COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

SHRP-LTPP Support
Study No: 3.20

Background

Strategic Highway Research Program (SHRP)/Long-Term Pavement Performance (LTPP) program entered into its second decade beginning in 1998. A portion of the discussions at the national level is now centered on SHRP product implementations.

The SHRP LTPP program is currently engaged in extended monitoring of selected LTPP sites across the country. For the western states FHWA currently contracts with Nichols Consulting Engineers, Inc. for data collection and management.

There are currently ten LTPP sites in Colorado being monitored by FHWA contractors:
080200, SPS-2, EB I-76 (Denver), MP 18.4
080800, SPS-8, EB Chestnut Street
081029, GPS-6S, WB U.S. 40 (Lay), MP 69.75
081053, GPS-6C, WB U.S. 50 (Delta), MP 75.3
083032, GPS-3, EB I-70 (Glenwood Spring), MP 95.75
087035, GPS-7S, EB I-70 (Glenwood Spring), MP 95.75
087776, GPS-3, EB I-70 (Denver), MP 289.7
087780, GPS-6S, WB U.S. 24 (Manitou Springs), MP 291.36
087781, GPS-6B, WB U.S. 50 (Las Animas), MP 402.18
087783, GPS-6S, EB I-70 (Rifle), MP 67.66

CDOT's role in this monitor is limited to providing work zone traffic control. Because of staffing changes and travel budget limitations, CDOT research staff will generally not be participating in related national meetings.

For more information reference:
http://www.fhwa.dot.gov/research/tfhrc/programs/infrastructure/pavements/ltpp/

Reporting Period: 1/1/14 through 3/31/14
Type: SP&R Start: 1/1/89

Principal Investigator(s):
Nichols Consulting Engineers, Inc.-Kevin Senn, Western Regional Project Manager,775-329-4955

State LTPP Coordinator: Aziz Khan, ARIB, 303-757-9522
State Field Work Coordinator: Skip Outcalt, 303-757-9984

FHWA Washington Contact:
Aramis Lopez, Jr., P.E., LTPP Team Leader
Tel: 202-493-3145

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
02/28/01	100	02/28/01	Coordinate the acquisition of weather data from the SPS-2 and SPS-8 sites near Barr Lake with the SHRP Western Region. SPS-2 and SPS-8 experiments were designed to investigate the effects of various structural and environmental factors on the long-term performance of rigid pavements.

09/30/01	100	09/31/01	Secure funding for participating in a FHWA pooled fund study to examine the practicability of using new equipment for acquiring WIM data at the SPS sites including the SPS-2 site in Colorado.
04//03/03	100	04/04/03	Attend the SHRP/LTPP regional meeting in Reno. Present the status of the LTPP sites and give a presentation on LTPP Product Implementation Activities
07/30/03	100	09/30/03	Investigation of the permeability/drainability of the permeable asphalt treated base (PATB) test sections at the SPS-2 sites at Barr Lake. The investigation will be a coordinated effort between FHWA and CDOT Research.
03//25/03	100	03/25/03	Establish an FWD Calibration Center in Region 6
08/30/03	100	08/30/03	Meet with the representatives of FHWA, CDOT's Chief Engineer, to discuss the status of the LTPP Studies in Colorado
09/15/03	100	10/23/03	Investigation of the LTPP sites on US 40 West of Lay, I70 at Rifle, SH 24 at Manitou Spring, and SH 50 at Delta acquiring 4 and 6 inch cores
09/28/04	100	02/15/05	Conduct lab testing on the acquired 6-inch cores for the sites at Lay, Rifle, Manitou Spring, and Delta.
01/31/04	100	04/15/04	Submit Rehabilitation data sheet for the LTPP sites at Rifle and Lay.
06/30/05			Annual field review of all the SHRP sites in Colorado. Marking and replacing missing signs.
04/30/04	100	03/25/04	Provide estimated traffic (sheet 10) and if available monitored traffic data for all the in-service sites to the SHRP/LTPP Western contractor.
12/30/04	100	06/30/05	Coordinate with FHWA to evaluate the condition of the WIM equipment for the SPS-2 site at Barr Lake and decide on a course of action to install a bending plate or just use the existing WIM (piezo- electric cables).
5/15/06		5/15/06	Bending plate WIM equipment was installed by IRD on I-76 at MP 39.7 near Keensburg for monitoring the traffic and truck weights for the SPS-2 site.
3/15/07	100		Coordinate with SHRP Western Region in acquiring core samples and bulk sample of subgrade, and base for some of the SPS-2 test sections on I-76 near Barr Lake. Decisions need to be made as who pays for this field investigation.
3/31/07	100	3/12/07	PI to submit sampling of materials at SPS-2 Site (I76 and Barr Lake). Nichols Consulting has been chosen by FHWA to conduct the sampling. Roberto de Dios is working with Nichols Consulting regarding traffic control for the coring and sampling activity. The revised Material Sampling and Testing Plans for LTPP SPS-2 and LTPP SPS-8 Projects were e-mailed to Skip and Roberto on 03/12/07.
7/25/07	100	N/A	Participate in the TRB Expert Task Group (ETG) committee for the LTPP Materials data collection and analysis in October 2005. The ETG is charged with setting priorities and work plan for data collection and analysis, technical assessment of ongoing work and recommendation to enhance the success of the LTPP products. With the retirement of Ahmad Ardani, CDOT will no longer have a representative on this ETG.
8/31/07	100	9/21/07	Perform another round of LTPP data collection. Nichols Consulting was hired by FHWA for this job.
12/31/07	100	12/31/07	Samples cored from the SHRP test location (SH 40) were brought to the Staff Materials and Geotechnical Branch Lab for testing and analysis. CDOT Lab personnel are testing these samples. These cores were collected by Nichols Consulting.
01/13/08	100	01/13/08	Roberto de Dios attended the LTPP Coordinators sessions at the TRB annual meeting.
4/29/08	100	4/29/08	Assessment, calibration and performance evaluation of LTPP SPS Weigh-In-Motion (WIM) Site ID 080200.
12/31/10	100	12/01/10	Field inspection of LTPP sites by FHWA contractor
12/31/11	100	9/30/11	Field inspection of LTPP sites by FHWA contractor

12/31/12		Cancelled	Field inspection of LTPP sites by FHWA contractor: because of coordination and weather issues site visits were cancelled for this year.
12/13/13		10/3/13	Field inspection of LTPP sites by FHWA contractor: CDOT provided traffic control for these inspections.
4/4/13	100	4/4/13	Aziz Khan attended a web cast hosted by Deborah Walker of FHWA to discuss the "Role and Responsibilities of LTPP State Coordinators".
7/24/13		7/31/13	SPS-2 WIM validation: FHWA contractors are scheduled to visit Colorado's: we presume this occurred. Contractor does not need traffic control and does not contact Research.
12/31/12			SPS-10 Evaluation of Warm Mix Asphalt vs. Hot Mix Asphalt is commencing.
			Future visits and other activities will depend on FHWA decisions

SIGNIFICANT EVENTS

12/31/13 CDOT's Region Materials Engineers have been contacted by Nichols Consulting Engineers, Chtd. to locate possible locations for SPS-10 study sites. The SPS-10 will evaluate the performance of Warm Mix Asphalt vs. Hot Mix Asphalt

01/31/12 The Study Manager, Roberto DeDios, retired from CDOT, A new study manager and the state coordinator will be name in the future. Aziz Khan is acting as the State Coordinator.

05/24/11 CDOT Field Test Engineer Skip Outcalt provided the requested information that was available at that time.

04/17/11 The Principal Investigator Kevin Senn of Nichols Consulting Engineers, Inc. solicited input on rehabilitation and maintenance activities on active LTPP test sections for the next two years.

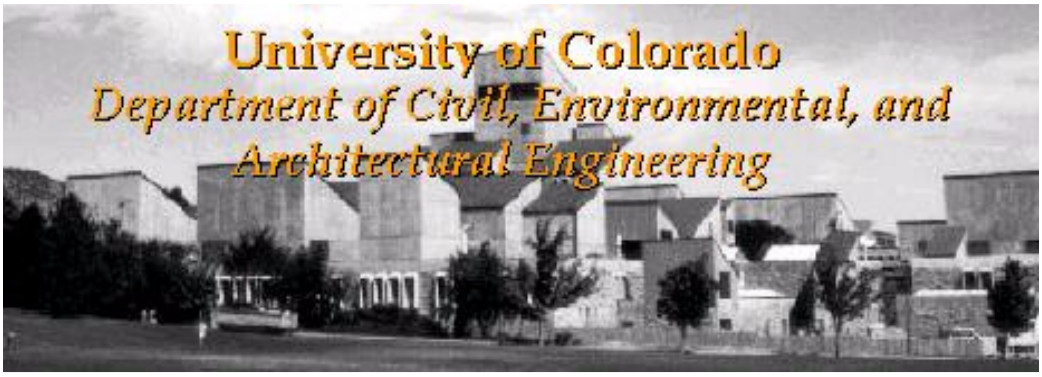
12/01/10 FHWA and Nichols Consulting Engineers (NCE) conducted the Long-Term Pavement Performance (LTPP) seminar at the Turnpike Conference Room in Materials Lab building.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Colorado Local Technical Assistance Program (LTAP)
Study No: 4.50

Background	Reporting Period 1/1/14 through 3/31/14 Type: SP&R Start: Ver:
The Colorado LTAP Center is part of the nationwide FHWA LTAP program aimed at providing technology transfer and exchange of transportation information to local communities. In all, there are over 57 LTAP programs in the United States, with at least one LTAP Center in each state. Providing training for rural and urban transportation communities is the number one priority of Colorado LTAP. Colorado LTAP is administrated in partnership with the FHWA by the Colorado Department of Transportation (CDOT). Funding for the program is as follows: FHWA (50%), CDOT (25%), and the University of Colorado at Boulder (25%).	Principal Investigator(s): Yunping Xi, University of Colorado/Boulder (303)-492-8991 Study Manager: Joan Pinamont (303) 757-9972 Study Panel Members: Joan Pinamont, CDOT (303) 757-9972 Rick Santos, FHWA

SEE NEXT PAGE FOR COLORADO LTAP QUARTERLY REPORT



COLORADO LTAP

LTAP Quarterly Report

Report Period
January 1, 2014 – March 31, 2014

Submitted to:
Federal Highway Administration
Colorado Department of Transportation
University of Colorado at Boulder

Submitted by:
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Colorado LTAP

3rd Quarter

January 1 – March 31, 2014

Program Dashboard:

Total number of training sessions*: 18
Total number of participants*: 460
Total number of participant hours*: 3,094
Total Newsletter circulation: 1,475 (hard-copy), 209 (electronic)
Total Brochure circulation: 1,012 (hard-copy), 185 (electronic)
Total number of LTAP FTEs: 2.25
*(*Only for classes held between January 1 and March 31.)*

Four Strategic Focus Areas

In 2008, FHWA issued guidance indicating that LTAP Centers transition from the traditional six tasks to a work plan that addresses the LTAP focus areas outlined in the national plan. The four focus areas are further divided into two general groups - the first three designed around external outcomes and processes, and the last a function of both internal and external LTAP center organization.

1. Safety – worker and roadway safety;
2. Infrastructure Management;
3. Workforce Development; and
4. Organizational Excellence

Colorado LTAP's FY2013-2014 work plan reflects this outline and completed activities emphasize these four focus areas.

A. Program Administration

- January 1 – March 31, 2014, Colorado LTAP had two full-time staff persons working for the center – Program Director, Renée Railsback and Training Coordinator, Cassandra Guild.
- The graduate student, Noom Musiket, continued working part time for the center this quarter. Noom handles the library loan program and training resources.
- Office Assistant, Marty Butcher also worked some during January through March. April will be her last month to work under Temporary Aid requirements and will have to be off until October.

B. Training

- Colorado LTAP continued offering courses in its three training programs – *Roads Scholar I*, *Roads Scholar II* and *Supervisory Skills and Development Program.* This quarter, there were 18 days of training events offered - 10 of the classes were *Roads Scholar I*, 3 *Roads Scholar II*, and 5 Supervisory Skills and Development Program class. Class evaluations received an average of 95% success for classes held this quarter.
- There were 7 Roadway Safety, 3 Worker Safety, 3 Infrastructure Management, and 5 Workforce Development courses offered this quarter. A full list of the courses offered in each focus area is shown in the table below. The list also shows the distribution of attendance between Local (City/County), Tribal, State, Federal, and Other (Contractors, etc.).
- There were 10 Roads Scholar I graduates and 5 Supervisory Skills graduates presented with their plaques this quarter.
- Started in 2012, Roads Scholar II program had its first program graduate last quarter. This quarter, a special award was designed and ordered to commemorate Rob McArthur, Town of Green Mountain Falls as the first graduate of the Roads Scholar II program. He will be presented with his awards at the June Advisory Board meeting.
- Details on any training course are available upon request; additional detail is also provided in the annual Work Plan.
- A complete list of classes held in the third quarter, January 1 – March 31, 2014 is included in Appendix A.

Class Name	Hrs. per Class	# Sessions	# Contact Hours						# Paritic pants	Total Participant Hours
				Local	State	Federal	Tribal	Other		Hrs/class x #Part.
ROAD SCHOLAR I PROGRAM										
Signing, Pavement Markings & MUTCD	7	4	28	98	0	0	0	1	99	693
Roadway Safety & Work Zone Traffic Control	7	3	21	106	0	1	0	2	109	763
Equipment Maintenance & Inspection	7	3	21	88	0	1	0	3	92	644
TOTAL Road Scholar I:	**21**	**10**	**49**	**292**	**0**	**2**	**0**	**6**	**300**	**2100**
ROAD SCHOLAR II PROGRAM										
Disaster Site Worker Outreach	4	3	12	40	0	0	0	2	42	168
TOTAL Road Scholar II:	**4**	**3**	**12**	**40**	**0**	**0**	**0**	**2**	**42**	**168**
SUPERVISORY SKILLS & DEVELOPMENT PROGRAM										
Developing the Leader Within	7	1	7	15	0	0	0	0	15	105
Written Communication	7	1	7	13	0	0	0	0	13	91
Ethics for Supervisors	7	1	7	23	0	0	0	0	23	161
Verbal Communication	7	1	7	33	0	0	0	0	33	231
Who's Coming Through the Door Today?	7	1	7	33	0	0	0	1	34	238
TOTAL Supervisory Skills:	**35**	**5**	**35**	**117**	**0**	**0**	**0**	**1**	**118**	**826**
TOTALS:	**60**	**18**	**96**	**449**	**0**	**2**	**0**	**9**	**460**	**3094**

C. General Program Support

Some tasks serve to advance all four focus areas. These are addressed in the *General Program Support* section of the report. Two tools utilized for technology transfer and information exchange include our quarterly newsletter publication and free lending library.

C0.1 Newsletter & Information Exchange

One of the main tools used for technology transfer and information exchange was a quarterly Newsletter publication. Newsletter articles were designed to educate transportation personnel to produce enhanced maintenance, workforce and safety outcomes. Due to the LTAP Spring schedule, the Spring Newsletter was postponed until next Quarter.

C0.2 Library Materials Distribution

- Continued to manage our in-house lending library consisting of over 2500 items - instructional videos, publications, and resources focusing on transportation design, maintenance, safety, and workforce related topics.
- In the third quarter, 61 items were *loaned* free to local transportation agencies. The table below shows the distribution by type and focus area. The most frequently loaned topics were work zone traffic control, maintenance of unpaved roads, winter maintenance, and chainsaw safety.
- Separate from the lending library, 835 FREE publications, guidebooks and videos were distributed.
- 166 titles of new or updated materials were added to the library in the 3rd Quarter – 0 books, 0 CDs, 0 DVDs, and 166 Free Publications. The new free publications addressed a variety of pavement management systems, concrete overlays, highway and intersection safety, asset management, emergency response, and work zone safety.
- Between January 1 – March 31, $641 was spent on new materials and postage for mailing loaned materials.

Focus Area	Pubs Checked Out	Free Pubs Sent
Highway Safety	10	154
Infrastructure Management	24	553
Value Delivery	0	12
Worker/Workplace Safety	21	108
Workforce Development	3	8
None	3	0

C0.3 Program Marketing, Outreach & Research

The Program Marketing, Outreach and Research portion of our work plan covers a spectrum of daily tasks related to technical assistance, local agency outreach, program marketing and promotion, and field research. We find making personal contact is an invaluable opportunity to assess local agency needs and challenges.

Technical Assistance** & **Research

- On average, LTAP center staff spends about 25% time providing technical assistance to local agencies. This quarter, there were more technical assistance requests than usual.
  - Examples of technical assistance provided this quarter included requests on paving gravel roads, cleaning and maintaining irrigation ditches, winter maintenance manuals, local agency requirements for traffic control supervisors (TCS) in rural areas, requirements for breakaway sign posts, traffic control technician training (TCT), gravel road maintenance and design manuals, MUTCD pocket guides, manufacturers to calibrate retroreflectometers, pavement marking management practices, and proper routing of concrete pavements.

Marketing** & **Outreach

- The Colorado LTAP Director, Renée Railsback, is a new Board Director on the Colorado Chapter of the American Publics Works Association (APWA). The CO APWA held one Board meeting this quarter.
- Renée was a presenter at the APWA Annual Awards Luncheon which recognizes local agencies throughout Colorado for their innovation and ingenuity in transportation projects. Renée presented two Awards in the "Structures" category to City/County of Broomfield and City of Pueblo.
- Renée is the Secretary and Newsletter editor of the Colorado Association for Roadway MAintenance (CARMA). With articles written by other CARMA board members, Renée designed and produced the CARMA Spring Newsletter. This publication is a main conduit to promote the Spring Street Conference; of which LTAP is a main developer.
- Colorado LTAP provided a booth of educational, promotional and free library materials at a select few transportation meetings and conferences that benefit the scope of the program. These opportunities also help to advance staff knowledge base on the latest transportation technologies, processes, and resources. Each year, this quarter is when the majority of transportation conferences occur.
  - A total of $516 was spent on Program Marketing and Outreach related to attending and preparing for the *Construction Inspection, Asphalt,* and *Concrete Conferences*. LTAP was provided a FREE vendor booth space at each of those conferences. LTAP made great connections with local agencies interested in hosting training free at their locations.

C0.4 Out-of-State Travel

FHWA encourages centers to participate in the activities of state, regional, and national organizations such as the National LTAP Association (NLTAPA), and to participate on NLTAPA work groups and committees when appropriate. NLTAPA helps expand the capacity of each Center to best meet customer needs by developing local agency resources for Center use, building awareness about LTAP amongst the transportation community, providing Centers a voice in Washington, and assisting FHWA in developing future strategies for the Program.

- The Program Director attended the National LTAP Association Business meeting held in Washington DC during TRB; and participated in meetings related to Executive Committee and Association business.
  - At the TRB meeting, Renée gave a presentation related to Colorado's recent flood event, about *Preparing Local Agencies and LTAP Centers for Responding to Natural Disasters*.

We have received 3 additional requests to present this presentation since – Wyoming Safety Congress as one of the guest speakers, South Dakota's Local Roads Conference, and as part of the LTAP Culvert Maintenance & Design classes.

- The Colorado LTAP Director currently serves on the National LTAP Association Executive Committee as the *President* of the Association. As President, Renée participated in the following activities:
  - Program Leadership planning meetings with the LTAP managers from FHWA's Technology Partnerships Program (TPP).
  - Monthly Executive Committee conference calls related to Association business.
  - NLTAPA Work Group Meetings for Safety, Communications, Training Resources, Partnerships, and National Conference Planning.
- Third quarter expenses of $922 were spent on Out-of-State Travel; however, this includes the $375 National LTAP Summer Conference registration fee, and does not include the TRB meeting airfare which was paid in December (and accounted for in the 2nd Quarter report).

C.1 Safety Programs

Colorado LTAP has a long history of providing infrastructure related training, technology transfer and technical assistance through its traditional services and Roads Scholar I and II training programs. There were 10 training classes offered on Safety topics this quarter. Programs and training completed between January 1 and March 31 in this focus area include:

- *Signing, Pavement Markings and MUTCD* – This was the first Roads Scholar I Core course offered this quarter. The class addressed the following topics: Roadway Signing - sign standardization, sign types, sign location and placement, retroreflectivity standards; and Pavement Markings - markings & delineators, retroreflectivity, object markers, pavement markings. An overview of the MUTCD with detailed discussion of chapters: 1. General Information, 2. Signing, and 3. Pavement Markings was covered. The class stressed understanding of the MUTCD its language and principles. There was discussion of specific work experiences regarding signing and the MUTCD. Eric Ferron with FHWA returned to teach this class. Participants would like to include more videos, more information dealing with construction and work zone safety sign placement, and a greater focus on low volume roads. This course was offered in 4 locations around the state. For a Core class, attendance was a little low at the Durango location. There were 2 Roads Scholar I graduates from City of Thornton and Larimer County that completed the program requirements with this course and were presented with their plaques.

- *Roadway Safety and Work Zone Traffic Control* – This was the second and final Roads Scholar I Core class offered this spring. The regular instructor for this class, Tom McDonald-IA LTAP, passed away unexpectedly last October. Bruce Drewes, former ID LTAP Director, stepped in to teach these classes. Bruce based the course design on Tom's previous training program, with the addition of some new material. The class considered safety hazards and how to keep workers safe while working on the roadways. The class addressed common safety hazards and countermeasures; introduction of statistics, liability, human factors; MUTCD (parts 1, 5 & 6); flagger safety; safety edge & narrow edge rumble stripes; night work; and typical work zone applications. Participants would like to see more examples of traffic

control scenarios and involve the students more with hands-on activities. This course was offered in 3 locations around the state; and was offered back-to-back with the Roads Scholar II course, *Disaster Response*. Attendance was high in all 3 locations.

- *Disaster Site Worker Outreach* – Each year transportation agencies are pressed into service to assist their communities in the event of natural and man-made disasters. Disasters can be as varied as the World Trade Center, Hurricane Sandy, Tornados, expositions of processing and milling sites, fires and flooding. This Disaster Site Worker Outreach training program was geared toward skilled support services workers (e.g. utility, demolition, debris removal, or heavy equipment operation) and provided pre-incident training essential for ensuring disaster site worker safety and health when responding to natural and man-made disasters. It made participants aware of the important differences between disaster sites and regular construction or demolition worksites. A portion of the class focused specifically on how to inspect, don, and doff air-purifying respirators. This was the only Roads Scholar II course offered in this quarter. It was a new program, taught by Bruce Drewes who also taught the Roadway Safety courses. Participants would have liked it to be longer than ½-day and suggested a deeper discussion on incident command for disasters. They felt the instructor presented real-life-common sense situations and examples. It was 4 Credit Hours and offered in 3 locations around the state. The Grand Junction location experienced low attendance.

Center staff worked on several initiatives to bring national and local attention to the importance of improving safety on our local and rural road system. There was $538 spent on the Safety Awareness and Retroreflectivity programs this quarter. Additional Safety related activities included:

- The Colorado LTAP Director has been invited by CDOT to participate in the State's update to the Strategic Highway Safety Plan (SHSP). Colorado LTAP is a member on the SHSP Steering Committee and also participates on the Rural Infrastructure and Data Emphasis Area Teams. LTAP participated in 3 of the SHSP meetings this quarter; and also encouraged local agency representatives to participate.
- Participated on a Safety Needs Assessment meeting with National APWA's Safety Committee, FHWA TPP members, and NLTAPA Safety Committee.
- Responded to Safety related technical assistance requests regarding local agency requirements for traffic control supervisors (TCS) in rural areas, requirements for breakaway sign posts, traffic control technician training (TCT), MUTCD pocket guides, and available manufacturers to calibrate sign retroreflectometers.
- Used the electronic mail list to promote available Safety related webinars and other distance learning opportunities offered through organizations such as FHWA and CDOT.

C.2 Infrastructure Management

Colorado LTAP has a long history of providing infrastructure related training, technology transfer and technical assistance through its traditional services and Roads Scholar I and II training programs. There were 3 training classes offered on Infrastructure Management topics this quarter. Programs and training completed between January 1 and March 31 in this focus area include:

- *Equipment Maintenance and Inspection* – This course provided basic instruction for the safe operation and preventive maintenance of road construction equipment including identifying problems with equipment systems; performing daily walk around inspections; and safety. This class focused on maintenance and inspection of heavy construction equipment including operator responsibilities and safety; types of oils, anti-freeze, and operational systems such as Fuel, Hydraulic, Cooling, and Electrical; and an afternoon hands-on in-field session inspecting heavy equipment. Dee Hadfield, Utah LTAP, was the instructor and he showed the importance of a good Equipment Inspection Program and how it can help keep the operating condition at a high level so the equipment is always available when needed. The class was offered in 3 locations, and Colorado LTAP partnered with County agencies in each location to provide the various pieces of construction equipment for the outdoor afternoon portion. This was the only Roads Scholar I Elective course offered this quarter. Participants felt the instructor was very knowledgeable and that the class could be 2-days long. They suggested to provide the daily inspection checklist as a separate handout and to offer more practice time on the outdoor equipment. There were 8 Roads Scholar I graduates that completed the program requirements with this class and were presented with their plaques.

Other than training, additional *Infrastructure Management* related activities included:

- Participated on two FHWA Webinars on: *Performance Measures* and *Permeable Pavements Infrastructure: Case Studies & Technical Resources*.
- Participated in the 2-day *ACEC-CDOT Local Transportation Training* workshop.
- Participated in CDOT's *Local Agency Materials Testing and Documentation* class.
- Provided a free booth display at the following infrastructure management related conferences this quarter – Construction Inspection, Asphalt, and Concrete.
- Center staff responded to Infrastructure Management related technical assistance requests regarding paving gravel roads, cleaning and maintaining irrigation ditches, winter maintenance manuals, gravel road maintenance and design manuals, pavement marking management practices, and proper routing of concrete pavements.
- Colorado LTAP used the electronic mail list to promote available infrastructure management related webinars and other learning opportunities offered by FHWA and CDOT including FHWA's *Alternative Contracting Methods Alternative Technical Concepts Webinar Series* and CDOT's *Local Agency Materials Testing & Documentation* course.

C.3 Workforce Development

The training classes, workshops and other educational offerings described above can all be considered part of LTAP's workforce development program. There were 5 additional training classes specific to Workforce Development topics offered this quarter. The following specific work force development initiatives were offered between January and March:

- Training programs for spring and fall 2014 were under development.
- Development of an iClicker (Audience Response System) Instructor Training Manual
- *Supervisory Skills & Development (SSDP) Training* – This program is specifically designed to address workforce development issues. The courses offered in this program each year are intended to provide a fundamental understanding of the roles and responsibilities of a new supervisor and to develop tools for succeeding in management. There were 5 graduates this quarter in the Supervisory Skills program.

- *Developing the Leader Within* – As a supervisor or team leader you are always leading others, whether you are aware of it or not. This class covered What does it mean to be a leader in today's organizations? How do you show up, build relationships, create a positive culture and model core concepts in today's fast-paced, diverse work environment? It was a highly interactive workshop teaching participants to assess and develop leadership strengths; develop ability to lead by influence rather than authority; understand what leader behaviors create the greatest impact; learn how to lead others to peak performance; and design a leadership credo. The course, offered in Rifle, was taught by Stefani Conley of Lundy Professional Development Resources, Inc. Participants felt Stefani was an amazing instructor that provided good hands-on exercises. This course had 1 graduate from City of Grand Junction was presented with his plaque.

- *Written Communication* – This course focused on how to write, edit, and proofread effective business communications simply, clearly, and logically no matter what method - electronic or otherwise. Participants practiced a simple method for organizing thoughts prior to writing; review spelling rules; learned tricks for remembering the "how to's" and the resources for checking spelling guidelines; reviewed punctuation pointers; learned how to improve etiquette by becoming aware of professional standards. The class taught how to think through documents before writing, especially to consider who the reader is and the purpose of writing, and how to write a draft document using grammar and format rules learned. Brice Davis of Lundy Professional Development Resources taught this class in Rifle. Participants felt Brice was very knowledgeable in written communications. This course had 1 graduate from City of Grand Junction was presented with his plaque.

- *Ethical-Do You Know What That Means?* – After the success of this redesigned class last year, Chuck Passaglia, a sole practitioner in employment law with Employment Law Solutions, Inc. returned to teach this class this year. Ethics has been described as how a person acts when no one is looking. This class covered a clear understanding of code of conduct provisions and the requirement of ethical behavior. This class was designed to raise awareness of ethical decision making and how to act properly when the rules are not clear or when no one is looking. Other topics covered included: What is ethics and why should I care; Understanding ethics rules; Ethics traps for employees; five moral theories every person should know; and an effective decision making model: *Ethics Outside the Rules*. Chuck presents with very high energy and kept the attendees interested in the material he was presenting. He engaged the attendees with questions and asked them to think about the complex subject of ethics and encouraged everyone to participate in the class. Several participants felt it was one of the best classes they have attended, and the instructor was excellent. Chuck received the highest ratings of all the Supervisory classes with a total evaluation rating of 99.21%.

- *Effective Verbal Communications* – This course covers aspects related to being correctly understood while communicating. This class focused on strategies to

improve interpersonal relationships at work by understanding the two way communication cycle, how to overcome communication barriers, and the responsibilities of both the speaker and listener, helping attendees learn to organize thoughts, to speak concisely, and ensure understanding. The course, offered in Castle Rock, was taught by Cathy Poe of Lundy Professional Development Resources, Inc. Participants felt there were some confusing examples and to include more videos. This course had 2 graduates both from the City of Golden.

- *Who's Coming Through the Door Today?* – This course covers aspects related to *dealing with people*. Attendees learned about the ever-changing workplace and how this diversity affects working relationships and communication styles. The class considered different generations, work styles, personalities, cultures, and gender that make up the unique workplace of today. The course was offered back-to-back with Verbal Communications, and also taught by Cathy Poe of Lundy Professional Development Resources, Inc. Participants felt the class was well presented, but would like more examples of situations. This course had 1 graduate from Arapahoe County.

C3.1 You Show Us Contest Support

Details of the You Show Us contest and winner were discussed in the last quarterly report. To encourage local agencies to share their successful programs and ideas, Colorado LTAP sponsored two participants from Cañon City to represent their winning project at the Local Road Coordinators' Conference in October. Brochures for the 2014 YSU Contest will be printed and mailed next quarter.

C3.2 Local Road Coordinators' Conference Support

Expenses in this category were completed last quarter.

C3.3 APWA Street Conference Administration & Library Materials

Colorado LTAP helps CARMA & APWA administer pre-conference planning, brochure design and distribution, registration, and agenda development for the Spring Street Conference held in Grand Junction each year. Colorado LTAP is reimbursed for all direct costs and an additional $2000; $1500 administration and $500 library training materials to benefit local agencies. A majority of the work for this conference was completed this quarter and the conference occurs in April.

C.4 Operational Excellence

Colorado LTAP seeks to provide high quality services to meet the needs of its customers. Several activities were conducted to help ensure that LTAP is meeting this goal - including obtaining more feedback on emerging needs of Colorado's customers as well as their perception of the program. Operational Excellence is a continuous service management improvement program, and efforts to improve our operational efficiency are continually implemented. Specific internal and external initiatives this fall included below.

- ❖ Colorado LTAP completed and submitted requirements for the annual Program Assessment Report (PAR) and Center Assessment Report (CAR) to FHWA in January 2014, as part of the evaluation effort for the National LTAP program.
- ❖ Colorado LTAP provided CDOT and FHWA quarterly and mid-year reports highlighting progress of Center operations including a budget/expense report.
- ❖ Program expenses for July 1, 2013 – June 30, 2014 are included in Appendix B. As we approach the end of the 13-14 contract year, complete program expenses are included.

C4.1 Information Technology Services

- ❖ Colorado LTAP managed their Information Technology Services (ITS) to provide communication services to state agencies, local governments, and partners across Colorado and the United States. ITS incorporated the study, design, development, implementation, support and management of Colorado LTAP's telecommunication and computer-based information systems this quarter. It included maintaining network and video services, telephone, emailing, program websites and operational databases.
  - o The website is a useful tool to communicate upcoming training courses and online registration, conferences, online training & webinars, needs survey, and to highlight resources specific to local agency needs, and is updated regularly. The web designer has been making continuous updates and suggesting new ideas for a fresh new design.
  - o Our toll-free number continues to be available for any LTAP customer to reach us for direct technical assistance.
  - o Expenses for ITS include web design and phone service and averaged $66/month.

- ❖ Colorado LTAP regularly updates the contact information of local transportation agency contacts for the efficient dissemination of training announcements, newsletter publications, library resources, outreach efforts, and technology transfer. LTAP staff work with transportation industry associations to identify potential customers, meet needs, and disseminate technology. The *electronic* mail list currently has 209 recipients of Newsletters and 185 recipients of event Brochures. This service expedites facilitates communication, and provides more efficient service and improved coordination and delivery of technical assistance and technology services. It is extremely helpful to regularly update locals on upcoming free online or webinar based training opportunities. The mailed hard-copy brochure and newsletter lists are still maintained (1475 for Newsletters and 1012 for Brochures) until the recipient chooses to switch to electronic mailings.

C4.2 Equipment

This budget category covers purchasing office equipment and supplies necessary for production of training materials, office tasks, and to keep up with technology that will help the program efficiently deliver technology deployment. The majority of expense in this category this quarter was related to the monthly lease and meter readings of the Konica Minolta copy machine. There was $266 additional equipment expense for a Transfer Kit for the other HP Color Printer and Computer Speakers to use in classes.

C4.3 Office Supplies

Expenses in this category are expenses related to the training program and library services including printer paper, certificate paper, name badges, mailing envelopes, notebook binders for

SSDP classes, and toner for the other HP printer, etc. There was $1,800 spent on office supplies this quarter. A majority of that was spent on Black-White and 3 Color toner cartridges for the HP Color printer.

C4.4 Staff Training

There were no expenses in this category this quarter.

C4.5 Monthly & Quarterly Advisory Meetings

- Colorado LTAP staff and Program Sponsors held one meeting in March to review project status and other program initiatives. A detailed program report was provided in January.
- *LTAP Advisory Board* - Quarterly Advisory Board meetings are organized to solicit input for program content, provide feedback on needed services, and evaluate the effectiveness of the program. There are 9 *voting* members on the advisory board representing cities and counties across the state. There are also 4 non-voting members representing the program and sponsoring agencies. The LTAP advisory board is currently represented by 2 City representatives and 7 County representatives. Board members are not paid for their participation, but are reimbursed for direct expenses incurred due to attending LTAP meetings.
  - This quarter's Advisory Board meeting was scheduled for February 21st in Lakewood; however had to be canceled due to a serious injury suffered by the LTAP Director.

C4.6 Program Needs Survey

The online survey software program was renewed in January. The Program Needs Survey will be redesigned this summer.

C4.7 NLTAPA Dues

In the fall of 2013, Colorado LTAP paid its 2014 annual National LTAP dues in support of the Executive Committee's work benefiting the advancement and resource development for all centers.

Financial Report

Total program expenses for July 1, 2013 – June 30, 2014 are included in Appendix B. The attached itemized categories shows the projected balance of ($38,908.20) for the 2013-2014 contract year. The total expenses were included in order to review status of each category in reference to the proposed budget. Part of the reason for the negative balance is that the LTAP program has not yet received its $27,500 matching funds from the CEAE Grad School or the $9,167 matching from the Dean's Office. There are outstanding registration fees that will cover any additional expenditures.

Appendix A: Profile Training Hours January 1, 2014 – March 31, 2014

Class Name	Location	Date	Hrs/class	# Part.	NS	WL	CAN	Tot. Part. Hours
ROADS SCHOLAR CORE COURSES								
RS CORE: Signing, Pavement Markings & MUTCD								
92.06%	Durango	2/4/14	7	11	3	0	1	77
98.13%	Pueblo	2/6/14	7	19	3	0	2	133
91.79%	Glenwood Springs	2/19/14	7	24	2	0	0	168
97.22%	Longmont	2/21/14	7	45	3	4	2	315
RS CORE: Roadway Safety & Work Zone Traffic Control								
91.53%	Colorado Springs	3/10/14	7	34	1	0	1	238
95.19%	Grand Junction	3/12/14	7	32	5	0	2	224
97.31%	Loveland	3/17/14	7	43	1	0	1	301
ROADS SCHOLAR I ELECTIVE COURSES								
RS ELECTIVE: Equipment Maintenance & Inspection								
95.85%	Aurora	3/17/14	7	38	2	0	3	266
99.07%	Colorado Springs	3/18/14	7	21	5	0	5	147
96.82%	Montrose	3/20/14	7	33	0	0	1	231
ROADS SCHOLAR II COURSES								
RS II: Safety Focus Area								
Disaster Site Worker Outreach								
93.33%	Colorado Springs	3/11/14	4	18	6	0	0	72
100.00%	Grand Junction	3/13/14	4	8	3	0	2	32
98.94%	Westminster	3/18/14	4	16	2	0	2	64
SUPERVISORY SKILLS & DEVELOPMENT PROGRAM								
SSDP: Developing the Leader Within								
98.89%	Rifle	1/15/14	7	15	1	0	0	105
SSDP: Written Communication								
97.44%	Rifle	1/16/14	7	13	0	0	0	91
SSDP: Ethics								
99.21%	Grand Junction	2/11/14	7	23	3	0	4	161
SSDP: Verbal Communication								
88.41%	Castle Rock	3/12/14	7	33	2	7	1	231
SSDP: Who's Coming Through the Door Today?								
97.74%	Castle Rock	3/13/14	7	34	3	1	2	238
96.05%	Total **3rd Quarter** Participants:			**460**				
Evaluations	Total **RS I** Participants:			300				2100
	Total **RS II** Participants			42				168
	Total **SSDP** Participants:			118				826
	Total **Workshop** Participants:			0				0
				Total Participant Hours:				**3094**

Appendix B: Total Program Expenses, July 1, 2013 – June 30, 2014

Itemized Categories
7/1/2013 through 7/1/2014

INCOME		**284,319.48**
1. SPONSOR REIMBURSEMENTS		
a. CDOT Reimbursement	210,000.00	
b. CU Matching	18,333.00	
c. Class Registration Fees	53,986.48	
c1. Deposits	54,890.00	
c2. Credit Card Charges	-903.52	
d. Partner Reimbursement	2,000.00	
EXPENSES		**-323,227.68**
A. PROGRAM ADMINISTRATION		-197,054.19
A1. Administration Costs	-160,794.25	
A2. Program Administration Fee	-36,259.94	
B. TRAINING PROGRAM		-102,974.73
B1.1 Training	-102,974.73	
a. Roads Scholar	-66,521.79	
b. Supervisory Skills	-19,237.91	
d. Special Training Programs	-13,585.27	
d2. Heavy Equipment Training, Spring	-7,717.60	
d3. Flagger Certification	-4,514.87	
d5. Training Enhancement Mat'ls	-1,352.80	
Other B. TRAINING PROGRAM:B1.1 Training	-3,629.76	
C.0 GENERAL		-14,210.43
C0.1 Newsletter & Information Exchange	-4,051.48	
C0.2 Library Services	-2,180.54	
C0.3 Prog Marketing Outreach Research	-3,999.92	
C0.4 Out-of-State Travel	-3,978.49	
1.TRB	-808.01	
2.Region 7 LTAP Meeting	-1,152.08	
3.National LTAP Meeting	-1,610.48	
4.Local Roads Conference	-407.92	
C.1 SAFETY PROGRAMS		-637.86
C1.1 Safety Awareness Programs	-7.00	
C1.2 Retroreflectivity Prog	-630.86	
C.2 INFRASTRUCTURE MANAGEMENT		-149.00
C2.3 Miscelaneous	-149.00	
C.3 WORKFORCE DEVELOPMENT		-691.89
C3.1 You Show Us Contest	-1,752.37	
C3.2 Local Roads Conference	-578.88	
C3.3 APWA Conf Admin & Library Matls	1,639.36	
C.4 OPERATIONAL EXCELLENCE		-7,509.58
C4.1 Information Technology Services	-616.82	
C4.2 Equipment	-2,718.24	
C4.3 Office Supplies	-2,505.78	
C4.4 Staff Training	-500.00	
C4.5 Advisory Meetings	-389.74	
C4.6 Annual Needs Survey	-204.00	
C4.7 NLTAPA Dues	-500.00	
C4.8 Program Parking	-75.00	
OVERALL TOTAL		**-38,908.20**

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Durable Wearing Surfaces for HMA
Study No: 10.37

Background	Reporting Period: 1/1/14 through 3/31/14 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
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).	

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 Genesee.
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 Genesee.
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

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 Genesee 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

Participation in Southeastern Superpave Center TPF-5(228)
Study No. 10.40

Background

See: http://www.pooledfund.org/Details/Study/456

In 1992, following 5 years of research and testing, the Strategic Highway Research Program (SHRP) introduced the Superpave system. The Superpave system included new specifications, test procedures and testing equipment for building more durable asphalt pavements. Five Superpave Regional Centers were established to provide technical leadership, assistance and training to highway agencies during the implementation of the Superpave system.

One of the Superpave centers established is the Southeast Superpave Center. This center is located at National Center for Asphalt Technology (NCAT), Auburn University in Auburn, Alabama. This Center has a well-qualified and educated staff. The Center has been responsible for a number of research studies. Some of the studies include: permeability characteristics of coarse-graded Superpave mixes, development of mix design criteria for 4.75 mm mixes, case studies of the tender zone in coarse-graded Superpave mixes, development of critical field permeability and pavement density values for coarse-graded Superpave pavements, evaluation of OGFC mixtures containing cellulose fibers, evaluation of the effect of flat and elongated particles on the performance of HMA mixtures and permeability of Superpave mixtures; evaluation of field permeameters. Currently, NCAT is performing the monitoring for the warm mix asphalt (WMA) experimental feature on I-70, west of Eisenhower Tunnel in Region 1. Three WMA additives are being evaluated in this research project.

CDOT has agreed to contribute $20,000 a year to a pooled-fund project with the understanding that NCAT will use these funds to conduct research identified by CDOT. The products of this research may include the development of specifications, practices, and equipment to help build and extend the service life of a hot mix asphalt pavement.

Reporting Period : 1/1/14 through 3/31/14
Type: SP&R Start:7/03 Ver:

Principal Investigator(s):
Dr. Randy West/Donald Watson, NCAT

Technical Panel Leader:
Bill Schiebel, Materials and Geotechnical Branch Manager

Study Panel Members:
Steve Olson, Materials and Geotechnical Br.
Jay Goldbaum, Materials and Geotech. Br.
Richard Zamora, HQ Project Development
Rex Goodrich, Region 3 Materials
Gary Dewitt, Region 4 Materials
Tim Webb, Region 5 Materials
Masoud Ghaeli, Region 6 Materials
Donna Harmelink, FHWA-Colorado Division

Research Study Manager: TBD

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
06/12/04	100	07/30/04	**Tire-Pavement Noise Testing:** CDOT ask NCAT to direct CDOT's funding to measuring of tire-pavement noise at various locations in Colorado. Beginning in the fall of 2004, NCAT used their Close-Proximity (CPX) noise trailer. Each year a summary of the data would be provided to CDOT. After the final evaluation a final report will be written that documents the performance of each of the evaluation sections.
10/18/04	100	10/18/04	NCAT measured noise levels using the CPX method on 21 sites.

12/31/04	100	4/08/05	NCAT provided a draft report regarding noise levels measured and compare measurement from the 17 sites the previous year.
06/30/05	100	07/05	Final report of CPX testing was accepted and loaded into CDOT Research Branch website.
10/12/05	100	10/18/05	NCAT performed CPX noise measurements in same locations as last year.
06/30/06	100	11/06	NCAT completed the final report for 2005 noise measurements. The report was accepted and loaded into Research Branch website.
10/31/07	100	9/30/07	NCAT completed another round of CPX noise measurements. CDOT initiated a comprehensive pavement noise study # 35.00 and results of NCAT testing have been incorporated into it. See CDOT research report 2012-13.
9/30/08	100	9/30/08	Perform warm mix asphalt pavement distress survey.
11/17/09	100	11/17/09	Perform warm mix asphalt pavement distress survey.
9/30/10	100	10/15/10	Perform warm mix asphalt pavement distress survey.
12/31/11	100	11/01/11	Submit final report for the assigned research project (WMA report) completed.
12/13/12	100	12/13/12	NCAT Short Course in Asphalt Technology was presented at the Colorado Asphalt Pavement Association office in Denver. Fourteen CDOT employees attended including two from the Research Branch.
Ongoing			NCAT continues related research: see http://www.pooledfund.org/Details/Study/456
9/30/13	50		CDOT will consider Colorado-specific activities for NCAT. The availability of NCAT services was announced in MAC meeting.

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: 1/1/14 through 3/31/14 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
6/30/13			Status update: project is lagging 1.5 to 2 months
8/31/13	75		Task 2 Draft guidelines; originally scheduled for 7/15/13; propose changing to 8/31/13
8/31/13	50		Task 3 Draft procedures: originally scheduled for 7/15/13; propose changing to 8/31/13
9/30/13			CDOT completes review of guidelines and procedures: originally scheduled for 9/15/13; propose changing to 1 month review due on 9/30/13
9/30/13			Status update: little progress has been made this past quarter after the 8/7/13 meeting
10/15/13			Task 2 Final guidelines
10/15/13			Task 3 Final procedures
10/31/13			Presentation
2/14/13			Proposed new date for Task 2 and 3 deliverables
			Presentation date to be determined

SIGNIFICANT EVENTS

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: 11.50

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 installed 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-appearance 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: 1/1/2014 through 3/31/2014
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	50	3/31/2014	Task 2 – 2014 Reflection Crack Performance
9/30/15	0		Task 2 – 2015 Reflection Crack Performance
10/31/15	0		Task4 – Draft Final Report

11/30/15	0		Task 5 – Presentation to Materials Advisory Committee
12/31/15	0		Task 4 – Final Report

SIGNIFICANT EVENTS

3/31/2014: The post-winter condition survey was conducted on I-70. Reflection cracking continues with predominantly transverse cracks appearing, but also alligator and some longitudinal cracking.

Test sections on US-85 in Region 4 have been identified and condition surveys on these sections will be scheduled for next quarter.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Preventing Transverse Bumps and Cracks in New Asphalt Overlays Over Crack Sealants
Study No: 11.60

Background	Reporting Period: 1/1/2014 through 3/31/2014 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
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.	

MILESTONES

Planned	**% done**	**Achieved**	**Description, Discussion, and Related Issues**
9/30/13	100	12/31/2013	Task 1 – Literature Review
07/31/14	30	12/31/2013	Task 2 – Identify Test Site(s)
07/31/15	30	12/31/2013	Task 3 – Install Test Sections
07/31/16	40	3//31/2014	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

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Alternative Materials Investigation for Selective Use of Permeable Pavements Outside of State Highway Travel Lanes and Shoulders
Study No: 12.00

Background The term permeable pavement is used to describe any one of several storm water quality best management practice (BMP) pavements that allow movement of water into the layers below the pavement surface. These pavements are typically intended for light vehicle parking areas, and not for roadway installations, high speed, or heavy traffic. Depending on the design, permeable pavements can be used to promote runoff volume reduction, provide treatment and slow release of the water quality capture volume (WQCV), and reduce effective imperviousness. Use of permeable pavements is a common Low Impact Development (LID) practice and can be used in combination with other BMPs to provide full treatment and slow release of the WQCV. Installations can also be designed with an increased depth of aggregate material in order to provide flood control storage for large storm events. The research will provide a side-by-side comparison of two interlocking concrete pavement installations, featuring two different water quality treatment methods below the pavement. The key difference between the two pavements will be that one incorporates a sand layer to clean the runoff via filtering while the other will rely solely on settling and subsequent aerobic digestion by a biological film of microorganisms that will develop naturally on the surface of the aggregate. CDOT will build the test section per UDFCD design at a maintenance yard and UDFCD will conduct the monitoring and reporting.	Reporting Period: 1/1/2014 through 3/31/2014 Start: TBD 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, 303-512-4420 Study Panel Leader: Mommandi, Amanullah, CDOT Hydraulics Program Manager Study Panel Members: Bob McDade, CDOT EPB Mike Banovich, CDOT EPB Bob Mero, R6 Materials Bill Schiebel, Staff Materials and Geotech Branch

MILESTONES

Planned	**% done**	**Achieved**	**Description, Discussion, and Related Issues**
7/15/12	100%	7/18/12	Select study panel
7/31/12	100%	8/27/12	Finalize scope of work that will be attached to the IGA.
11/1/12	100%	12/11/12	Establish Location of Test Sections: CDOT and UDFCD agreed to place two test sections in the Maintenance Yard at 5701 Federal Blvd.
1/31/13	100%	1/31/13	Execute an intergovernmental agreement (IGA) with the Urban Drainage and Flood Control District: A work agreement was sent to the purchasing staff responsible for intergovernmental agreements.
2/25/13	100%	2/25/13	Reject Maintenance Yard at 5701 Federal Blvd. due to site problems; establish new location at CDOT maintenance shed located at 6050 Wadsworth Blvd.
2/28/13	90%		Design Test Sections

6/30/13			Build Test Sections
7/15/13			Begin Monitoring test sections
7/31/13			Initial Falling Weight Deflectometer (FWD) test
7/15/15			Monitoring concludes
7/31/15			Final FWD test
10/15/15			Draft report
12/31/15			Final Report publication

SIGNIFICANT EVENTS

9/30/2012: An extensive process requirement for Local Government agreements when construction is involved has prevented moving forward. It is necessary to first establish the location of the test sections before continuing.

12/11/2012: After review of several alternatives it was agreed for CDOT to construct two test sections at their maintenance yard at 5701 Federal Blvd. UDFCD will provided the design and perform the research and provide up to $50,000 to supplement CDOT's $70,000 to construct the test sections.

1/31/2013: Contract signed, Notice to Proceed sent to PI

3/31/2013: UDFCD signed a $20,090 contract with the engineering/surveying firm of VisionLand Consultants, Inc. on February 1, 2013 to complete a site survey and design of a permeable pavement section. The initial site selected for the project (known as the "super shed") at 5701 Federal Blvd was rejected after a subsequent detailed survey of the site determined that the paved area tributary to the existing inlet is much too flat for the purpose of gathering stormwater from very small storms (i.e., $\leq$ 0.5 watershed inches of total runoff). Several other CDOT sites were investigated by UDFCD personnel and eventually the CDOT maintenance facility on the east side of Wadsworth Blvd at 60th Avenue (extended) was chosen based on the favorable grades and general layout, and proximity to Ralston Creek (a water of the U.S.). UDFCD signed a $1,635 contract amendment with VisionLand Consultants to include a second site survey, which has now been completed. UDFCD will meet with VisionLand on April 10, 2013 to discuss design options based on the recently acquired information.

6/30/2013: VisionLand Consultants has completed 30%, 60%, and 90% plans for the site, all of which have been reviewed by UDFCD and CDOT personnel. CDOT and UDFCD are meeting on 7/11/2013 to discuss construction options as the standard CDOT construction management model is not amenable to the special nature of this construction of a research project site with limited funding and specialized construction techniques and methods.

9/30/2013: Following the CDOT / UDFCD meeting on 7/11/2013, UDFCD is waiting for CDOT to determine whether there is a contracting alternative that will allow this project to move forward. No CDOT reimbursement has been requested to date. UDFCD has spent $13,889.44 on design work.

12/31/2013: No progress to report since 9/30/2013. UDFCD does have additional funding in 2014 that can be allocated to this project, and it is our understanding that Bob McDade has funding to match our additional funds. We would very much like to construct this pavement test section in 2014 and recommend that we look for a site not owned or otherwise controlled by CDOT but that has characteristics similar to a CDOT maintenance site. This will allow UDFCD to manage the construction more efficiently via our streamlined construction management process.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Asphalt Emulsion Full Depth Reclamation Best Practices
Study No: 12.75

Background	Reporting Period: 1/1/14 through 3/31/14 Type: SP&R Start: 11/5/12 End:
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.	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	85		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	50		Task 2-Design, Plans, Specs
12/7/13	75		Task 3-Progress Reports
12/7/13	50		Task 4-Panel Meetings
11/15/13	25		Task 5-Draft Final Report
12/31/13	0		Task 6-Final Report
12/7/13	0		Task 7-Presentation

SIGNIFICANT EVENTS

12/31/13 A draft of the final report has been submitted for review.

9/30/13 Gathering of pertinent background information continued this period with literature review and interviews including a visit to an emulsion full-depth reclamation project in Centennial. An outline of the final report and a rough draft was completed.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

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

Background	Reporting Period: 1/1/2014 through 3/31/2014 Type: SP&R Start: 11/5/12 End:
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.	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	75	12/31/2013	Task 1-Reviews
9/1/13	20	12/31/2013	Task 2-Field Survey
12/7/14	35	3/31/2014	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

3/31/2014: Direct tension bond strength tests were conducted for the SH13 and I-70 projects. The results are presented below:

Preliminary Results

Ten six inch cores taken from I-70 near Fountain and SH13 near Rifle were tested to determine if debonding

observed in the field could be measured using a direct tension test. Three two inch cores were drilled from the center of each six inch core to obtain a total of thirty tests. A stainless steel grip is epoxied to the surface of each two inch core and a direct tension load is applied until failure.

Results indicate an average for the apparent bonded samples to be 0.73 Joules with a standard deviation of 0.66 Joules. The average work required to separate the unbonded samples is 0.22 Joules with a standard deviation of 0.29 Joules. Although the average values from the direct tension test appear to discriminate between the bonded and unbonded samples, the variation in the data is so great to make the test of questionable value.

The question then is; is the test too variable to be of use, or is the test actually measuring variable work to separate the samples reflecting variability in tack coat application rates?

Recommendation

Based on this preliminary data it is recommended that the testing program be modified. Rather than trying to locate test pavements that display bonded and unbonded behavior and then evaluating the bond strength in the laboratory, we suggest constructing a pavement with varying quantities of tack coat and then evaluating the bond strength.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Design and Analysis Procedures for Asphalt Mixtures Containing High-RAP Contents and/or RAS Pooled Fund
Study No: 13.10

Background Despite recent advancements in the design of asphalt mixtures containing Reclaimed Asphalt Pavement (RAP), many states are still cautious in their regulations to avoid durability problems related to the recycling process. In many states, RAP is currently not allowed in highest-class asphalt mixtures and in polymer-modified asphalt products. In addition, high percentages of RAP exceeding 25% are not commonly used in practice. On the other hand, many state agencies are taking a more aggressive approach by considering increasing the allowable percentages of RAP in hot-mix asphalt (HMA) to take full advantage of this promising technology. For instance, up to 50% RAP has been used in some asphalt mixtures, which produced an acceptable level of performance. To ensure successful use of RAP, confidences in the mixture design procedure require addressing many concerns related to the interaction between virgin and recycled materials and durability of the produced mixture. Current AASHTO recommendations make it difficult to design asphalt mixtures with high-RAP contents. Modifications to the current specifications are needed to assure agencies that satisfactory performance will result from the use of high-RAP content HMA mixes.	Reporting Period: 1/1/14 through 3/31/14 Type: Pooled-Fund Start: End: Principal Investigators: TBD Study Manager: TBD Study Panel Members: Masoud Ghaeli, Region 6 Materials, 303-398-6701 Bill Schiebel, Region 1 Materials, 303-398-6801 Mike Stanford, Materials and Geotechnical Br.

MILESTONES

Click on the following link to access Transportation Pooled-Fund website to view the solicitation details for this specific research project.

http://www.pooledfund.org/Details/Solicitation/1318

SIGNIFICANT EVENTS

1/31/13 The CDOT Study Manager, Roberto DeDios, retired from CDOT

9/30/12 Setting up of lead state pooled-fund commitment program is underway.

9/30/12 Per the Research and Implementation Council decision, CDOT has committed $28,000 to support this research once the pooled-fund project has been established.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Potential Impacts of Solar Arrays on Highway Safety and Operations
Study No: 32.08

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: 1/1/14 through 3/31/14 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	95%	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	95%	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	80%	12/31/2012	**Task 3. Potential CDOT Reference Site Search/ study /Interview**
2/15/2013			Reference Site Identification
9/01/2013		12/12/2012 1/28/2013 9/25/2013 12/24/2013	Reference Site Observations Performed: (CSUP, NW Parkway State Highway 93 (City of Arvada), Federal Center (Golden, Colorado) and US 36 near University Research 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	70%		**Task 4-Report Development: Draft Report** **Report on snow drifting**
10/30/2013		 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			CDOT Draft Reports Review (Presentation)
12/30/2013			Final User Impact Report Development/CDOT Transmittal
12/30/2013	80%	12/31/2012	**Task 5- PI Project Management (Communication)**
12/30/2013			Project Close Out
		   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

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Mule Deer and Elk Right-of-Way Escape Ramp Design 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: 1/1/14 through 3/31/14 Start: 05/09/12 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: 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

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	75%		Collect ramp, road, landscape, and other covariates

07/31/14	85%		Monitoring – 20 months of video monitoring data collected to date. Review and compilation of results for 9 months of video data completed. Camera deployment efficiency and success evaluated. Mule deer have been observed at and successfully using all of the 11 ramps. 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			Cost-benefit analysis
01/14/15	30%		Ramp use and design analysis
01/14/15			Draft report (75 days prior to report publication)
03/30/15			Final Report publication
03/30/15			End of contract.

SIGNIFICANT EVENTS

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

To date, 20 months of picture and video data have been collected at the 11 escape ramps and 2 jump-outs within the study area. Data will continue to be collected through July 2014 for a total of 2 full years of data. Video data have been downloaded and placed on secure servers and preliminary analyses have been conducted to evaluate camera effectiveness and limitations.

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.

Following video data collection, which is scheduled to be completed at the end of July 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

Use of Waste Tires (Crumb Rubber) on Colorado Highways
Study No: 34.24

Background

The Colorado Department of Transportation (CDOT) has used rubber in hot mix asphalt (HMA) for over 25 years. Since the early 80's, CDOT used AC-20R which was an AC -20 base grade of asphalt cement with a styrene-butadiene-rubber polymer blended at a terminal plant and shipped to the various locations throughout Colorado. Since CDOT's AC-20R was performing well, CDOT retained the ductility value along with the toughness and tenacity requirements for the newly initiated PG 64-28 grade of binder when the Department switched to the SuperPave performance graded HMA specifications in 1995. In 1994, CDOT built three trial sections in Colorado where crumb rubber was blended into the dense graded HMA using the dry method (crumb rubber is added as a component of the aggregates). Based on the information from Research Report Number CDOT-DTD-R-99-9, these trial sections proved to be a feasible asphalt pavement alternative and were performing well. The research noted that this process increased the cost per ton by 21 percent when the crumb rubber was added at a rate of 20 pounds per ton. It was recommended that CDOT not pursue any use of crumb rubber until it became cost effective. Other state DOTs have tried the dry method with their dense graded HMA but opted not to continue using the process because of similar concerns and other problems. Therefore, CDOT will not pursue investigating this method at this time.

The use of crumb rubber in chip seal using the wet method was also investigated in the late 80's with the results and findings documented in the Research Report Number CDOH-DTP-R-86-3. The finished product performed comparably well with the conventional chipseal materials used for pavement rehabilitation but was found to be more expensive. With the influx of improved crumb rubber technologies, it is thought that the asphalt pavement life could be longer and the use of crumb rubber employing the wet and terminal blend method might prove cost-effective. For this reason, CDOT is revisiting the use of crumb rubber in HMA utilizing pilot test sections to gather the required information for developing specifications for wet and terminal blend method.

It is proposed to evaluate the feasibility of using waste tires (crumb rubber) in the construction of asphalt pavements. As part of the evaluation, two pilot test sections and one control section using the Superpave Performance Grade, PG 64-28 asphalt binder in dense graded HMA will be built. The two pilot test sections will be built with crumb rubber modified (CRM) asphalt mix using the wet method (crumb rubber is first reacted with asphalt binder in an open system plant before mixing with the aggregates) and the terminal blend method (a special form of the wet process in which reaction takes place in a closed system plant). Each test section will consist of approximately 1,000 tons of 2-inch asphalt overlay placed in the same single lane of the roadway. The control section will be constructed with the conventional polymer modified binder, PG 64-28 without the crumb rubber modifier.

The goal of this project is to evaluate the performance of crumb rubber test sections and as appropriate, develop Colorado-specific materials and construction specifications for rubberized asphalt pavement. The Colorado Department of Public Health and Environment (CDPHE) provided the grant money to construct the two pilot test sections in this research project.

Reporting Period: 1/1/2014 through 3/31/2014
Type: SP&R Start: 12/1/09

Principal Investigator: Dr. Scott Shuler, CSU
970-491-2447

Research Study Manager:
Skip Outcalt, CDOT-DTD Research
303-757-9984
richard.griffin@state.co.us

Technical Panel Leader:
Jay Goldbaum, CDOT Materials Pavement Design Program, 303-398-6561

Study Panel Members:
Rick Chapman, CDOT R-4 Materials
John Cheever, Aggregate Industries
Gary DeWitt, CDOT R-4 Materials
Denis Donnelly, CAPA
Eric West, Westest
Masoud Ghaeli, CDOT R-6 Materials
Roy Guevara, CDOT Materials Asphalt Program
Rex Goodrich, CDOT R-3 Materials
Donna Harmelink, FHWA
Bryan, Roeder, CDOT-DTD Research
Stephen Henry, CDOT Materials Asphalt Program
Bob Mero, CDOT R-6 Materials
Bill Schiebel, CDOT R-1Materials
Niki Upright, CDOT R-4 Construction

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
12/1/09	100	12/1/09	Notice to proceed
3/31/10	100	3/31/10	Task 1 – Literature Review
3/31/10	100	3/31/10	Task 2 – Planning
6/30/14	90	3/31/14	Task 3 - Data Collection
12/31/14	95		Task 4 – Project Status Reporting
6/30/14	100	9/30/13	Task 5 – Draft and Report Presentation and Submittal: Draft report was submitted to CDPHE as the 2013 interim report
6/30/14			Final Report: Update draft report with 2014 data for the final report.

SIGNIFICANT EVENTS

3/31/2014: No activity. The final condition survey will be completed in the next quarter as well as the final report.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Clear Roads Winter Highway Operations Pooled Fund, TPF-5(218)
Study No: 40.03

Background

The Clear Roads pooled fund project began in 2004 with four members and a focus on real world testing of winter maintenance materials, methods and equipment. During its five years of funding and overseeing research projects, the pooled fund grew to include fourteen member states funding two or three research projects annually. As the group grew, however, there was much interest in expanding the project scope to include more technology transfer and direct support for staff in the field. The group proposes to close the original pooled fund project---TPF-5(092) and request funding and support for a new Clear Roads project with this solicitation. See the Clear Roads Web site at www.clearroads.org for both the history and latest information on this project. It is now TPF-5(218).

This new Clear Roads pooled fund project will maintain its focus on advancing winter highway operations nationally but will include a more pronounced emphasis on state agency needs, technology transfer and implementation. State departments of transportation are aggressively pursuing new technologies, practices, tools and programs to improve winter highway operations and safety while maintaining fiscal responsibility. This pooled fund is needed to evaluate these new tools and practices in both lab and field settings, to develop industry standards and performance measures, to provide technology transfer and cost benefit analysis and to support winter highway safety. This project responds to research and technology transfer needs not currently met by other pooled fund projects. Existing partners make every effort to coordinate with other agencies to avoid duplication of efforts and to encourage implementation of results.

State and local winter maintenance organizations will be able to make informed operational and purchasing decisions based on objective evaluations of promising materials and equipment. By pooling resources, agencies will be able to conduct more extensive studies across a greater range of conditions than could be done by a single agency with only its own funds. By collaborating and sharing information, agencies will benefit from each other's experiences and avoid the duplication of research efforts. The outcomes of these projects will help agencies get the maximum financial benefit out of their investments in materials, equipment and technologies.

Reporting Period: 1/1/14 through03/31/14
Start: 1/22/10 Complete: TBD

Principal Investigator(s):
Minnesota Department of Transportation

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

Study Panel Members:
Paul DeJulio, R5 – retired, Dave Wieder new study panel member
Dave Wieder, Operations & Maintenance

FHWA Washington Contact: TBD

MILESTONES

Planned	% Done	Achieved	Description, Discussion, and Related Issues
12/31/09	100	1/22/10	Complete initial funds transfer to Pooled-Fund Study lead agency.
12/31/10	100	1/20/11	Complete second fiscal year funds transfer. *Initiated 11/30/10.
12/31/11	100	1/20/12	Transferred $25,000 for FY12 commitment
12/31/12	75%		Transfer $25,000 for FY13 commitment: entered commitment on web site and sent transferred request to DTD Business office.

SIGNIFICANT EVENTS

The details of this study and progress reports are available at:
http://www.pooledfund.org/Details/Study/446

April 2013: CDOT has acquired RIC approval for commitments of three additional years:

FY14	$25,000
FY15	$25,000
FY16	$25,000

Jan 2013: David Weider, CDOT Maintenance and Operations Branch Manager, is the Vice Chair for this organization and will become chair in May, 2013.

CDOT committed the following funds in support of this project:

FY10	$25,000
FY11	$25,000
FY12	$25,000
FY13	$25,000

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

CDOT Thermal Mapping
Study No: 40.04

Background The purpose of this project is to evaluate the technical merit, costs and benefits of Thermal Mapping Statewide in winter maintenance operations. Thermal Mapping is a recognized method of determining road surface temperature variation across a highway network which, when combined with forecast information can be utilized to optimize treatment times and treatment approach leading to safer and more cost effective operations. Thermal Mapping will also identify cold spots on the network which may require specific treatment and will also investigate whether the current deployment of RWIS stations within the region are in the best locations and whether there are any gaps in the coverage.	**Reporting Period:** 1/1/14 through 3/31/14 **Type:** SP&R **PO:** 211018892 **Start:** 09/09/13 **End:** 05/01/15 **Principal Investigator(s):** Colin Walsh, VAISALA Rose Mooney, VAISALA, 314-872-0541 **Study Manager:** David Reeves, CDOT Research, 303-757-9518 **Study Panel Members:** David Wieder / Maintenance & Operations Branch Manager Phillip Anderle / TSM&O Manager Jill Sott / ITS Engineer Gary DeWitt / Engineer (R4) Mark Eike / Deputy Maintenance Superintendent (R3) Kyle Lester / Maintenance Superintendent (R5) Christian Kelly / LTC Ops (R4) Tom Aguilar / LTC Ops (R4) Ed Gentry / LTC Ops (R4)

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
	100	05/22/13	Notice to Proceed
	100	07/30/13	Kick-Off Meeting
	100	10/12/13	Task 1 - Mobilization- including specification clarification , kick-off meeting, planning surveys and network confirmation
	100	11/23/13	Task 2 – Data surveys Including all training of CDOT personnel and monitoring of forecasts
12/31/13	50		Task 3 – Data analysis - Analysis of the data from the Thermal mapping surveys to create a GIS Thermal map of the agreed network
03/01/14	0		Task 4 – Deliverables - Production of client specific GIS files for ingestion into the client's MDSS, and production of the Final Report and presentation for the Study Panel

SIGNIFICANT EVENTS

- 07/30/13 Kick-off meeting held at CDOT with:
  - CDOT: Aziz Khan, Christian Kelly, Gary DeWitt, Jill Scott, Mark Eike, Phillip Anderle, Skip Outcalt, David Reeves;
  - Vaisala: Colin Walsh, David Weld, Rose Mooney & William Tupa.

    - Identified final network to be Thermally Mapped and the personnel involved.
- October 2013 – Task 2 Data Collection
    - Training in data collection was held in Colorado with Leonard Molina, Scott MacCloud and William Tupa before data collection began in earnest.
    - Some issues with collecting data under Damped conditions due to consistent weather conditions but this was finally completed on November 23rd.
- December 2013– Data analysis has been completed for Extreme conditions. All analysis will be completed as soon as the complete RWIS network has been ingested into the Vaisala Navigator system
- March 2014 – Final draft report has been delivered

ANTICIPATED WORK NEXT PERIOD

- Review of report by study panel

ISSUES

- The only issue that has been identified is the inability to collect data on the US36 and US34 as part of this project to the damage caused by flooding.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

LOS for Snow and Ice Control
Study No: 40.05

Background Common sense dictates that winter storms affect traffic speeds but CDOT does not have a measure for that. This study aims to formulate a tie-in between how CDOT performs snow and ice operations with traffic speeds and congestion. This study will use low cost, low maintenance vehicle mounted sensors to measure the impact of snow and ice operations on traffic speeds and congestion following winter storm events.	**Reporting Period:** 1/1/14 through 3/31/2014 **Type:** SP&R **PO:** 411000056 **Start:** 12/26/2013 **End:** 12/01/2016 **Principal Investigator(s):** Duer Reeves, CEO, Weather Cloud 720-519-8600 Mike Chapman, Project Manager, UCAR 303-497-8395 **Study Manager:** David Reeves, CDOT Division of Transportation Development, 303-757-9518 **Study Panel Members:** David Wieder / Maintenance & Operations Branch Manager (HQ) Phillip Anderle / Real Time ITS Manager (TSM&O) Nitin Deshpande / Traffic Signal & Ramp Metering Program Manager (TSM&O) Mark Eike / Deputy Maintenance Superintendent (Region 3, Section 6) Kyle Lester / Maintenance Director Matt Rickard / ITS Maintenance Manager (TSM&O) Tom Aguilar / LTC Ops (Region 4) Wes Templeton / Maintenance Supervisor (Region 4) Ed Gentry / LTC Ops (Region 4) Jason Wallis / DTD Mobility Analysis Unit Manager (HQ)

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
	100	02/21/14	Kick-Off Meeting
			Task 1 – Develop Project Management Plan
03/15/14			1.1 Project Management Plan (PMP) - draft
As needed	0		1.2 Revised PMP
Quarterly	25		1.3 Quarterly Reports
As needed	25		1.4 Meeting minutes
	0	10/15/14	Task 2 – Procure and Install Mobile Sensors

	0	11/15/14	Task 3 – Mobile Data Verification
	0	02/15/15	Task 4 – Weather Condition Travel Speed Analysis
	0	04/15/15	Task 5 – Reporting and Outreach
			Deliverables:
		05/15/15	Final Report (Deliverable)
		05/15/15	Final Power Point Presentation (Deliverable)

SIGNIFICANT EVENTS

- 2/21/14 – Project kick-off meeting was held
- 3/1/2014 – Sensor re-design began to allow for more autonomous operation. New sensor will be:
  - windshield mounted
  - energy harvesting – photovoltaic to battery
  - incorporate full GPS location and time functionality
  - able to store 48 hours of observations for times when no cell functionality
  - measure irradiance, precipitation type, precipitation intensity, and windshield wiper frequency to determine weather conditions
  - low maintenance
  - low cost
- 6/9/2014 – Sensor re-design is on track for July completion

ANTICIPATED WORK NEXT PERIOD

- Sensor re-design to meet customer needs complete
- Modeling of traffic patterns and historical weather patterns on selected routes begins

ISSUES

- No issues and project is on track.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Snow on LED Traffic Signals
Study No: 40.06

Background 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:** 1/1/14 through 3/14/14 **Type:** SP&R **PO:** 211019483 **Start:** 08/05/13 **End: 06/30/15** **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:** Rich Sarchet / Region 5 Traffic & Safety – Traffic Operations Engineer Jeff Lancaster / Region 1 Traffic & Safety – Maintenance/Operations Supervisor Jim Chase / Region 1 Traffic & Safety – Maintenance/Operations Supervisor Mike DelCupp / DTD Data Collection Unit Manager

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
	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%		Task 2 - Testing and analysis of superhydrophobic coatings
01/15/14	25%		Task 3 - Scaled model testing of aerodynamics
3/15/14	100%		Task 2-Evaluation of superhydrophobic coatings.
			Draft Report
			CDOT Review Draft Report
			Final Report

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

ANTICIPATED WORK NEXT PERIOD

- February 201- Continued superhydrophobic coating development
- March 2014- Perform scaled aerodynamic analysis of traffic signal in windtunnel
- March 2014 - Begin testing of top candidates from lab results in outdoor testbed
- June 2014- Make aerodynamic modifications to stop light.

ISSUES

- Original transparent superhydrophobic coating that was to be sourced from commercial company has not been provided. This has necessitated in-house development of a transparent superhydrophobic coating. Superhydrophobicity has been achieved and work on transparency is ongoing.
- Superhydrophobic coatings are not proving effective at extremely cold temperatures.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Innovative Vegetation Practices for Construction Site Plant Establishment
Study No: 42.00

Background	Reporting Period: 1/1/2014 through 3/31/2014 Start: 5/21/13 Contract Amount: $135,992.50
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.	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 Tripp Minges, CDOT EPB Water Quality Susie Smith, CDOT R6 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	99	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	10	7/15/2014	Schedule and conduct Construction QC field work (spring)
6/1/2014	10	8/15/2014	Schedule and conduct Forensic field work (summer)
09/14/14			Draft Report (75 days prior to report publication)
12/1/14			Final Report publication

SIGNIFICANT EVENTS

- Completed I-25 Monument to Colorado Springs construction site review via three visits; summaries developed and submitted to CDOT.
- Attended one Construction site review at Sterling I-76 and attempting to schedule follow up visit
- Provided a presentation to the CDOT Study Panel in April on the status of the project and path forward.
- Developing schedules for Forensic and Construction QC studies from June-August, 2014.
- Developing R&D database for report development in fall 2014.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Best Practices in Debris Removal
Study No: 50.00

Background

Highway debris represents a traffic safety problem that requires a prompt response from state or local transportation agencies. The most common practice for debris removal currently is for agency personnel to leave their vehicles and remove the debris by hand in the case of large debris (tires, lumber, freight loss, rock fall) or to sweep traveled lanes, shoulders, or intersections in the case of crashes, mechanical failure, or embankment erosion. This exposes agency workers to safety risks, especially on high speed and/or high volume roadways. For example, a CDOT maintenance worker in Region 1entered several lanes of traveled roadway to pick up debris and was struck by a passing vehicle doing in excess of 65 miles per hour, causing serious injuries. Currently, CDOT has no widely distributed formal guidelines for safely and effectively removing debris from the roadway.

Equipment modifications and innovations have been developed that can remove debris from highways without exposing agency workers to moving traffic. For example, some equipment modifications implemented by CDOT are effective at removing debris, but must travel at low speeds, potentially creating upstream crash hazards or driver distraction. Innovative equipment has been introduced to the market which allows for high-speed debris removal, such as the Gator Getter®.

There has been very little independent research on the safety, effectiveness, and traffic impact of debris removal practices, equipment modifications, or technical innovations and little formal guidance exists on the best practices for debris removal.

The objective of this research is to develop a set of recommendations and identify effective practices for debris removal for the Colorado Department of Transportation and to outline a training program for implementation of these best practices. The training program would be delivered through the CDOT Training Academy as Phase II of the research. A separate proposal, including scope, budget, and schedule, will be developed for Phase II at the completion of this study as described in the Schedule section of this proposal.

Reporting Period: 1/1/14 through 3/31/14
Type: SP&R
PO: 211017976 – CSU
PR: 11039644 – Gator Getter
Start: 12/12/12
End: 06/30/15

Principal Investigator(s):
Kelly C. Strong, Ph.D, Colorado State University, 970.491.4021
Rodolfo Valdes Vasques, Ph.D., CSU, 970.491.0278

Study Manager:
David Reeves, PE, CDOT Applied Research & Innovations, 303-757-9518

Study Panel Members:
Chris Ukowich / Maint. Safety Officer (R4)
David Wieder / Maint. & Operations (HQ)
Phillip Anderle / Maintenance (R4)
Darrell Lingk / Statewide Regional Safety Officer (HQ)
Gary Goldsberry/ Deputy Maintenance Superintendent (R6)
Giovanni Ciddio / Regional Safety Officer (R6)
Zacharia Junk / Debris Removal Crew (R4)
Edward Stieber / Maintenance (R4)
Robert Fontenot / Maintenance (R2)
David Weld/ CDOT Research (HQ)
Steve Cordova/CDOT Maintenance (Metro)
Paul Fox/ CDOT Maintenance (R1-6)

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
12/12/12	100	12/14/12	Notice to Proceed
01/15/12	100	3/1/2013	Kick-Off Meeting
12/01/12	100	4/1/2013	Purchase 2 Gator Getters
8-12/2013	100%	6/12/2013	Task 1 - Literature review
1-4/2014	100%	8/31/2013	Task 2 - Field Observations
4-8/2014	100%	10/31/2013	Task 3 - Interview Operators and Maintenance Staff

5-12/2014	100%	10/31/2013	Task 4 – Performance Evaluation
1-6/2015	10%		Task 5 – Outline Recommendations
7/2015	50%		Task 6 – Final Report
			Project Complete

SIGNIFICANT EVENTS

- Initial conclusions and recommendations have been formulated. The first draft of the final report is almost complete

ISSUES

- None

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Development of Risk-Based Decision Methodology for Facility Design
Study No: 62.60

Background	
The ultimate goal of this research study will be more effective utilization of construction and maintenance funds to develop a consequent-consistent risk approach to facility design for CDOT. The primary objectives of this study are to: 1. Develop a Colorado-specific methodology for risk analysis of various types of facilities designed and built by CDOT, accounting for natural and intentional hazards and incorporating life-cycle assessment considerations. The facilities of interest will be chosen in coordination with CDOT engineers, who will provide the requisite design details, analyses and data to the investigators. 2. Conduct a full risk-based analysis of design standards for signalization mast arms (or other design facility for which CDOT data are available), and develop draft design guidelines for a risk-based assessment based on this analysis. 3. Provide operational guidelines for further development of consequent-consistent risk-based approaches for performance design of other types of CDOT facilities.	**Reporting Period:** 1/1/14 through 3/31/14 **Type:** SP&R **PO:** 271001703 **Start:** 07/02/12 **End:** 06/20/14 **Principal Investigator(s):** Dr. Ross Corotis, CU Boulder, 303.735.0539, Corotis@colorado.edu Dr. Abbie Liel, CU Boulder, abbie.liel@colorao.du Yolanda Lin, CU Boulder Abhishek Paul, CU Boulder **Study Manager:** David Reeves, P.E., CDOT Research Branch, 303-757-9518 **Study Panel Members:** Lynn Croswell, Staff Bridge (HQ) Steve Hersey, Traffic Engineer (R6) David Wieder, Maint. & Operations (HQ) Branch Manager Office (HQ) David Swenka, Traffic & Safety (HQ) Darrell Link, Statewide Safety Officer (HQ)

MILESTONES

Planned Date	% done	Achieved Date	Description, Discussion, and Related Issues
07/01/12	100	07/02/12	Notice to Proceed
03/31/13	100	04/01/14	Task 1 – Develop risk methodology
05/31/13	100	01/16/13	Meeting with CDOT Study Panel
05/31/13	100	05/29/13	Meeting with CDOT Study Panel
09/30/13	100	04/01/14	Task 2 – Methodology & critical decision-making metrics
09/30/13	100	12/06/13	Meeting with CDOT Study Panel
01/31/14	100	04/22/14	Task 3 – Propose a general CDOT policy in applying concept of risk- and consequent-based analysis
06/20/14	87.5		Task 4 – quarterly reports (8 total)
05/31/14	60		Task 5 – Final Report
06/20/14	0		Task 6 – CDOT Review Draft Report; presentation of results to CDOT

SIGNIFICANT EVENTS

Objective 1

3/31/14

This objective, which is basically associated with Task 1, was 95% completed at the end of the previous period.

Work this period refined some of the wording and developed comparison graphics between the CDOT proposed method and the various methods used by other state's agencies.

12/31/2013
A summary of the manner in which risk-based methodologies can be applied for CDOT was developed and presented for the December 6, 2013 meeting. Feedback from that meeting is being followed for both the general concept and illustrative examples of mast arms and bridges.

9/30/13
The team continued to investigate the implications of MAP-21 as relevant to this research project. In particular, additional guidelines made available through the Federal Highway Administration have been noted and updated.

6/30/13
The procedures used for a risk-based approach to decision making were extracted from the states that seem to be leading in this regard (California, Florida and Washington). This material was summarized and contrasted, and presented to CDOT at a meeting, focusing especially on comparing the complexity of the risk-based analysis used for projects of different scopes. These approaches provide the fundamental approach that can be applied for the overall MAP-21 requirements.

3/31/13
The framework for a risk-based methodology at CDOT was presented early in the quarter (1/16/2013). Based on the feedback from this presentation, the team further investigated the implications of the Moving Ahead for Progress in the 21st Century Act (MAP-21) as applicable to the development of a relevant risk-based methodology for CDOT. It was found that there are many synergistic applications between the MAP-21 requirements and the proposed methodology, particularly in MAP-21's risk-based asset management and performance-based programs.

12/31/12
The primary focus for this objective has been completed; this included the continued collection and evaluation of information on risk-based systems as used by other states and countries, as well as other documentation on risk-based approaches to project and infrastructure management. Incorporating the key concepts and best practices from the evaluated frameworks, a general recommended approach was developed. Our presentation shortly after the quarter ended presented results and requested feedback for the development of a specific methodology for CDOT.

09/30/12
Significant effort has been focused on Objective 1, the development of a methodology for risk analysis. During this quarter we searched for information on other states that have incorporated some sort of risk-based approach to maintenance procedures in particular.

Objective 2
3/31/14
With regard to the bridge design example, this quarter, three strategically chosen ground motions were applied to each of the two computational bridge models in order to investigate their relative dynamic performance. One bridge represents a seismic zone 1 bridge, the lowest seismic zone, and the other represents a bridge in seismic zone 2, according to the AASHTO specifications. The displacements at the top of the bridge piers were saved from CSiBridge, the structural analysis software used to model the bridges. Using these displacements from the three ground motions, two probabilistic seismic demand models (one for each bridge) were developed to perform

a Monte Carlo simulation to investigate likely structural performance of bridges in Colorado's two seismic zone regions. The study found that the structural performance of either bridge during a seismic excitation that could occur in Colorado is not likely to control when designing a bridge. The changes in seismic design do not lead to significant changes in performance, but neither do they substantially alter material costs. Other hazards, such as wind or snow, could be investigated using the same framework to further understanding of the hazards that could engage with Colorado bridges.

12/31/13
The bridge chosen during the previous quarter has been modeled and is being validated through pushover analysis and hand calculations. The team will then apply appropriate ground excitations to investigate the structure's response. The process will then be repeated for a modified version of the bridge structure in which provisions for seismic hazard have been included in the design.

9/30/13
A "typical bridge" was chosen under the guidance of CDOT Bridge Inspection Engineer, Lynn Croswell. This bridge is located in the metro-Denver area on SH71 over I-76. It is a two-span, prestressed concrete box girder and is considered representative of current construction and design.

6/30/13
The team is working to develop illustrative procedures as to how the proposed risk-based approach could be applied to two applications: (1) decisions about inspection and maintenance of CDOT mast arms and (2) seismic design standards for overpasses. These procedures are intended to provide a substantive illustration of the proposed methodology to assist CDOT in carrying out such approach for future decisions. For the mast arm study we wrote up in report form the complete description of the mast arm inspection data and the analysis of that data. This led to the typical structural defects (specifically corrosion, cracks and collision damage and missing bolts) that have then been used to identify the set of finite element models that will be run.

3/31/13
We obtained the PONTIS database for on- and off-system bridges in Colorado. We plan sort through these records in order to identify a representative, "typical" straight bridge on which to perform seismic performance analysis through the developed methodology from Objective 1 for pre- and post- AASHTO LRFD seismic bridge design revisions (2009). We also completed analysis of the mast arm inspection data, identifying a small set of the typical major structural defects that occurred. These will guide the finite element analyses to be done.

12/31/12
The mast arm inspection data was analyzed, and those mast arms with structural defects were pulled out for further study. Statistical summaries of various defects were prepared.

09/30/12
We also were provided all of the mast arm inspection data by CDOT personnel. We have sorted the more than 60,000 inspection reports and identified those that discovered structural issues. From these we further sorted to determine those with potentially important implications for the safety of the mast arm, At this point we have about 400 inspection reports with structurally-important concerns, primarily due to vehicle impact or corrosion.

Objective 3
3/31/14
A summary of the literature review has been completed. Additionally, two illustrative examples (maintaining a portfolio of mast arms and assessing the seismic design of bridges) of the framework have been developed and written during this quarter. These findings need to be reviewed, submitted, and presented to CDOT.

12/31/13
A summary of the data, analyses, and recommendations regarding signal mast arms has been written and presented to CDOT (12/6/13).

ANTICIPATED WORK NEXT PERIOD

A report will be submitted to CDOT, and a meeting will be scheduled to present the findings from this study.

ISSUES

- No issues and project is on track.

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: 74.91

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.	Reporting Period: 1/1/14 through 3/31/14 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

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	20%		Task 6a: Compare and calibrate results to develop design methodology
12/31/13	0%		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	10%	N	Redirection of the resources and aim of the project to a parametric computational study.

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: 1/1/14 through 3/31/14 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	10	In progress	Task 1: Continuation of obtaining data from 3 piezometers
08/30/2014	50		Task 2: Setting up numerical model and calibration
05/30/2015	0		Task 3: Sensitivity analysis
08/30/2015	0		Task 4: Improvement of experimental system in the field
05/30/2016	10		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

SIGNIFICANT EVENTS

Note 1: We have collected and analyzed data from the three piezometers and Grizzly Peak SNOTEL station.

Note 2: We have made good progress setting up a hydrological model using the software Hydrus-2D. We expect to have a calibrated model by the end of the summer.

Project completion

The project is expected to complete on July 2016.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Hybrid A-Frame Micro-pile/MSE Wall with Impact Barrier, Unique Design and Construction Approach (Phase-I)
Study No: 80.25

Background

To protect the public travelling on Colorado mountain roadways from accidents, a well-designed and constructed impact road barrier and shoulder area is a critical component. Many roadways in the mountains were built on very steep terrain by cutting existing rock material and filling at very steep slopes to accommodate a two lane configuration with no or very limited shoulder room. While MSE walls have been commonly used in Colorado, their effectiveness is not clear if they are placed on a narrow steep cut due to the limited development length of reinforcements near the toe of the wall. Furthermore, roads across steep terrains require CDOT Type 7 or Type 10 steel bridge rails that can absorb significantly higher dynamic vehicle impact loads (e.g., 54 kips peak) to redirect a vehicle back onto the road without serious damage to any part of the reinforced soil region underneath. Under such stringent simultaneous design demands, the installation of micropiles in the form of an A-frame into a MSE walls to provide the lateral impact resistance of the barrier-wall system has the potential of being a capable and unique engineering solution for our state's transportation system.

Using both vertical and inclined piles (in the same plane or staggered) that are connected to a continuous carrier/grade beam, such a system can provide the head stiffness necessary to support a strong impact barrier on a widened roadway or expanded shoulder in difficult terrains. This novel approach has however not been deployed previously due to a lack of research and development on the foundation engineering mechanics problem. This study aims to develop an improved knowledge base on the possibility of using a A-frame micropile-MSE wall system as an effective alternative for mountainous roadway constructions.

The objective of this proposed study is (i) to assess the merit and limitations of the A-frame micropile-MSE wall-foundation design with a top barrier under design impact loads, (ii) to understand the basic load transfer mechanisms involved and their sensitivity to different site and structural conditions, (iii) to develop the design methodology and specification worksheets for approval and usage by CDOT's engineering division. The ultimate goal is to furnish CDOT sound technical information to use the design as a new option, with a sound engineering mechanics basis and confidence for difficult mountain locations.

Reporting Period:
1/1/2014 through 3/31/2014
Type: SP&R Start: 1/30/12

Principal Investigator:
Ronald Pak
303-492-8613

John McCartney
303-492-0470

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

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
3/22/12	100%		Held first panel meeting to discuss, update and revise scope of work and research direction
4/24/12	100%		Field visit to Hwy 119 Blackhawk construction site of MSE with metal reinforcement, discuss issues of drilling through reinforcement
5/10/12	100%		Choice of targets of analysis
7/16/12	90%		Calibration and study of basic benchmark cases for FEM simulation of MSE system with and without A-frame micropiles

8/27/12	100%		Meeting at CDOT to discuss preliminary MSE and micropiles simulation results
3/3/13	100%		Research updates and discussion with CDOT team
10/18/13	100%		Research updates and discussion with CDOT team

UPDATED RESEARCH TASKS

Planned	**% done**	**Achieved**	**Description, Discussion, and Related Issues**
1/31/12	90%		Task 1 Literature review and national survey of state DOTs
7/30/12	90%		Task 2: Review of CDOT methodologies and experience relevant to design of hybrid Micro-pile/MSE walls ~~with imp~~act barriers.
12/1/12	80%		Task 3a: Construct computer models and perform parametric study using finite element code LS DYNA fo<u>r a MS</u>E wall subject to gravity load with a A-frame micropile system to resist late<u>ral load</u>s with corroboration with benchmark numerical and experimental results.
2/1/12	80%		Task 3b: Develop refined micropile's finite element meshing for bond-slip conditions with MSE and pile cap. Optimize and finalize mesh design for the multiple rows of pile-MSE-barrier for parametric study of key variables.
3/1/13	90%		Task 3c: Extend modeling methodology to global stability problem of foundation slope under MSE loads with and without micropiles.
12/1/13	80%		Task 4: Develop design methodology, and construction worksheets for hybrid micropile-MSE walls for CDOT consideration.
2/15/14	80%		Task 5: Draft and submit final report and recommendations

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
Study No. 84.50

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: 1/1/14 through 3/31/14
Type: SP&R Start: Ver:

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
5/03	100	7/03	Establish study panel and develop scope of work
9/03	100	10/03	Issue request for proposals
5/04	100	7/04	Select principal investigator: Out of 4 proposers, Dr. Xi at the University of Colorado was selected.
8/15/13	50		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			Literature review
11/15/13			Selection of testing site and materials
11/15/15			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

8/1/13 The construction project (Arapahoe Road over Cherry Creek) will be advertised for bidders.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Innovative and Economical Steel Bridge Design Alternatives for Colorado: Hybrid Girders, Double-Composites, Epoxy FRP Cover Plates, and External Post Tensioning
Study No: 85.10

Background

Hybrid weld plate SMC girders are a valid competitor not only to continuous hybrid steel girders but also to the dominant precast post-tension prestressed spliced girders. However to move along from steel wide flange rolled beams to welded plate girders, more rigorous theory and validation regarding continuity, fatigue, buckling and plasticity at the negative moment region needs to be investigated. Specifically, during the Phase-I study, several key detail issues arose which have not been addressed adequately throughout the U.S. or in Colorado. These include:

(1) Concrete slab steel distribution that is required to ensure shear capacity near an interior support where two beams come together. It is anticipated that there is significant shear lag as the lateral distance between the steel and beam joint increases, as depicted in Figure 1;
(2) Rotation at the interior support that is not accounted for when the assumption of a continuous beam design is made has not been addressed. This is a critical issue when going from preliminary design, i.e. beam size selection, to design detailing; and
(3) Possibility of beam web crippling at the interior support due to the rotation described in 2. Figure 1 depicts this rotation which is currently not accounted for in SMC design.

This phase II study addresses these three issues above and then focuses on other potential approaches that include:

(1) External post tensioning using either steel or FRP rods;
(2) Use of hybrid steel girders to enable the use of high performance steel in key regions of the girders;
(3) Use of double composite steel-concrete bridges as depicted in Figure 2 (this can also be a beam with two webs angled to form a tub and a bottom concrete flange poured; and
(4) Application of an FRP cover plate to the bottom flange using epoxy to optimize the cross section.

Reporting Period: 1/1/14 through 3/1/14
Type: SP&R Start: 06/09 Ver:
Completion/End Date: 7/31/2014

Principal Investigator:
Rebecca Atadero & Suren Chen, CSU

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

Study Panel Members:
Trever Wang, (Panel Leader)
Staff Bridge, 303-512-4072

Tawedrose (Teddy) Meshesha
Staff Bridge, 303-757-9046

Mahmood Hasan
Staff Bridge, 303-757-9064

Thomas Kozojed
Staff Bridge, (303) 757-9337

Dan Groeneman
Staff Bridge, 303-512-4079

Matt Greer
FHWA, 720-963-3008

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
2/09	100	2/09	Project approved
12/1/09	100	12/1/09	Project begins
3/30/10			Hold first panel meeting to discuss literature review and remaining scope of work
5/1/10	100	5/1/10	MPC proposal submitted to perform experimental portion of project
6/15/10	100	6/15/10	FEA modeling approach refined
6/15/10	100	6/15/10	MPC proposal funded

9/21/10	100	9/23/10	Survey sent out for first time
10/22/10	100	10/22/10	Follow up survey sent out
Jan 2011	100	2-1-11	Survey Finished
	100	Dec 2011	Spreadsheet program to investigate innovative approaches is completed.
April 2013	100	Sept. 2013	Completion of preliminary FE Analysis
June 2013	100	6-3-13	Update meeting with CDOT to confirm study direction
June 2014	75		Physical Testing in the Lab
June 2014			Complete Analysis of physical test and calibration of FE models
July 2014			Develop Design equations based on physical test.

TASKS

Planned	**% done**	**Achieved**	**Description, Discussion, and Related Issues**
3/15/10	100		Task 1: Literature review
6/1/10	100		Task 2: National survey
6/30/12	85		Task 3: FEA Investigation
12/31/11	100		Task 4: Investigate innovative approaches
12/31/12	75		Task 5: Laboratory test program
3/1/13	20		Task 6: Quarterly reports & Final report

SIGNIFICANT EVENTS

12/1/09	Project officially begins. Project completion/end date is 10/22/11. PI/CSU would request an extension beyond the completion date (if needed) with a brief justification at least six months ahead of the end date.
3/10	Kickoff Meeting
5/1/10	MPC proposal on experimental task submitted
6/1/10	New PI transition meeting in Denver
12/1/10	PhD student Nathan Miller identified to pick up the project in the spring.
3/17/11	Project Meeting with CDOT with new PIs and PhD student
8/15/12	Nathan Miller quits his PhD program
9/15/12	Bob Johnson is a new PhD student who has picked up the project. Bob has teaching commitments in the fall.
6/3/13	Research progress meeting with Study panel to confirm plans for research direction.
3/27/14	Casting of concrete slab on test specimen

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Investigation of Optimal Seismic Design of Typical Bridges in Colorado
Study No: 87.00

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: 1/1/14 through 3/31/14
Type: SP&R Start: 02/12 Ver:

Completion/End Date: 07/31/2014 (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
C.K. Su, Materials and Geotechnical 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.
~~07/01/2013~~ 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.

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.

TASKS

Planned	% done	Achieved	Description, Discussion, and Related Issues
7/01/2012	100	7/30/2012	Task 1: Literature review and survey
7/01/2012	100	7/1/2012	Task 2: Identify representative bridges
2/01/2013	100	1/30/2013	Task 3: Develop 3-D SAP analytical model
~~6/01/2013~~* TBD	-	-	~~Task 4: Calibration with nonlinear FEM software~~**
~~07/01/2013~~ 09/01/2013	100	11/1/2013	Task 5: Investigation of design detailing
~~1/01/2014~~ 04/01/2014	100	02/10/2014	Task 6: Illustrative examples
~~1/31/2014~~ 5/15/2014	80		Task 7: Quarterly reports and final report

*Note: We suggest swapping Task 4 and Task 5 for the following reasons: (1) The SAP-based models show good simulation accuracy. Originally planned ABAQUS models are currently viewed as being not as essential when compared to Task 5, which are more critical to the project. (2) ABAQUS modeling requires intensive and detailed modeling of critical connections in the bridge; the configuration of which is not fully available until Task 5 is implemented. The simulation of ABAQUS is expected to take significant time, which may cause unexpected delay of other tasks. Therefore, it is felt more reasonable to look into the details first (Task 5) and then decide whether it is still necessary to conduct Task 4. If approved, we suggest moving Task 5 up and changing the planned finish time from 10/01/2013 to 7/01/2013.

**Note: Based on the analysis results of Tasks 3 and 5, it is felt that the originally planned Task 4 is not needed and will not add much benefit to the study findings. Therefore, the study team put more time and efforts on finishing Task 5 and Task 6 to provide more detailed information to help future CDOT work.

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.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Full Closure Strategic Analysis
Study No: 90.10

Background Full closures of roadways are becoming an increasingly considered and utilized strategy to assist in completing maintenance and construction efforts. Accordingly, CDOT Headquarters and Region 6 Staff have identified a need for additional strategic consideration of full roadway closures. This study will review current full closure practices in Region 6 and elsewhere and develop an approach to judging the merits of particular full closure scenarios to equip CDOT Staff for full closure decision making. Several potential freeway and arterial full closure scenarios will be analyzed to evaluate the range of full closure impacts. Project deliverables include a decision tool to assist CDOT with future full closure scenarios.	**Reporting Period:** 1/1/14 through 3/31/14 **Type:** SP&R **PO:** N/A - Region 6 NPS **Start:** 11/19/12 **End:** 9/10/13 (rev. from 6/30/13) **Principal Investigator(s):** Lyle DeVries, PE, PTOE, Felsburg Holt & Ullevig, 303.721.1440 Colleen Guillotte, PE, Felsburg Holt & Ullevig, 719.314.1800 Dave Hattan, PE, PTOE, Felsburg Holt & Ullevig, 303.721.1440 **Study Manager:** Alazar Tesfaye, CDOT Region 6 Traffic, 303.757.9511 **Study Panel Members:** Steve Hersey, PE, CDOT Region 6 Traffic David Reeves, PE, CDOT Applied Research

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
	100	11/19/12	Notice to Proceed
	100	12/19/12	Kick-Off Meeting
6/30/13	25		Task 1 – Project Administration and Meetings
2/1/13	100	2/15/13	Task 2 – Literature Review
2/28/13	100	5/15/13	Task 3 – Review of current CDOT practices
3/15/13	85		Task4 – Decision Criteria Development
5/15/13	30		Task 5 – Arterial Analysis
5/15/13	30		Task 6 – Freeway Analysis
6/15/13	50		Task 7 – Develop Decision Tool
6/30/13	15		Task 8 – Documentation

SIGNIFICANT EVENTS

- Notice to proceed was provided in the latter portion of Q4 of 2013, and progress has followed in Q1 of 2014. Significant events include:
    - Progress meetings in January and March of 2014 with CDOT staff to discuss work products and facilitate key decisions
    - Further development and refinement of the 3-step process for addressing potential full closure scenarios

- Development of initial case studies (8) for template application to decision-making

ANTICIPATED WORK NEXT PERIOD

- Completion of the final product, including a decision process, case studies, and final tools for use by CDOT Staff in evaluating full closure opportunities

ISSUES

- None to report

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Freeway/Parallel Arterial Safety Mobility Patterns
Study No: 90.69

Background Observations and initial examination of ADT and peak-hour volume data on Denver regional arterials suggests questions as to if and why they are happening, and what the implications are on corridor travel and accident patterns? This proposed research task will investigate these trends and address questions, to assist CDOT in better determining which improvements would more likely decrease accident experience while improving corridor capacity. The research will focus on a selected freeway section and corresponding regional arterials corridors. The study will address the effects of arterial traffic volume diversion patterns and the discontinuities on freeway versus arterial safety parameters. The final product of this research will be a report presenting the traffic and safety statistics and trends along a selected freeway/arterial corridor, with conclusions as to what improvements are most likely to improve safety and corridor thru-put on both.	**Reporting Period:** 1/1/14 through 3/31/14 **Type:** SP&R **PO:** 231003850 **Start:** 12/11/12 **End:** 9/8/2013 **Principal Investigator(s):** Dr. Ron Hensen, Ph.D, PE, Short Elliott Hendrickson, Inc. (SEH) (720) 540-6811 Mr. Jon Larson, PE, PTOE, SEH (303) 441-5417 **Study Manager:** David Reeves, Applied Research & Innovations Branch, 303-757-9518 **Study Panel Members:** Steven Hersey, R1 Traffic & Safety Engineer Benjamin Kiene, R1 Traffic & Safety Engineer Richard Zamora, Project Development Branch Manager David Swenka, Traffic & Safety Engineer Charles Meyer, Traffic & Safety Manager

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
09/09/11	100	12/12/12	Notice to Proceed Issued
01/01/13	100		Work Element 1 – Project Initiation
01/01/13	100	12/20/12	Kick-off meeting
01/15/13	100	5/3/2013	Revised Project Schedule
8/23/13	100		Work Element 2 – Data Gathering
10/18/13	100		Work Element 3 – Screenline Analysis
11/8/13	90		Work Element 4 – Literature Review
1/10/14	90		Work Element 5 – Accident Patterns
3/21/14			Work Element 6 - Draft/Final Report
4/25/14			Work Element 7 – Final Report
12/ 2012 to 4/2013	50		Work Element 8 – Project Management

SIGNIFICANT EVENTS

- 12/11/12 – Notice to proceed issued to SEH.
- Revised project schedule completed
- August 23, 2013 - Data collection completed
- October 18, 2013 – Significant completion of data analysis
- December 12, 2013 – Meeting with CDOT to discuss findings from the data analysis.

ANTICIPATED WORK NEXT PERIOD

- After the meeting with CDOT, the research panel will discuss next steps for the project.
- Weekly update to David Reeves and SEH project employees to maintain project schedule.

ISSUES

- Project completion date was extended from 9/8/13 to 6/31/14

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Phase II Study on Safety Performance at the Colorado DOT
Study No: 93.01

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 recommendations to build on current CDOT safety efforts

Reporting Period: 1/1/14 through 3/31/14
Type: SP&R Start: 03/06/12
Old PO: 271001635
PO: 471000126 Expires: 3/5/2013

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:
David Wieder / Maintenance and Operations Branch Manager Office (HQ)
Darrel Lingk / OTS Director (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

4/30/13	30		Current CDOT Conditions
6/30/13	0		Current CDOT Network
6/30/13	30		Comparable Organizations
6/30/13	10		CDOT Document Analysis
6/30/13	20		Expert Panel Review
7/31/13	0		Recommendation Development
7/31/13	0		Final Report
9/30/13	0		Final Presentations

SIGNIFICANT EVENTS

- 4/10/13 – Completion of introduction text and video for survey
- 4/11/13 – CDOT holds survey

ANTICIPATED EVENTS FOR Q1 2014

- Discussion of document analysis to determine how to proceed with study

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: 1/1/14 through 3/31/14
Start: 3/1/09
Complete: TBD

Principal Investigator(s):
CSU/Dr. Christopher Thornton, 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
Mohan Sagar, CDOT Specifications 303-757-9649
Fred Schultz, CDOT Maintenance 303-757-9103
C.K. Su, Materials and Geotechnical 303-757-9750
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.
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 soil testing results for final analysis
9/30/13	100	9/30/13	Additional literature review completed.

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 Estes Park
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. Inspected culvert 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.

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: 1/1/2014 through 3/31/2014
Start: 10/5/12
Complete: TBD

Principal Investigator(s):
CSU/Dr. Christopher Thornton, 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
Scott Leiker, CDOT R-6 Hydraulics 719-2485493
Dave Wieder, CDOT-Maintenance 303-357-8973
Carl Valdez, CDOT R-2 Maintenance

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

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.

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:

- New design procedure for debris culverts will be developed
- The procedure will be based on rigorous treatment of debris flows
- Design nomographs will summarize results of debris flow computations through culverts so that the design engineer will not be facing complex numerical modeling tasks
- 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: 1) introduction of new parameters to pipe size selection guidelines to accommodate debris flows and 2) development of criteria by debris-basin material types and ranges of basin slopes.

Reporting Period: 1/1/2014 through 3/31/2014
Start: 10/5/12 Complete: TBD

Principal Investigator(s):
CSU/Dr. Christopher Thornton,
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
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Mike Banovich, CDOT Environmental
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Al Gross, CDOT R-1 Hydraulics
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Dennis Cress, CDOT R-2 Hydraulics
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Fred Schultz, CDOT Maintenance
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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	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

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.

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: 1/1/2014 through 3/31/2014
Start: 10/5/12 Complete: TBD

Principal Investigator(s):
CSU/Dr. Christopher Thornton, 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:

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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.

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.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Alternative Outlet Structure for Water Quality Detention Basins to Reduce Clogging
Study No: 106.20

Background	Reporting Period: 1/1/2014 through 3/31/2014 Start: 09/21/12 Contract Amount: $70,000
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.	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

MILESTONES

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 80th 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 equations 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).

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 within the Park Creek Metropolitan District, managed by the Stapleton Master Community Association. Retrofitting of those two ponds is currently being negotiated 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. Reconnaissance 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.

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.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

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

Background	Reporting Period: 1/1/14 through 3/31/14
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.	Start: 10/1/10 Complete: 9/30/16 Contract: Principal Investigator(s): Michael Kohn, 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, R-1 Hydraulics Jeffry Anderson, Bridge Design and Management Branch Mark S Mueller, Maintenance and Operation Carl Valdez, R-2 Maintenance Hani Lavassani, R-6 RE South Program Veronica Ghelardi, Hydraulics Engineer, FHWA - Resource Center

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	0	Expected: July 31, 2014	Update Database with data from FY2013 once it's published.
7/31/15	0	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 access 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 has recently been updated to include flood data through water year 2012 (October 1, 2011 to September 30, 2012). During the summer of 2014, after the USGS publishes all data from water year 2013 (including the September 2013 flood), the database will be updated again to include data through water year 2013.

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.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Design of Forebay and Micropool for Highway Stormwater Detention Basins
Study No: 114.02

Background Low Impact Design, an innovative and green method for stormwater design, 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: 1/1/14 through 3/31/14 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:

MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
11/20/13	100	11/20/13	PO # 211020742 issued to Guo and MacKenzie to start project.
11/20/14	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	Watershed models with and without a detention pond shall be completed. Survey of these ponds will be contracted out. Expected the CDOT maintenance force will clean up the sites.

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

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Feasibility Study of Developing and Creating a Standardized Subset of Bridge Plans
Study No. 214.01

Background

Future highway projects have the potential to benefit from the past 20 to 30 years of successfully completed projects. This has primarily resulted from favored structure types and project scales. Using the past in such a manner that allows for an accelerated and advanced starting point lends itself towards a reduction in design time and fee. This proposed subset of standardized plans is one means of implementing Colorado Department of Transportation (CDOT) and Federal Highway Administration (FHWA) mandates: Every Day Counts (EDC), Accelerated Bridge Construction (ABC), and Geosynthetic Reinforced Soil Integrated Bridge System (GRS-IBS). Incidental benefits of using prefabricated bridge elements are maximizing design concepts and speed in construction that minimizes cost. GRS-IBS specifically minimizes the stiffness of bridge approaches and correspondingly can reduce differential settlement (bridge bumps).

The objective of the study is to determine if the development of standardized subset of bridge plans is feasible and cost-effective. The study should also determine what portion of the design type should be included as the "standard plans" and what type/range of bridges should be standardized.

Reporting Period: 1/1/14 through 6/31/14
Type: SP&R Start: Ver:

Principal Investigator(s): Chengyu Li, Senior Group Manager – Structures, Atkins, Inc. (720) 475 7030

Study Manager: Aziz Khan, Applied Research and Innovation Branch

Study Panel Members:

Panel Chair: ShingChun (Trevor) Wang, Bridge Design and Management
Mahmood Hasan, Bridge Design and Management
Matt Greer, Colorado Division of FHWA
Mohamed Zaina, Bridge Design and Management
Jessica Terry, Bridge Design and Management
Joshua Laipply, Bridge Design and Management

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	50		Issue bid invitation: purchase requisition was entered on 7/4/13, the first day FY14 funding codes could be used.
8/31/13			Select PI from bidders.
9/15/13			Issue PO and notice to proceed
10/01/13	100	10/08/13	Kickoff meeting
	100	3/25/14	Literature Review. Surveyed Status of Standard plans and Automated detailing in Colorado and other states. Prepared summary of data found.
	100	4/07/14	Collected and analyzed Pontis data for on system structures 1993-2013
	20		ABC and GRS
	50		Investigate standard Bridge Widths
	30		Available tools for automated design and plan generation investigated, impediments identified.
	20		Investigate superstructure sections and identify design variables

10/13/14			Draft final report
12/15/14			Publish final report

SIGNIFICANT EVENTS

7/1/13 Funding becomes available

10/8/13 Kickoff meeting. CBC will not be included in potential Standard plans. GRS abutments were added to study. Estimate of cost and work to implement standard plans added to scope. Estimate of savings potential from use of standard plans added to scope. Available tools for design and detail automation will be investigated.

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: 1/1/14 through 3/31/14

Start: 7/1/13
Complete: 9/30/15
Contract:

Principal Investigator(s):
Michael Kohn, 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, R-1 Hydraulics
Jeffry Anderson, Bridge Design and Management Branch
Mark S Mueller, Maintenance and Operation
Carl Valdez, R-2 Maintenance
Hani Lavassani, R-6 RE South Program
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	5	Expected: September 2014	Collect, document, and archive paleoflood data at each site
6/30/14	5	Expected: September 2014	Determine the peak discharge, age, and uncertainty of each paleoflood
6/30/14	0	Expected: September 2014	Perform site specific flood-frequency analysis using PeakFQ/EMA
12/31/14	0	Expected: March 2015	Develop regional flood-frequency equations
3/31/15	0	Expected: June 2015	Determine the uncertainty of the new flood-frequency equations
9/30/15	0	Expected: December 2015	Publish USGS Scientific Investigations Report and update StreamStats and Colorado Flood Database

SIGNIFICANT EVENTS

All USGS and Colorado Division of Water Resources streamgage data was compiled and the sites to be used in the flood frequency study and paleoflood data collection have been determined. All known previously collected paleoflood data has been collected for eastern Colorado. The remaining sites have been prioritized to make sure the most critical sites are visited and if it exists, paleoflood data is collected. New paleoflood data collection is scheduled to begin in the July of 2014. After the new paleoflood data collection is completed, the at-site flood frequency analysis will be completed. The paleoflood data collection was delayed due to the September 2013 flooding which has delayed the completion dates of most of the major milestones.

PROJECT COMPLETION

The project completion/end date is September 30, 2015 per the CDOT/USGS Funding Contract signed in September 2013.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Survey, Evaluation and Long-Term Monitoring of the EDC GRS Abutment Performance for Multiple Span CDOT Bridges Replacement Project
Study No. 214.05

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. 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.	Reporting Period: 1/1/14 through3/31/14 Type: SP&R Start: Ver: 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

TASKS AND MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
5/31/13	80		Establish Study panel and develop scope of work: in order to expedite the instrumentation of the GRS systems, it was decided to break out the research into three parts: instrumentation, GRS Abutment data analysis and reporting. It is hoped that CDOT can use a Task Order through and existing geotechnical monitoring contract to assure that the instrumentation can keep up with the construction.
7/25/13	10		Issue task order for instrumentation and monitoring: A meeting is scheduled with a geotechnical monitoring consultant to discuss a possible task order.
8/15/13			Issue bid invitation for research reports
8/30/13			Instrumentation consultant finalizes instrumentation design
9/15/13			Select PI(s) from bidders.
10/15/13			Issue PO and notice to proceed to researcher(s)
10/31/13			Order and take delivery of instrumentation equipment
12/19/13			Install instruments in Phase I abutment

9/12/14			Install instruments in Phase II abutment
2/20/15			Complete geotechnical monitor 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

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

Survey, Evaluation and Long-Term Monitoring of the EDC GRS Wall Performance for Multiple Span CDOT Bridges Replacement Project
Study No. 214.06

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: 1/1/14 through 3/31/14 Type: SP&R Start: Ver: 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

TASKS AND MILESTONES

Planned	% done	Achieved	Description, Discussion, and Related Issues
5/31/13	100	11/20/13	Establish Study panel and develop scope of work: in order to expedite the instrumentation of the GRS systems, it was decided to break out the research into three parts: instrumentation, GRS Wall data analysis and reporting. It is hoped that CDOT can use a Task Order through and existing geotechnical monitoring contract to assure that the instrumentation can keep up with the construction. *CDOT issued RFP for the analysis Scope of Work on 11/20/13.*
10/15/13	100	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).*
12/19/13	20		Tasks associated with Phase I Wall *Kickoff Meeting was held 1/23/14, and plans of the geotechnical instrumentation contractor (Shannon & Wilson) were discussed.* *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.*
9/12/14			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

7/1/13 Research funding becomes available
11/20/13 CDOT releases RFP for the Scope of Work
12/26/13 Issues PO to CU Denver's Reinforced Soil Research Center (Wu & Hoffman)
1/23/14 Kickoff Meeting

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: 1/1/14 through 3/31/14 Type: SP&R Start: 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
5/31/13		6/21/13	Establish Study panel and develop scope of work
7/31/13		7/5/13	Issue request for proposals to Colorado public universities. Proposals are due 8/5/13
8/19/13		9/3/13	Select PI from bidders.
9/15/13		9/6/13	Issue PO and notice to proceed
10/8/13	100	10/08/13	Kick Off meeting
12/12/13	100	12/12/13	CU-Boulder established the contract for the project
12/31/13	50	12/31/13	Study CDOT bridge database and prepare a list of bridge for sample collection
1/15/16			Draft final report
3/15/16			Publish final report

SIGNIFICANT EVENTS

10/08/2013: Kick off meeting in CDOT. Dr. Xi and Ben Gallaher made a presentation on the scope of work.
12/12/2013: CU-Boulder established the contract for the project. An account number was assigned to the research team.

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH STUDY PROGRESS REPORT

CDOT Snow Route Optimization Research Project
Study No: 314.01

Background 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:** 1/1/14 through 3/31/14 **Type:** SP&R **PO:** 411000103 **Start:** 01/06/14 **End:** 12/31/14 **Principal Investigator(s):** Matthew Krueger Tel 303-262-4062 matthew.krueger@vaisala.com **Study Manager:** David Reeves, CDOT Division of Transportation Development, 303-757-9518 **Study Panel Members:** David Wieder Kyle Lester David Reeves Isaac Lopez Ed Gentry 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	80		Task 1 - Mobilization- including specification clarification, kick-off meeting, current operations info gathering and confirmation
06/30/14			Task 2 –Mid Term Report -Detailing options, regarding network and resources and recommended software for operational decision making improvement.
07/31/14			Task 3 – Review by CDOT before route design begins
12/31/14			Task 4 – Route Design, Software implementation/testing and final research report

SIGNIFICANT EVENTS

- 03/12/14 Kick-off meeting held at CDOT with:
  - CDOT: Christian Kelly, David Reeves, Mark Eike, Phillip Anderle, Thomas Aguilar, Matt Rickard, Isaac Lopez, Mickey Madalino, Mommandi, David Wieder (all CDOT)
  - Colin Walsh, Rose Mooney, Rachel Adams, Matt Krueger, Tony Coventry (all Vaisala)
  - Proposal review and clarification of the area in which to conduct the study.
- 03/17/14 – Follow-Up open forum with Boulder Area Decision Makers with:
  - Isaac Lopez, Paul Guajardo, Andrew Doel, Mike DuBrava, Scott Klemm, Scott MacCloud, Mike

Zoller, Leonard Molina, Al Roys (all CDOT).
  - Colin Walsh (Vaisala)
  - In depth discussion and open forum about the current difficulties facing operators with regard to cycle times. All the information will be investigated and commented on in the Report.

ANTICIPATED WORK NEXT PERIOD

- Complete information gathering in April 2014
- Producing the mid-term report before the end of June 2014.

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: 1/1/14 through 3/31/14
Type: SP&R Start:8/20/13 PO:211019805:

Principal Investigator(s): David Merritt, Transtec

Study Manager: Aziz Khan

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		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		7/31/13	Select PI from bidders. Received one proposal from Transtec on 7/25/13
9/15/13		8/20/13	Issue PO and notice to proceed
9/9/13		9/9/13	Task 1: Kickoff meeting
12/1/13			Task 2:Literature Search
2/15/14			Task 3: Information Collection
7/1/14			Task 4: Field Evaluations
9/1/14			Task 5: Data Analysis
10/1/14			Task 6: Draft Report

12/1/14			Task 6: Final Report

SIGNIFICANT EVENTS

12/17/13: Project team was notified by CDOT that the section of US 34 affected by flooding had been opened to traffic and coordination of the first site visit in Jan./Feb. 2014 could begin.

Project team resubmitted a request for information on the US 34 project, including design information, construction information, and previous profiles collected on the project.

Project team proceeded with Literature Search in a limited manner until CDOT was able to determine whether the US 34 project could still be studied.

9/18/13 Flooding temporarily closed the road (SH34) where the test sections for the project are. Only about 0.2 miles of the 2+ mile project were damaged, so the study should be able to proceed with a site visit this coming winter.