2014**	**4/30/2015**																			**Ongoing**
	Email Quarterly Project Status Reports	*9/1/2014*	*4/30/2015*	✉			✉			✉			✉			✉			✉			N/A
	Email Monthly Progress Reports	*9/1/2014*	*4/30/2015*	✉	✉	✉	✉	✉	✉	✉	✉	✉	✉	✉	✉	✉	✉	✉	✉	✉	✉		
1	**Hold Kick-Off Meeting**	**9/1/2014**	**9/15/2014**																			**Task 1**
	Kick-Off Meeting	*9/1/2014*	*9/15/2014*	△																		100%
2	**Collect Product Information**	**9/16/2014**	**12/31/2014**																			**Task 2**
	Literature Review, Survey and Product Data Matrix	*9/16/2014*	*12/31/2014*				△	→								△						90%
	Task 2 Tech Memo	*11/1/2014*	*9/31/2015*													◆						
3	**Develop Recommendations**	**10/1/2015**	**11/30/2015**																			**Task 3**
	Revise Product Data Matrix and Develop Recommendations	*10/1/2015*	*10/31/2015*														□					0%
	Task 3 Tech Memo	*10/1/2015*	*11/30/2015*														→	◆				
4	**Prepare Research Report**	**12/1/2015**	**2/28/2016**																			**Task 4**
	Draft Research Report	*12/1/2015*	*1/31/2016*																□	→		0%
	Final Research Report	*1/1/2016*	*1/31/2016*																		◆	
	Project Close-Out Meeting	*1/1/2016*	*1/31/2016*																		△	

Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb

✉ **Email**
△ **Meeting**
→ **CDOT study panel review**
□ **Draft Deliverable**
◆ **Final Deliverable**

Red text in the milestones table denotes dates adjusted from the original contract.

SIGNIFICANT EVENTS

Second Quarter 2015

- The researchers attended a demonstration of the Artec Mobile Channelizer System on June 18, 2015.

ANTICIPATED WORK NEXT PERIOD

Third Quarter 2015

- Complete Task 2 tech memo by September 30, 2015.
- Survey CDOT study panel regarding evaluation criteria.
- Revise draft product data matrix.
- Receive and tabulate CDOT ranking of products.
- Develop recommendations and submit Task 3 tech memo by November 30, 2015.

ISSUES

- The researchers respectfully request modification of the project schedule as shown in the milestones table above. The red text denotes proposed dates (adjusted from the original contract) and these dates need to be approved by CDOT.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

DEFEnS – DEbris and Flood Early warNing System

Background

Forecasting peak streamflows and river stage in basins impacted by wildfires is problematic. The volume of water available as direct runoff is magnified because of the steep hydraulic grades and hydrophobic soils, which inhibit infiltration; reduce the time of concentration; and increase peak stage. The runoff response to weather events can be reduced to minutes (min) rather than hours (hr), which for emergency management agencies and the public leaves little time for a proactive response.

Three non-contact stage and surface-water velocity radars will be installed to measure stage and velocity of debris and water flood flows that may develop in response to rainfall thresholds. Installation of the radars will augment the gage infrastructure associated with the September 2013 CDOT/USGS Waldo Burn Scar Emergency Gaging Network, which includes three precipitation gages, one non-contact stage radar, and one video camera.

In addition to the video feed, near-real time data including (1) stage thresholds such as 25, 50, and 75 percent-bankfull and (2) surface-water velocity will be measured, recorded and integrated with a communication network. Cell phones, VHF radios operating at a nominal frequency of 174 MHz, which is compatible with NWS broadcast parameters, and satellite telemetry will be deliver these metrics to CDOT staff. Gage data and thresholds can be monitored by the NWS WFO throughout the event. In addition to mass media dissemination, Flash Flood Statements can be broadcast immediately over NOAA Weather Radio – All Hazards to better alert emergency responders to the potential magnitude and impact of the flooding.

Communication challenges (topographic extremes, shadowing) may occur because of the location of the sensors (streamgages and raingages). Repeaters or additional radios may be needed to address these challenges; however, relying solely on a terrestrial-based communications system may not be prudent. Other communication platforms such as satellite telemetry will be piloted during this phase of the project either as a proof-of-concept or to provide redundancy in the rare event the radio network fails. Alternative infrastructure will include GOES and Iridium networks. Arrival times and routing of debris and flood waves at specified receptors or locations will be estimated using the stage and surface-water velocity measured at each gage location. Basin and hydraulic channel characteristics will be established using ArcGIS and measured in the field, where appropriate. Algorithms in NHDPlus Version 2 may be evaluated to estimate of flow and velocity in Waldo Canyon.

Reporting Period: 04/01/15 – 06/30/15

Start: 10/01/14
Complete: 09/30/17
Contract:

Principal Investigator(s):
John Fulton, USGS,
303-236-6890

Study Manager:
Aziz Khan, Research Branch,
303-757-9255

Study Panel Leader:
Amanullah Mommandi,
Project Development Branch
303-757-9044

Study Panel Members:
Alfred Gross, Staff Hydraulics

FHWA - Resource Center

FHWA Washington Contact:

MILESTONES

Planned	% Completed	Achieved	Description, Discussion, and Related Issues
Oct 2015	100	Apr 2015	Executed agreement between CDOT and USGS
Apr 2015	100	Apr 2015	Selected basin-of-interest
May 2015	100	Jun 2015	Initiated procurement of radars, data loggers, and ancillary equipment
May 2015	100	Jun 2015	Submitted an access permit to the U.S. Forest Service and received verbal approval-to-proceed
May 2015	100	Jul 2015	Procurement awarded for radars, data loggers, and ancillary equipment
May 2015	100	Jun 2015	Conducted recon and siting visits
Jun 2015	90	Jul 2015	Received equipment
Jun 2015	90	Jul 2015	Installed equipment and conducted GNSS surveys

SIGNIFICANT EVENTS

A slight delay in the project start date was associated with the execution of the CDOT and USGS agreement; however, the timing will not affect subsequent milestones. Data collection will continue through October 2015 at which time the radars will be taken off-line for the winter. The units will be placed back on-line in the spring 2016 and operated through October 2016.

PROJECT COMPLETION

The project completion/end date is September 30, 2017 in accordance with the CDOT/USGS bilateral task order signed April 1, 2015.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Snow on LED Traffic Signals
Study No: 40.06

Description:

Snow and ice build-up on traffic lights during storms is a safety issue for vehicular traffic. While there have been attempts to mitigate this issue through a variety of approaches, none of them have been successful. The replacement of existing traffic lights with lower power LED lights has reduced the amount of heat available, which has previously aided in keeping the lens clear of snow and ice. CDOT seeks a solution that will maintain the low power consumption of the replacement traffic lights as well as not require either application of coatings immediately prior to a storm or cleaning of snow and ice during a storm.

The research effort encompasses the following phases:

- literature review
- application and testing of various superhydrophobic coatings
- perform scaled aerodynamic analysis of traffic signal in windtunnel
- initial field testing of coatings
- optimize heat transfer pathways
- final design

Reporting Period: 7/1/15 through 9/31/15
Type: SP&R
PO: 411005657
Start: 05/05/15
End: 06/05/18

Principal Investigator(s):
Dr. Ronald A. L. Rorrer, University of Colorado – Denver, 303-556-2553

Study Manager:
David Reeves, CDOT Division of Transportation Development, 303-757-9518

Study Panel Members:
Andi Staley / Region 3 Resident Engineer
Jeff Lancaster / City & County of Denver
Jim Chase / Region 1 Traffic & Safety – Maintenance/Operations Supervisor
Mike DelCupp / DTD Data Collection Unit Manager
Rich Sarchet (Retired) / Region 3 Traffic & Safety – Traffic Operations Engineer

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
Phase I			
	100	08/05/13	Notice to Proceed
08/13/13	100	08/13/13	Kick-Off Meeting
10/15/13	100	10/15/13	Task 1 - Literature Review
12/15/13	50%	6/30/14	Task 2 - Testing and analysis of superhydrophobic coatings
01/15/14	100%		Task 3 - Scaled model testing of aerodyncamics
3/15/14	100%		Task 4- Laboratory evaluation of superhydrophobic coatings.
12/30/14			Task 5- Field evaluation of superhydrophobic coatings
			Draft Report
			CDOT Review Draft Report
			Final Report
Phase II			
8/15/15	70%	11/30/15	Task 1-Modification of air flow around the individual lenses/visors (August 2015-November 2015)
10/1/15	0%	5/1/16	Task 2- Field testing of the current coating system (October 2015-May 2016)
2/1/16	0%	5/1/16	Task 3- Field test aerodynamic modifications (February 2016-May 2016)
5/1/16	0%	8/15/16	Task 4- Investigate other adhesive systems (May 2016-September 2016)
Phase III			**Future Phase to be Proposed to Mountain Plains Consortium**
8/15/16		10/30/16	Task 5-Field test other adhesive systems (September 2016-October 2016)
11/1/16		4/30/17	Task 6- Field test combined modifications (November 2016-April 2017)
4/1/17		8/15/17	Task 7- Investigate potential heating elements (April 2017-August 2017)

SIGNIFICANT EVENTS

- 08/05/13 - Notice-to-Proceed sent
- 08/13/13 - Kick-off meeting held at CDOT
- 09/17/13 - Received three traffic signals from CDOT for analysis and testing
- Completed literature review
- 11/15/13 - Created rapid prototype model or traffic light for aerodynamic testing
- 11/01/13 - tested commercial non-transparent superhydrophobic coating
- 12/15/13 – Created in-house superhydrophobic coating
- 3/15/14- Evaluated various superhydrophobic coatings for efficacy in snow and ice mitigation
- 6/30/14-Developed aerosol application of superhydrophobic coatings

ANTICIPATED WORK NEXT PERIOD

- August 2015- Create modifications to wind tunnel traffic light to utilize air flow around lens to direct snow and ice away from lens.
- October 2015 - Begin testing of top superhydrophobic candidates from lab results in field.
- February 2015- Make aerodynamic modifications to actual traffic light and test in field.
- May 2015-Investigate other adhesive systems as potential alternatives.

ISSUES

- Field testing access is a potential issue for both coatings and aerodynamic modifications.
- Other adhesive systems that offer longer term durability may need to be investigated.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Evaluating the Effects of Concrete Pavement Curling and Warping on Ride Quality
Study No. 414.02

Background

Curling and warping are two phenomena that occur as a result of these differences within a slab. Curling is a behavioral response of a concrete slab subjected to a change in temperature with depth. The deformed shape and internal stress development due to curling is a commonly calculated as a function of the temperature gradient, coefficient of thermal expansion, geometry, elastic properties, density, and subbase restraint (support). Curling occurs throughout the pavement's life. From the time that the concrete is stiff enough to resist deformations, curling is a dominant mechanism. Warping is a similar type of response of a concrete pavement, but is the result of changes in a slab's moisture state rather than its temperature. Significant warping can even occur within hours of placement if proper control is not instituted to prevent moisture loss at the surface. Long-term warping also can lead to a permanently deformed slab. Most often warping will lead to slabs with a "bowl" geometry, since moisture loss at the surface and resulting shrinkage is the predominant mode. But occasionally warping can be a slab to an "arch" geometry in wet climates or when a significant loss of moisture into the subbase occurs.

On highway 34 near Greeley in 2012 a 9-inch concrete pavement (Class P) was placed on pavement that underwent full depth reclamation (FDR). The eastbound lanes had smoothness problems related to slab curl while the westbound lanes did not. This result provides a side-by-side comparison of a curling pavement and non-curling pavement that have the same design.

Using the east and west bound lanes as a comparison, this study will evaluate the construction conditions that lead to curling and warping.

Reporting Period: 4/1/15 - 6/30/15
Type: SP&R Start:8/20/13 PO:211019805:

Principal Investigator(s): David Merritt, Transtec Study

Manager: Skip Outcalt

Study Panel Members:

Panel Chair: Gary DeWitt, Region 4 Materials Eric Prieve, Materials and Geotechnical Branch Brandon Joy, Materials and Geotechnical Branch Donna Harmelink, FHWA Colorado Division

TASKS AND MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
5/31/13	100	6/12/13	Establish Study panel and develop scope of work
7/31/13	100	7/15/13	Issue bid invitation: purchase requisition was entered on 7/4/13, the first day FY14 funding codes could be used.
8/31/13	100	7/31/13	Select PI from bidders. Received one proposal from Transtec on 7/25/13
9/15/13	100	8/20/13	Issue PO and notice to proceed
9/9/13	100	9/9/13	Task 1: Kickoff meeting
12/1/13	100	12/31/13	Task 2:Literature Search
2/15/14	100	8/31/14	Task 3: Information Collection - Information collection included: pavement design information, construction dates, paving sequence/paving logs, concrete mix design and materials, QC/QA test results, and any profile data collected preciously by CDOT or the contractor.
7/1/14	100	2/13/14 8/6/14	Task 4: Field Evaluations - The initial site visit (Feb. 2014) was used to install temperature sensors in the pavement slab, document pavement condition, and collect diurnal profile data (using the CDOT profiler) over a 24 hour period. - During the second site visit (Aug 2014), diurnal profile data was collected over a 24+ hour period and slab temperature data during profiling were downloaded from the temperature sensors installed previously.
9/1/14	100	6/20/15	Task 5: Data Analysis - The following analyses were completed under this effort: pavement profile data analysis using ProVAL, slab curing analysis and correlations to roughness and slab temperature gradients, early-age slab temperature analysis using HIPERPAV, long-term performance analysis using AASHTOWare PavementME.
10/1/14	90		Task 6: Draft Report
12/1/14			Task 6: Final Report

SIGNIFICANT EVENTS

- Analysis of all data collected during the project were finished during this reporting period.
- The Draft Report was mostly completed during this period.
- A no-cost time extension for the project was granted by CDOT to allow adequate time for CDOT review of the final report and possibly an in-person project meeting to report results. The new project end date is Dec. 31, 2015.

ANTICIPATED EVENTS FOR Q2 2015

- The Draft Report and Implementation Plan will be completed and submitted to CDOT for review and comment. Any requested revisions will be completed and the Final Report submitted to CDOT as the project deliverable.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Outside Review of CDOT Low-Volume Road Treatment Strategies for Hot Mix Asphalt (HMA) Pavements
Study No: 415-01

Background

Within the last two years, CDOT has changed features of the Pavement Management System to utilize a Drivable Life metric rather than Remaining Service Life along with Tiering (consideration of traffic loading aligned with different pavement treatments). Roads greatly affected by this pavement design are rural roads with low-volume traffic counts that have an annual average daily traffic (AADT) of less than 2,000 and an average annual daily truck traffic (AADTT) of less than 100.

An outside review and re-examination of our long established low-volume road treatment strategies for HMA pavement is needed. Evolving maintenance methods and improvements in pavement design and HMA mixes may require adjustments to our low-volume road treatment strategies. An independent review of the new process and forecasting the system condition to a future 15-year benchmark could offer alternatives in type of pavement treatments resulting in efficiencies in budgeting and construction efforts. A review of processes utilized in other states with similar climate and budgets could expand CDOT's use of non-traditional construction approaches by capturing expected performance life while recognizing different levels of existing roadway conditions. CDOT manages a total of 9,105 centerline miles in its pavement network, 2,806 centerline miles of which are low-volume roads. Currently, CDOT asset management estimates that an annual expenditure of twenty-four million dollars ($24 M) is required for treatment of low-volume roads.

The ultimate goal of the study is to incorporate the latest state-of-the-practice into our low-volume road asphalt pavement treatment program. Also, this study aims to improve life-cycle cost of Colorado's HMA pavements by applying the most appropriate low-volume road treatment strategies at the most appropriate time.

Reporting Period: 4/01/15 - 6/30/15
Type: SP&R Start: 05/05/15 Ver:

Completion/End Date: 11/5/2017

Principal Investigators:
Rebecca Atadero, CSU
Khaled Ksaibati, KK Engineering

Study Manager:
Gabriela Vidal, Research Branch

Panel Leader:
Gary DeWitt, CDOT Region 4 Materials
Stephen Henry, CDOT Materials and Geotechnical Branch

Study Panel Members:
Bob Mero, CDOT Region 1 Materials
Michael Stanford, CDOT Materials and Geotechnical Branch
Jay Goldbaum, CDOT Materials and Geotechnical Branch
Tyler Weldon, CDOT Division of Highway Maintenance
Donna Harmelink, FHWA Colorado Division

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
May 2015	100	5/27/15	Kick-off Meeting
Summer 2015			CDOT Survey
Summer 2015			Local Governments Survey
Summer 2015			Low Volume Roads Committee Survey

TASKS

Planned	% done	Achieved	Description, Discussion, and Related Issues
8/1/15	90		Task 1: Comprehensive Plan Development
11/1/15	10		Task 2: Literature Search
11/1/15	20		Task 3: Regional Survey
2/1/16	20		Task 4: CDOT Survey
11/1/16	-		Task 5: Synthesis Preparation
5/1/17	-		Task 6: Impact of current strategies on future conditions
5/1/17	-		Task7 :Treatments performance
5/1/17	-		Task 8:Evaluating Treatments on Roads with Marginal Conditions
8/1/17	-		Task 9:Review CDOT Treatment Strategies
Ongoing	-		Task 10:Progress Reports Submission
8/1/17	-		Task 11: Final Presentation Preparation
8/1/17	-		Task 12:Final Report Preparation

SIGNIFICANT EVENTS

5/5/15 Research project and funds are awarded.
5/27/15 Kickoff meeting held at CDOT R4

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

CDOT Oil & Gas Impacts on Transportation
Study No: 312.01

Background Colorado's oil and gas industry is continually evolving, and there have been considerable changes in drilling techniques and geographic focus since the 2010 CDOT research study on Enegery Development and the Transportation System. This research study builds upon the 2010 study and aims to answer the following questions: • What are other states with similar levels of oil and gas activity doing to recoup the costs of the industry's impacts to roads? • What areas of the state are currently most affected by the oil and gas industry and what might future scenarios of oil and gas activity in Colorado look like? • How do the trip generation characteristics of oil and gas development differ based on variables such as: well organization (i.e., number of wells per pad), drilling technology (i.e., horizontal vs. vertical), fracking activity, pipeline infrastructure, and development phase (i.e., construction, drilling, completion, production)? • What are the truck typologies and duration for various phases of development and what are the corresponding impacts (ESAL)? • What are the industry's impacts (in terms of reduction of drivability life and costs to offset the impacts) on a per-mile basis? • What variables affect the level of industry impacts (e.g., current drivability life, seasonality of activity, freeze/thaw cycle, duration of activity compounded with environmental impacts, etc.) • How do the bridges on the State Highway system with weight and/or height restrictions affect the industry (e.g., rerouting requirements, bridge replacements for improved access)? • What State Highways are generally most susceptible to industry impacts, given the current road conditions, current oil and gas activity and future development scenarios?	Reporting Period: 04/1/15 through 07/30/15 Type: SP&R Start: 06/1/14 End: 08/30/15 PO: 401000205 for $99,999 (Expires 5/31/2016) PO: 411004836 for $19,670 (Expires 3/13/2016) Principal Investigator: Jenny Young, PE, AICP, Felsburg Holt & Ullevig Study Manager: David Reeves Study Panel Members: Stephen Henry –Pavement Management Aziz Khan –Research Amanullah Mommandi –Research Mark Nord –Staff Bridge Erik Sabina –Information Management Michelle Schueuerman –Multimodal Planning Branch Ermias Weldemicael – Transportation Performance Danny Wells –Oversize/Overweight Permits Aaron Willis –Statewide Planning

MILESTONES

Planned Completion Date	% Complete	Achieved	Description, Discussion, and Related Issues
8/30/15	95%		Task 1 – Project Management and Meetings; PM ongoing; 6 of 6 TAC meetings
9/30/14	100%	12/15/14	Task 2 – State Highway Inventory;
9/30/14	100%	10/9/14	Task 3 – Research; technical memorandum documenting research of other states' funding practices used to address increasing trnaposrtation costs due to resource development

11/30/14	100%	12/8/14	Task 4 – Existing and Future Oil & Gas Activity; study team has documented currently producing wells and well permit locations throughout the state; met with COGCC to discuss future oil and gas activity
12/31/14	100%	3/31/15	Task 5 – Cost Implications of Oil & Gas Vehicles; study team has researched oil and gas trip generation characteristics and truck typology and has begun developing a tool for calculating per-mile costs of oil and gas industry impacts
1/31/15	100%	1/31/15	Task 6 – Oil & Gas Model Update; study team has begun to compile information on state highways most impacted by current oil and gas activity
8/30/15	90%		Task 7 – Documentation; a draft technical research report was submitted to CDOT on February 13, 2015
Transportation Commission Preperation Tasks			
3/31/15	100%	3/26/15	Task A – Estimate magnitude of statewide industry impacts
4/15/15	100%	4/15/15	Task B – Prepare presentation and associated material to solicit input on research methodology and findins
8/30/15	95%		Task C – Conduct outreach of study results to stakeholders including STAC and Transportation Commission

SIGNIFICANT EVENTS

4/15/15 Finalized informational memo for Transportation Commission

6/26/15 Completed comparison of state transportation budgets